Critical Success Factors for Implementing Building Information Modelling (BIM) and Sustainability Practices in Construction Projects: A Delphi Survey

Abstract

The research study aims to explore and assess the critical success factors (CSFs) that can amplify the integration of BIM and sustainability practices in construction projects. Delphi survey technique was employed to solicit the perceptions of experts on the 30 identified CSFs by means of a two-round Delphi survey. The expert panel's responses were analyzed using descriptive and inferential statistical tools. The key drivers identified in the study are related to people-centric as well as data and technology-centric interventions in the built environment. Crucial deductions were formed based on a comparative analysis of the experts' groups. The study's findings have provided valuable lessons for local authorities, policy makers, and project stakeholders to strengthen the drive for achieving full adoption of green-BIM initiatives. The study has also provided effective recommendations for increasing the uptake of BIM and sustainability practices in the construction industry and has contributed to the body of knowledge about smart urbanization and hands-on practice in the built environment.

Keywords: Critical success factors; Delphi survey; BIM; construction projects; sustainability; sustainable smart city.

1. Introduction

Construction projects are nowadays quite complex involving several and interwoven processes and activities (Olatunji et al., 2017b; Olawumi & Ayegun, 2016) which calls for a smart and innovative system of technologies to process and manage the different project activities. Also, the Brundtland Commission report (WCED, 1987) has drawn the attention of the construction sector to implement sustainable construction practices in its activities to enhance the environmentally-friendliness of its products (infrastructures, buildings) with the ultimate aim of achieving sustainable smart cities.

Olawumi et al. (2017) regarded Building Information Modelling (BIM) as one of the smart technologies available to the construction industry along with radio-frequency identification (RFID), augmented reality which can help to facilitate collaboration among project stakeholders/ Also, it can serve as links to connect domain knowledge areas such as sustainability, facility management, safety, project management, etc. to ensure a one-source management of project's information and processes throughout the construction project's lifecycle stages. Also, Olatunji et al. (2016) highlighted further that the success of these tools hinges more on the initiatives of project stakeholders through their decision-making process and collaboration in their projects. According to Kovacic et al. (2015), Lee and Yu (2016), and Ma et al. (2018), there has been an appreciable increase in BIM adoption in some countries' construction industry. However, despite this progress in BIM adoption (although not yet worldwide), there has been little advancement in the implementation of sustainable construction practices in infrastructural projects.

Morlhon et al. (2014) argued nonetheless that the implementation of BIM is complicated due to the different standards and protocols involved which has hindered organizations to use and handle it actively. However, despite this apparent disadvantage, it permits the additional analyses of concepts such as energy performance, clash detection, and other sustainability measures (Olawumi et al., 2017). Also, BIM-enabled sustainability analysis tools can assist in the simulation of building energy performance and carbon footprints as well as reduce the cost and time involved (Ahn et al., 2014). Although, the interoperability issues between BIM design and analysis tools is still a prevalent problem in the construction industry (Abanda et al., 2015).

The integration of smart technologies such as BIM to amplify sustainability practices in construction projects can help to reduce and/or project the building energy as well as the evaluation of the lifecycle assessment in conjunction with rating systems such as LEED, BREEAM, etc. (Al-Ghamdi & Bilec, 2015). Sustainability is related to dimensions such as social, economic and environmental variables; and the use of technologies can optimize its adoption in any setting (Raut et al., 2018). More so, adopting sustainability strategies can lead to innovation which can also help to achieve competitive advantage for participating companies and reduce project overall cost (Chofreh & Goni, 2017). The deployment of cloud technologies also facilitate collaboration and improved the project governance mechanisms (Alreshidi et al., 2016). However, the lack of archival data and access to vital project information have steeped the progress and adoption of BIM in the industry (Wong et al., 2014). A case study analysis of the benefits of BIM in construction project carried out by Barlish and Sullivan (2012) showed that BIM is yet to achieve its full potential in the industry due to several factors; which include the lack of commitment from project clients. Moreover, previous authors (GhaffarianHoseini et al., 2017; Jalaei & Jrade, 2015; Reinhart & Wienold, 2011) sees smart technologies such as BIM as one of the essential vehicles to drive the implementation of sustainability practices. Meanwhile, Olawumi and Chan (2018c) developed an assessment template and scoring system to provide a quantitative metrics of measuring and comparative evaluation BIM implementation in developing countries Hence, this study intends to identify and examine the critical drivers that amplify the use of BIM to enhance the implementation of sustainable practices in construction projects.

Gardas et al. (2018a) and Raut et al. (2017) considered issues related to sustainability in any industry as a concept that is best implemented by top hierarchy of organizations, and such firms derives the benefits of its contribution to sustainable development in aspects such as economic, social, environmental. Guo et al. (2018) and Xue (2018) corroborated it by arguing for greater leadership and the institutionalization of a governance arrangement in the industry. Gardas et al. (2018b) emphasized the need for a holistic view and balancing of the three pillars of sustainability during its implementation process. More so, Jakhar (2017) and Kang (2018) regards communication and stakeholder engagement as a crucial variable in facilitating sustainable development.

The current study intends to explore the critical drivers that can enhance the successful implementation of both BIM and sustainability practices in construction projects. Although, there are some projects which have employed either of the two concepts to varying levels of success. However, this study focuses on construction projects in which the clients or project team plans to adopt smart technologies such as BIM along with sustainable practices in their projects. The benefits of adopting both concepts (BIM and sustainability practices) have been highlighted in the literature (Oti et al., 2016; Tah & Abanda, 2011).

The structure of the paper is organized as follows. Section 1.1 discusses the knowledge gaps, research objectives and value the current study intends to offer to both knowledge and practice. Section 2 provides a review of the several smart-sustainable construction practices in the literature and the drivers for BIM and sustainability practices implementation. Section 3 highlights the research methods, statistical tools employed, and hypothesis postulated. Section 4 discusses the research findings, section 5 highlights the contribution of the study's findings to knowledge and findings; and section 6 concluding the study and providing areas for future studies.

1.1 Knowledge gap, research objectives and value

Cugurullo (2017) argued that several models of urbanization of cities are flawed because little attempts are made to integrate sustainability into its planning and design. Hence such urban development becomes unsustainable in the long-run. A review of case studies by previous authors (Caprotti, 2016; Taylor Buck & While, 2017)reveals the disconnect between the development of smart cities and the ideals of sustainability. One significant disconnection between the two concepts as argued by Cugurullo (2017) is that there is little or no innovation but a rather replication of traditional strategies of urbanization. Also, as pointed out by extant literature (Chang & Sheppard, 2013; Colding & Barthel, 2017; Datta, 2015) they hardly integrate sustainability or fulfill its promises of making it sustainable.

Conceptually and in practice, it has been seen that the use of smart technologies in construction project development to achieve smart city initiatives may not act in concert with the ideas of adopting sustainability to achieve eco-city. A good case analysis was exemplified by Cugurullo (2017) in the comparison between Hong Kong (a smart city) and Masdar City, Abu Dhabi (an eco-city initiative). Given these limitations in knowledge and practice, the current study intends to break the 'aura of singularity' in the application of these concepts to city urbanization by projecting the possibility of sustainable smart cities that works on the principles that a smart city can be sustainable and an eco-city can be smart.

This paper is situated to provide the underlying connection that links the disconnection between smart city initiatives and sustainability by inviting expert teams to deduce the key drivers that amplify the cohesive implementation of smart technologies such as BIM and sustainability practices in construction projects. The three research questions that the current study intends to answer are as follows:

i. What are the key drivers that can amplify the use of smart technologies such as BIM to enhance sustainability practices in construction projects?
ii. How significant are the key drivers to the actualization of smart construction processes and the ultimate aim of sustainable smart cities?
iii. How do the perceptions of the expert panel differ based on their professions and regions?

The current study argues in favor of sustainable smart cities as against the singularity of either the advancement of smart-city or eco-city initiatives. The findings of this study are intended to contribute to the existing body of knowledge on urban sustainability and BIM by providing the principal actors such as the government, project stakeholders, academics with the key drivers that can enhance the cohesive implementation of sustainable smart cities. Also, the findings when serves as a policy tool and consultation instruments for government agencies and private organizations interested in the ideals of sustainable smart cities. Also, the comparison of the perceptions of the expert panel's members based on their regions will indicate the level of adherence to sustainable smart cities ideals in such countries. Moreover, the results are expected to strengthen project teams and construction organizations in their drive to implement sustainable practices in their projects.

2. Smart, sustainable construction practices: A desktop review

In recent years, several infrastructural projects have sprung up in urban cities across the world promoting the ideas of sustainable built environment tagged with names such as 'smart cities' or 'eco-cities' (Cugurullo, 2017). Also, several approaches have been suggested by advocates of sustainable smart cities toward ensuring the execution of construction projects with these ideas in mind. However, according to Batty (2012), Bettencourt and West (2010), the standards of these advocates of these projects for smart, sustainable cities are unclear, undefined, and often chaotic. Hence, making the drive and concept of city-making to achieve sustainability impossible.

Moreover, some cities have demonstrated possibilities in adopting smart technologies in its infrastructural development to emerge as smart cities such as Hong Kong (Cugurullo, 2017), Milano (Milano Smart City, 2017), Barcelona (Barcelona City Council, 2017) and Vienna (Smart City Wien, 2017). Also, a portrayed example of an eco-city is Masdar City envisioned as a greenprint for innovative sustainable development and a city for the future (Masdar Initiative, 2017). Although, Masdar City is often promoted as the world's most sustainable city (Cugurullo, 2017). However, its failure makes the most use of smart technologies has weakened its ability to resolve some issues related to energy, water supply chain management and ecological impact of the settlement (Crot, 2013; Cugurullo, 2013). The above example of an eco-city (Masdar City) further strengthens the stand of this paper for a cohesive implementation of smart technologies (such as BIM) and sustainability practices in the construction industry.

For a smart city such as Hong Kong, Cugurullo (2017) argued that the smart interventions in the city are insensitive to the ideals of sustainable development with resulting environmental pollution and other urban problems. More so, Hong Kong adopted a project-based approach to smart urbanism rather than a whole system; leading to a fragmented system of different entities (Cugurullo, 2017). Hence, it is required for cohesive and strategic planning to synergy different fragmented smart projects and also integrates sustainability practices to achieve a smart, sustainable city.

There are some sustainability assessment techniques or building rating systems (such as LEED, BREEAM, etc.) that have been developed to evaluate who well a building project meet some defined criteria for such infrastructure to be considered green or sustainable. Moreover, Sala et al. (2015) highlighted some inadequacy in some of these techniques will make them unreliable and inconsistent and much of the issues are linked to the fuzziness of the sustainability concept itself. Nevertheless, there have been some application of smart technologies and sustainability practices in some projects such as BIM for sustainable material decisions (Ahmadian et al., 2017); BIM for sustainable design (Wong & Fan, 2013), GIS-based facility management (Kang & Hong, 2015); BIM-based energy analysis (Gourlis & Kovacic, 2017). A comprehensive review of the body of literature was examined by Olawumi and Chan (2018a).

Yusof et al. (2016) examined the influence of project's stakeholders' behavior on the implementation of sustainability practices which reveal a positive correlation between the firm's management practices in respect of energy efficiency and waste and the implementation of sustainability ideals during project execution. Since construction projects are people-driven, it is expected the project stakeholders are well-informed on the ideals of sustainable development. More so, Eurostat (2013) reported that 859 million tons of waste were generated from construction activities in the European Union; also, Fuertes et al. (2013) regards the construction industry as a significant source of water, noise, and air pollution.

In countries such as China and Malaysia, construction-related activities account for 45-46% of the overall energy consumption (MIGHT, 2014; Zhaojian & Yi, 2006); along with about 30% of solid waste in China (Lu & Tam, 2013); and 30% of greenhouse gas emissions in Malaysia (MIGHT, 2014). These case studies reveal the immense potential for the construction industry to embrace the ideals of sustainability (Birkeland, 2014) as well as its cohesive implementation with smart technologies. Therefore, since the construction activities involved several stakeholders such as the clients, architects, project managers, engineers among others (Olawumi & Ayegun, 2016); it is necessary for the stakeholders to well experienced in the use and implementation of smart tools such as BIM and adhere to the ideals of sustainability (Tsai et al., 2014). Table 1 highlights the drivers (CSFs) for the cohesive implementation of BIM and sustainability practices in construction projects.

[Insert Table 1]

3. Research Methodology

The study aims at exploring and prioritizing the critical success factors (CSFs) that amplify the integration of BIM initiatives and sustainability practices in construction projects. Towards achieving the aim of the study, a Delphi survey technique was adopted which is suitable as a primary research approach for studies of cross-disciplines with the objective of establishing the subject matters in the fields. Chan and Chan (2012) perceived that it is useful to achieved consensus among a group of experts while Hasson et al. (2000) pointed out the uniqueness of Delphi approach for studies in interrelated subject matters. Data was collected over a two-round of Delphi surveys to establish the CSFs gleaned from the extant literature. Olatunji et al. (2017a) stressed the significance of the data collection technique adopted for a study as it affects the achievement of the set objectives among others.

The expert panel consisting of fourteen (14) members from the academics and industrial practitioners whose experiences and efforts were solicited to rank the 30 identified CSFs that help amplify the integration of BIM and sustainability practices in construction projects. Several previous research studies relating to the built environment have utilized the Delphi survey technique. Chan and Chan (2012) developed a performance measurement index for target cost contracts and Chan et al. (2015) evaluated the critical risk factors for PPP water projects. Hyun et al. (2008) assessed the effect of alternative delivery methods on design performance of buildings, and Hallowell and Gambatese (2010) conducted a review of the application of Delphi technique in construction-related research. More so, statistical tools were employed to analyze the data collected after the rounds of Delphi survey. The statistical methods used include Cronbach's alpha reliability testing, mean score ranking, Shapiro-Wilk test of normality, Kendall's concordance test and Chi-square test, inter-rater agreement (IRA), Spearman's rho correlation test and Mann-Whitney analysis.

3.1 Format of the Delphi technique

A comprehensive review and content analysis of the extant literature forms the bedrock of establishing the CSFs that amplify the integration of BIM initiatives and sustainability practices in construction projects. Thirty (30) factors were identified from the literature and formed part of the items of the Delphi empirical questionnaire survey as well as soliciting specific details about the respondents. The factors were ranked by the respondents on a 5-point Likert scale: 1 = strongly disagree and 5 = strongly agree.

Chan et al. (2001) and Yeung et al. (2007) stated that careful identification and selection of respondents to form the expert panel is key to a successful and credible outcome of a Delphi technique. Hence, the study adopted a purposive sampling technique to ensure the invited experts have derived required experience and abundant knowledge on the subject matters. The targeted respondents must fulfill some set of criteria before their invitations, and these include: (1) the respondent must have a broad level of experience and leadership in the construction industry. (2) the respondent must have utilized BIM and implemented sustainability practices in previous or current projects; and (3) the respondent should be well acquainted with BIM and sustainability concepts as well as a robust understanding of their interrelationships.

Moreover, Giel and Issa (2016) noted that a 2-3 round of Delphi survey is sufficient to attain the required consensus from the expert panel. Hence, this study adopted a two-round Delphi survey over a five-month period involving fourteen (14) experts. Hon et al. (2011) noted that a Delphi expert panel must consist of a minimum of seven (7) respondents and Turoff (1970) caps the size of an expert panel at fifty (50) members. Previous studies such as Arditi and Gunaydin (1999) utilized 14 experts; Hyun et al. (2008) used seven (7) experts and 12 experts were used by Gunhan and Arditi (2005). Meanwhile, to ensure the credibility and reliability of the results, regular feedbacks after each round of survey were sent to the experts as well as ensured the anonymity of the respondents.

3.2 Expert panel's demographics

The expert panel was constituted of experts from the construction academics and industrial practitioners with seven members from each constituency. The respondents are from eight different countries or regions, that is, four (4) experts from the United Kingdom, three (3) respondents from Hong Kong, two (2) from the United States, and one respondent each from South Korea, Sweden, Mainland China, Germany, and Australia. The invited experts have a broad level of experience in the construction industry with a sizeable number (9) of the experts having more than 11 years of experience in the industry, of which five (5) experts have more than 20 years of experience.

More so, the respondents have used BIM technologies and have implemented sustainability practices in previous or current construction projects. Moreover, most of the experts noted that they usually adopt BIM initiatives and sustainable construction practices in their projects which is a good sign of their depth of knowledge and experience in these two concepts. Also, building projects were the prime projects in which the experts usually adopt BIM initiatives, and sustainability practices, followed by refurbishment and redevelopment works.

Meanwhile, as highlighted by the Delphi experts, government agencies and clients are the key stakeholders influencing the implementation of BIM and sustainability practices, followed closely by the project team members and contractors. Also, the expert panel advocated the implementation of these concepts at the planning stage of a project or latest at the design stage to influence project decisions. Moreover, to allow for further comparative analysis of the expert panel responses, a 'West vs. East' experts comparison was adopted similar to the dichotomy used by Chan et al. (2011). The 'West group' was constituted of 8 experts from countries such as the United Kingdom, Sweden, the United States and Germany and the 'East group' is made up of 6 experts from other countries (i.e., Hong Kong, South Korea, Mainland China and Australia).

4. Discussion of results and analysis of findings

The study employed a set of descriptive and inferential statistical methods to analyze the data collected from the expert panel across the two-round of Delphi surveys and undertake comparative analyses among the respondents' groups. These include: (1) Cronbach's alpha reliability testing; (2) mean score ranking; (3) Shapiro-Wilk test of normality; (4) Kendall's concordance test and Chi-square tests; (5) inter-rater agreement (IRA); (6) Spearman's rho correlation test; and (7) Mann-Whitney analysis.

4.1 Reliability testing and Normality testing

Cronbach's alpha (α) reliability test was employed to assess the questionnaire instrument and its associated scale to ensure that it measures the right construct and for internal consistency (Olatunji et al., 2017a). The α-value ranges from 0 and 1 and a Cronbach's alpha value of 0.70 and above is adjudged as sufficient for further analysis (Field, 2009; Olatunji et al., 2017a). The α-value for the first round of Delphi survey was 0.824 and α-value of 0.808 was recorded in the second round; which is significantly higher than the 0.70 thresholds.

Moreover, the Shapiro-Wilk test of normality was conducted to figure out the distribution of the data whether there are normally distributed or not. The thirty CSFs have a significance level $p < 0.05$ which implies non-normally distributed datasets; therefore, non-parametric statistical methods would be employed for subsequent analyses.

4.2 Mean Score Ranking of CSFs

The thirty (30) CSFs were ranked based on their mean scores which aggregate the respondents' responses in each round of Delphi survey. More so, if two or more factors have a similar mean score (M), the standard deviation (SD) is employed in the ranking. According to Olatunji et al. (2017a), the factor with the smaller SD value is assigned higher rank than others, however, if they share similar SD value. The factors will maintain the same ranking.

The mean score ranking of the 30 CSFs for the first round of Delphi survey is shown in Table 2 and that of the second round in Table 3. The mean score for the 30 identified CSFs in the first-round ranges from M= 3.57 (SD=1.342) for "*C7- availability of financial resources for BIM software, licenses, and its regular upgrades*" to M= 4.36 (SD= 0.745) for "*C21- early involvement of project teams*" at a variance of 0.79. Meanwhile, for the second round, we have a slightly higher variance of 0.93 and a mean range of M= 3.50 (SD=1.286) for "*C7- availability of financial resources for BIM software, licenses and its regular upgrades*" to M= 4.43 (SD= 0.646) for "*C21- early involvement of project teams*".

Moreover, an analysis of the findings after the second round of Delphi survey revealed that the respondents alter their prioritization of some factors with some factors interchanging rankings. These factors such as factor c2 to factor c9 (ranked 4th), factor c27 to factor c5 (ranked 14th), factor c14 to factor c22 (ranked 13th) among others. Meanwhile, some factors improved in their ranking after the second round, that is, factor c15 from rank 12 to 11, factor c5 from rank 17 to 14, factor c6 from rank 27 to 26; factor c8 from rank 10 to 8, etc. However, some factors reduced in their ranking such as factor c2 from rank 4 to 6, factor c4 from rank 9 to 10, factor c11 from rank 15 to 16, factor c18 from rank 18 to 19 and factor c30 from rank 26 to 28.

Some factors, however, retain their ranking after the second round of Delphi survey despite changes in their mean score. These include factors c1, c3, c7, c10, c12, c13, c16, c17, c19, c20 and c21 among others. More so, one of the primary goals of a Delphi technique is the achievement of good consensus among the expert panel after the closure of the Delphi rounds. After the second round of Delphi survey, the consensus was achieved by the expert groups on the top-five key CSFs that amplify the integration of BIM initiatives and sustainability practices in construction projects. The respondents from the West group featured all the overall top-five CSFs in their rankings while the industry practitioners featured 4 of the top-five key factors, the academics featured three factors and the East group featured only one factor. There was also a relative consensus among the expert panel on the least important factor.

4.3 Agreement of respondents within each expert group

Kendall's concordance test (W) was used to measure the level of agreement within a respondent group, and the consistency of agreement across rounds of Delphi survey (Chan & Chan, 2012) and its values range from 0 (perfect disagreement) and 1 (perfect agreement). The W's value of the expert panel improved from 0.110 to 0.114 after the second round of Delphi surveys (see Table 2 and 3).

Moreover, although Kendall's coefficient of the expert panel is less than the average value of 0.5, Zahoor et al. (2017) regarded the value as significant. Gisev et al. (2013) further argued that it is difficult to achieve a higher W value with an increase in the size of the respondents. Hence, an increase in the W value across the rounds was given more consideration. Furthermore, chi-square (X^2) tests were employed since the factors being ranked are more than seven in number (Hon et al., 2011). The X^2 values for the expert panel are shown in Table 2 and 3. The chi-square value for the expert panel improved from 44.605 to 46.308 in the second round which is higher than its critical chi-square value of 42.557 (for p=0.05) at a degree of freedom (df) of 29 from the statistical table. Meanwhile, the significance level is slightly significant at $p=0.032$ ($p<0.05$).

[Insert Table 2]

[Insert Table 3]

4.4 Significance of the factors and validation of the experts' agreement via IRA analysis

The critical success factors were prioritized on their significance levels based on the scale interpretation given by Li et al. (2013) and also adopted by Zahoor et al. (2017) in their Delphi study. The mean score interpretations are "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" ($M \geq 4.51$). In the first round of Delphi survey, none of the factors was graded 3.51 or below.

More so, all the CSFs factors retained their significance level after the second round of Delphi survey except c7- "*availability of financial resources for BIM software, licenses, and its regular upgrades*" which was downgraded by the expert panel from 'very important' to 'important.' Overall, the factors can be considered critical to amplifying the integration of BIM initiatives and sustainability practices in construction projects. Factors such as c3- "*more training programs for cross-field specialists in BIM and Sustainability*," c20- "*client requirement and ownership*" and c23- "*supportive organizational culture and effective leadership*" among others (Olawumi & Chan, 2018b) are graded 'very important' by the expert panel.

Meanwhile, some factor categories considered as critical areas of focus for construction stakeholders to amplify the implementation of BIM and sustainability practices in the industry. These include key categories such as category "organization and project-related issues" which factors such as c19, c22, and c24; category "industry culture" with factors such as c9 and c11. Also, we have category "legal issues" with factors c12 and c14 and category "education, knowledge, and learning" with factor c2 which are regarded as very important with the strong consensus reached on these categories.

Furthermore, the interrater agreement (IRA) statistics (IRA $a_{wg(1)}$) developed by Brown and Hauenstein (2005) was used to analyze and validate the respondents' agreement on each factor. A key advantage of the IRA statistics is that it is not dependent on the size of the respondents' group or the measurement scale. The IRA statistics along with the significance level was used to assess the level of consensus reached by the respondents at each round of Delphi survey for each CSFs (see Table 4). The IRA coding was provided by Lebreton and Senter (2008) as follows 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 formula for evaluating the IRA statistics for each CSFs is shown in equation 1, and equation 2 and 3 is used to define the mean boundaries, lower and upper limits respectively beyond which the IRA statistics might not reflect accurately the strength of the consensus reached by the expert panel.

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

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

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

Where M= mean value of that factor, A= maximum scale value (i.e. 5), B= minimum scale value (i.e. 1), SD= standard deviation, n= sample size of respondents (i.e. 14 in this study). The lower mean boundary (M_{lower}) is 1.29, and the upper mean boundary (M_{upper}) is 4.71 for both rounds of Delphi survey. Moreover, one factor c7- "*availability of financial resources for BIM software, licenses and its regular upgrades*" have a "lack of agreement" after the second round of Delphi survey, and the factor was ranked the least important by the expert panel. It is consistent with the fact that different organizations have different policy and strategies for their software procurement and upgrades, while some firms do regularly upgrade their BIM facilities others might do otherwise to save costs.

Meanwhile, two factors improved significantly in their agreement levels (Table 4) after the second round such as c22 from "moderate" to "strong" agreement and c19 from "strong" to "very strong" agreement. However, one factor c11 decrease slightly in its agreement level from "very strong" to "strong" agreement while the other CSFs factors maintain their agreement level after the second round. The findings from the IRA statistics and significance level analysis provide a sound basis to support the strong consensus achieved by the expert panel as well as validate the agreement on each factor.

Hence, the significance level grading, as well as the IRA statistics, was used to rank each factor in descending order of their significance level as shown in Table 5. The CSFs' significance levels range from "important" to "very important," and the IRA statistics range from "lack of agreement" to "very strong agreement" based on the findings after the second round of Delphi survey. The five (5) most significant CSFs that amplify the integration of BIM initiatives and sustainability practices are c19- "number of subcontractors experienced with BIM projects"; c2- "greater awareness and experience level within the firm"; c17- "increased involvement of project stakeholders in green projects." Others are c18- "clarity in requirements and measures for achieving sustainable projects"; and c26- "interoperability and data compatibility." Hence, when construction stakeholders give adequate consideration and priority to these critical issues, it would enhance the possibilities of achieving the goal of a sustainable smart city.

[Insert Table 4]

[Insert Table 5]

4.5 Agreement of respondents between the expert groups

Inferential statistical methods such as the Spearman rank correlation test and Mann-Whitney U-test were applied in the comparative analysis of responses from the expert panel groups.

4.5.1 Spearman rank correlation test

The level of agreement and concordance between any two expert groups was evaluated using the Spearman rank correlation (r_s) test (Chan et al., 2010). Its value ranges from -1 (perfect negative correlation) and +1 (perfect positive correlation) and when the significance level is statistically significant ($p<0.05$), the null hypothesis is rejected. The null hypothesis (H_0) states that "there is no significant correlation between the two expert groups on the rankings of the CSFs." The findings reveal a weak but positive correlation between the academics and the practitioners' groups at a coefficient of 0.246 and a significance level (p) of 0.189. Since the correlation is not significant ($p>0.05$), hence, we fail to reject the null hypothesis.

Also, the analysis reveals a weak but positive correlation between the 'West' and 'East' groups at a coefficient of 0.290 and a p-value of 0.120. The p-value is not significant since there is no sufficient evidence to reject the null hypothesis, we fail to reject the H_0. More so, the West and East groups shared similar ranking and consensus on two factors (c3 and c24) while the other group (academics and practitioners) does not have consensus ranking on any CSFs factor.

4.5.2 Mann-Whitney U-test

Mann-Whitney U-test was employed to investigate any significant differences or divergencies between the median values of the same CSF between two respondents' groups. When the significance level (p) of the U-test for a factor is less than 0.05 ($p<0.05$), the null hypothesis is rejected. The null hypothesis states that "there are no significant differences in the median values of the same factor between the respondents of the two expert groups." Also, a smaller 'U' value indicates a considerable divergence in the opinions between two expert groups.

The findings of the Mann-Whitney test between the academics' and practitioners' groups (see Table 6) reveal a significant statistical difference in the median values of two CSFs while the other factors were not significant ($p>0.05$). Hence, there was sufficient evidence to reject the null hypothesis for the two factors (c8 and c9). More so, the U-value for the two CSFs were smaller in comparison with the other factors; lending further proof of the divergence in the opinions of the two expert groups on these two factors.

Meanwhile, for factor c8- "*information and knowledge-sharing within the industry*," the median value of the academics group (9.29) is higher than those of the industry practitioners (5.71). The results show that the academics perceived the CSFs factor to be more important than the practitioners' group and this is consistent with the findings of Olawumi et al. (2017) and Olawumi and Chan (2017) which reveal a broad and wider knowledge sharing and research network hub among the academics. Olawumi et al. (2017) further highlighted the robust networks among academic researchers across regions and countries which had contributed to the substantial contribution to the construction industry through the development of tools and standards for BIM and sustainability. However, the somewhat fierce competition and rivalry among related construction organizations inhibit the sharing of vital information that could enhance their projects.

Similarly, for factor c9- "*effective collaboration and coordination among project participants*," the median value of the academics group (9.50) is higher than those of the industry experts (5.50); which implies that the academics agreed more on the factor to be of high importance compared to the practitioners. These findings correlate with the characteristics of most construction firms whereby the project team is disbanded almost immediately after the project, and even during such projects, there is little or no collaboration due to inherent conflicts and rivalry. However, the scenario is entirely different for the academics group which gives proper priority to collaboration in the execution of their research projects and to win a project grant or funding; most funding agencies do emphasize partnership and linkage among researchers from different faculties or universities.

[Insert Table 6]

The results of Mann-Whitney U-test between the respondents from the West and East groups (see Table 7) reveal significant statistical variation in the median values of three (3) CSFs while the other factors are not significant ($p>0.05$). Hence, there was sufficient evidence to reject the null hypothesis for the three factors (c9, c12, and c21). More so, the U-value for the three CSFs were smaller in comparison with the other factors; lending further proof of the divergence in the opinions of the two expert groups on these three factors. Also, like the U-test analysis between the academics' and practitioners' group, there was a statistical divergence in the opinion of the West and East groups on factor c9.

The median value for factor c9- "*effective collaboration and coordination among project participants*" of the West group (9.00) was greater than those of the East group (5.50). The findings reveal the experts from the 'West' group ranked the factor as more important than the experts from the 'East.' The result is consistent with the fact that the western countries have taken led in the development of BIM and sustainability implementation in the projects and have discerned an effective collaboration among project stakeholders as crucial to the full and consistent adoption of these concepts in current and future projects.

Also, for factor c12- "*development of an appropriate legal framework for BIM use and deployment in projects*," the median value of the respondents of the 'West' group (9.00) was higher than those of the 'East' group (5.50). The result implies that the 'West' group perceive the factor of high significance to amplifying the integration of BIM initiatives and sustainability practices in construction projects than those in the 'East' group. In a similar vein, for factor c21- "*early involvement of project teams*," the median value of the 'West' group was greater than the 'East' group. The findings indicate the experts in the 'West' group ranked the factor higher than their counterparts in the 'East' group. The findings illustrate the significant divergence in the opinions of experts from the two distinct regions with different levels of development and progress in the implementation and adoption of BIM initiatives and sustainability practices in construction projects.

[Insert Table 7]

5. Contribution to new knowledge and practice

The study investigated the drivers that can instigate the cohesive implementation of BIM initiatives and sustainability practices in construction practices towards achieving sustainable smart cities. Allwinkle and Cruickshank (2011) and Hollands (2008) maintained that for a city can lay claims to be smart; it must be based more than its use of smart technologies which Ahvenniemi et al. (2017) argued must include the ideals of sustainability. More so, Mora et al. (2017) reported on the lack of the knowledge and tools necessary to support the initiative of smart, sustainable cities and the discussions on such are few among academia. Hence, the evaluation of the thirty (30) critical success drivers that could aid the cohesive implementation of BIM and sustainability practices in construction practices is envisaged to give a good starting point for discussion for local authorities, policymakers as well as the academics.

The key drivers can be drafted as a consultation tool by government departments in charge of city urbanization and construction organization in designing a more robust policy and legal instrument to drive the initiative of a smart, sustainable city from a local context perspective. Although, some of these key drivers might not be significant in some countries or regions are discovered by the comparative analysis among the expert panel; however, there is still a disparity in these countries regarding what is obtainable in knowledge (academics) and practice. As argued by Cugurullo (2017), some developed cities that claim to be smart cities are not sustainable. Hence, there is still a need to bridge the gap in this direction.

More so, the findings of this study can form the basis of 'collaborative' intellectual, scientific exchange among the academics, policymakers, project stakeholders, government towards having a unified understanding and promoting common currency on ICT-based sustainable urbanization. According to Mora et al. (2017), this will help to resolve the current divisions in the scientific community on the terms of reference of what constitutes the drive for smart urbanization. Meanwhile, from Table 5 which highlighted the significant drivers, it is evident that for a sustainable smart city initiative to be achieved in a local region, much had to do with the people- stakeholders involved in such projects. For instance, the first three drivers are people-centric- such as the stakeholders' awareness and experience level as well as their involvement in green projects.

The next three key drivers (from Table 5) are data and technology-centric which have drivers such as clarity regarding requirement and measures of achieving the required sustainability in a project, data exchange and a well-managed database or archive of past projects to allow for comparison purposes. Therefore, for the achievement of any sustainable smart initiative whether regarding a city or a single infrastructure such a building, there must be a proper integration of the knowledge and skills of the stakeholders and their unhindered access to relevant data and technology to boost the prospect of sustainable smart urbanization.

6. Conclusions

The drive towards the achievement of sustainable smart cities and buildings can be strengthened and enhanced when construction organizations and project stakeholders alike implement sustainable construction strategies and adoption green-BIM technology. Hence, the current study has explored and assessed the critical success factors (CSFs) that amplify or enable the integration of BIM and sustainability practices at the design stage of construction projects. Content analysis technique was adopted to identify the thirty (30) CSFs from extant literature under six categories upon which the developed empirical questionnaire survey was based.

Also, the Delphi survey technique was adopted as the primary research approach which involved fourteen experts from eight countries across two-round Delphi surveys. The expert panel is distinctly from both the academia and the industry, with seven members each. The data from each round of Delphi survey was subjected to various statistical analyses such as the Cronbach's alpha reliability testing, mean score ranking, Shapiro-Wilk test of normality, Kendall's concordance and Chi-square tests, inter-rater agreement (IRA), Spearman's rho correlation test, and Mann-Whitney analysis. An acceptable level of consensus was reached by the expert panel after the second round of Delphi survey, and the IRA statistics was used to validate the agreement reached by the expert panel on each of the CSFs. Overall, the expert panel achieved a considerable improvement in their level of agreement after the second round of Delphi survey although some respondents' groups have a slight but not significant decrease.

More so, the experts altered their rankings of some factors after the first round of Delphi survey, although few items retained their rankings, a few reduced in the ranking. The significance level and the IRA value of each factor were further adopted to rank the CSFs in descending order of significance. The three most significant CSFs that can amplify the integration of BIM initiatives and sustainability practices in construction projects include "increased number of subcontractors experienced with BIM projects," "greater awareness and experience level within the firm," and "increased involvement of project stakeholders in green projects." Also, key CSF categories were also identified which include "organization and project-related issues," "industry culture," "legal issues" and "education, knowledge, and learning."

Comparative analysis between the academics and the practitioners' groups reveals significant divergences in their perceptions of two factors as earlier discussed. In both instances, the academics group rated the factors, "information and knowledge-sharing within the industry" and "effective collaboration and coordination among project participants" to be of higher significance than their industry counterparts. Also, there were statistically significant differences in the opinions of the experts from the West and East groups on three CSFs. Meanwhile, the West group agreed on the three factors “development of an appropriate legal framework for BIM use and deployment in projects, “effective collaboration and coordination among project participants” and “early involvement of project teams” to be of higher importance than the experts from the East group. The findings are subjected to the limitation of the sample size of the expert panel.

The discussion section focused on how the current research findings contributed to both knowledge and practice. Future research studies should envisage to consider a country or project-based case study approach to substantiate the identified drivers towards extending the scope of the current findings. The study’s findings have given valuable lessons to various project stakeholders as well as presented the salient drivers that can amplify the integration of BIM initiatives and sustainability practices in construction projects. The study has also contributed to the existing body of knowledge in sustainability and BIM research areas in the built environment by exploring the key factors and categories as well as the comparative analysis of the respondents’ regions. It is expected that the findings of the current study will generate stronger impetus to achieve full implementation of green-BIM and sustainable smart cities initiatives in the built environment.

References

Abanda, F. H., Vidalakis, C., Oti, A. H., & Tah, J. H. M. (2015). A critical analysis of Building Information Modelling systems used in construction projects. *Advances in Engineering Software*, *90*, 183–201. https://doi.org/10.1016/j.advengsoft.2015.08.009

Abdirad, H. (2016). Metric-based BIM Implementation Assessment : A Review of Research and Practice. *Journal of Architectural Engineering and Design Management*, 1–27. https://doi.org/10.1080/17452007.2016.1183474

Abolghasemzadeh, P. (2013). A comprehensive method for environmentally sensitive and behavioral microscopic egress analysis in case of fire in buildings. *Safety Science*, *59*, 1–9. https://doi.org/10.1016/j.ssci.2013.04.008

Abubakar, M., Ibrahim, Y. M., Kado, D., & Bala, K. (2014). Contractors Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry. *Computing in Civil and Building Engineering ©ASCE*, 167–178.

Adamus, L. W. (2013). BIM: Interoperability for Sustainability Analysis in Construction. In *Central Europe towards Sustainable Building 2013: Integrated building design BIM* (pp. 1–4).

Ahmadian, A. F. F., Rashidi, T. H., Akbarnezhad, A., & Waller, S. T. (2017). BIM-enabled sustainability assessment of material supply decisions. *Engineering, Construction and Architectural Management*, *24*(4), 668–695. https://doi.org/10.1108/ECAM-12-2015-0193

Ahn, K.-U., Kim, Y.-J., Park, C.-S., Kim, I., & Lee, K. (2014). BIM interface for full vs. semi-automated building energy simulation. *Energy & Buildings*, *68*(B, SI), 671–678.

https://doi.org/10.1016/j.enbuild.2013.08.063

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., & Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities*, *60*, 234–245. https://doi.org/10.1016/j.cities.2016.09.009

Aibinu, A., & Venkatesh, S. (2014). Status of BIM Adoption and the BIM Experience of Cost Consultants in Australia. *Journal of Professional Issues in Engineering Education Practice*, *140*(Autodesk 2011), 1–10. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000193.

Akinade, O. O., Oyedele, L. O., Ajayi, S. O., Bilal, M., Alaka, H. A., Owolabi, H. A., … Kadiri, K. O. (2017). Design for Deconstruction (DfD): Critical success factors for diverting end-of-life waste from landfills. *Waste Management*, *60*, 3–13. https://doi.org/10.1016/j.wasman.2016.08.017

Aksamija, A. (2012). BIM-Based Building Performance Analysis : Evaluation and Simulation of Design Decisions Integration of BIM-Based Performance Analysis with Design. In *ACEEE Summer Study on Energy Efficiency in Buildings* (pp. 1–12).

Al-Ghamdi, S. G., & Bilec, M. M. (2015). Life-Cycle Thinking and the LEED Rating System: Global Perspective on Building Energy Use and Environmental Impacts. *Environmental Science and Technology*, *49*(7), 4048–4056. https://doi.org/10.1021/es505938u

Allwinkle, S., & Cruickshank, P. (2011). Creating smart-er cities: An overview. *Journal of Urban Technology*, *18*(2), 1–16. https://doi.org/10.1080/10630732.2011.601103

Alreshidi, E., Mourshed, M., & Rezgui, Y. (2016). Cloud-Based BIM Governance Platform Requirements and Specifications: Software Engineering Approach Using BPMN and UML. *Journal of Computing in Civil Engineering*, *30*(4). https://doi.org/10.1061/(ASCE)CP.1943-5487.0000539

Alsayyar, B., & Jrade, A. (2015). Integrating Building Information Modeling (BIM) With Sustainable Universal Design Strategies To Evaluate the Costs and Benefits of Building Projects. In *5th International/11th Construction Specialty Conference* (pp. 1–10).

Antón, L. Á., & Díaz, J. (2014). Integration of LCA and BIM for Sustainable Construction. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, *8*(5), 1378–1382.

Arditi, D., & Gunaydin, H. M. (1999). Perceptions of process quality in building projects. *Journal of Management in Engineering*, *15*(2), 43–53.

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*, *11*(3), 241–252.

Barcelona City Council. (2017). BCN Smart City. Retrieved July 20, 2017, from http://smartcity.bcn.cat/en

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM - A case study approach. *Automation in Construction*, *24*, 149–159. https://doi.org/10.1016/j.autcon.2012.02.008

Becerik-gerber, B., & Kensek, K. (2010). Building Information Modeling in Architecture, Engineering, and Construction: Emerging Research Directions and Trends. *Journal of Professional Issues in Engineering Education and Practice*, *136*(3), 139–147. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000023

Brown, R. D., & Hauenstein, N. M. A. (2005). Interrater agreement reconsidered: An alternative to the rwg Indices. *Organizational Research Methods*, *8*(2), 165–184. https://doi.org/10.1177/1094428105275376

Caprotti, F. (2016). *Eco-Cities and the Transition to Low Carbon Economies*. Berlin: Springer. Retrieved from http://117.3.71.125:8080/mobile/bitstream/handle/DHKTDN/8516/Eco-Cities and the Transition to Low Carbon Economies%2C caprotti.2014.pdf?sequence=1&isAllowed=y

Chan, A. P. C., Lam, P. T. I., Wen, Y., Ameyaw, E. E., Wang, S., & Ke, Y. (2015). Cross-Sectional Analysis of Critical Risk Factors for PPP Water Projects in China. *Journal of Infrastructure Systems*, *21*(1), 04014031. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000214

Chan, A. P. C., Yung, E. H. K., Lam, P. T. I., Tam, C. M., & Cheung, S. O. (2001). Application of Delphi method in selection of procurement systems for construction projects. *Construction Management and Economics*, *19*(7), 699–718. https://doi.org/10.1080/01446190110066128

Chan, C. T. W. (2014). Barriers of Implementing BIM in Construction Industry from the Designers' Perspective: A Hong Kong Experience. *Journal of System and Management Sciences*, *4*(2), 24–40.

Chan, D. W. M., Chan, A. P. C., & Choi, T. N. Y. (2010). An empirical survey of the benefits of implementing pay for safety scheme (PFSS) in the Hong Kong construction industry. *Journal of Safety Research*, *41*(5), 433–443. https://doi.org/10.1016/j.jsr.2010.07.001

Chan, D. W. M., & Chan, J. H. L. (2012). Developing a performance measurement index (PMI) for target cost contracts in construction: a delphi study. *Construction Law Journal (CLJ)*, *28*(8), 590–613. Retrieved from http://repository.lib.polyu.edu.hk/jspui/handle/10397/5364

Chan, J. H. L., Chan, D. W. M., & Lord, W. E. (2011). Key Risk Factors and Risk Mitigation Measures for Target Cost Contracts in Construction - A Comparison Between the West and the East. *Construction Law Journal*, *27*(6), 441–458.

Chang, I. C. C., & Sheppard, E. (2013). China's eco-cities as variegated urban sustainability: Dongtan Eco- City and Chongming Eco-Island. *Journal of Urban Technology*, *20*(1), 57–75.

Chofreh, A. G., & Goni, F. A. (2017). Review of Frameworks for Sustainability Implementation. *Sustainable Development*, *25*, 180–188. https://doi.org/10.1002/sd.1658

Colding, J., & Barthel, S. (2017). An urban ecology critique on the "'Smart City"' model. *Journal of Cleaner Production*, *164*, 95–101.

Crot, L. (2013). Planning for sustainability in non-democratic polities: The case of Masdar city. *Urban Studies*, *50*(13), 2809–2825.

Cugurullo, F. (2013). How to build a sandcastle: An analysis of the genesis and development of Masdar City. *Journal of Urban Technology*, *20*(1), 23–27.

Cugurullo, F. (2017). Exposing smart cities and eco-cities: Frankenstein urbanism and the sustainability challenges of the experimental city. *Environment and Planning*, 1–20. https://doi.org/10.1177/0308518X17738535

Datta, A. (2015). New urban utopias of postcolonial India 'Entrepreneurial urbanization' in Dholera smart city, Gujarat. *Dialogues in Human Geography*, *5*(1), 3–22.

Field, A. (2009). *Discovering Statistics Using SPSS*. *Sage Publication* (Vol. 58). https://doi.org/10.1234/12345678

Gardas, B. B., Raut, R. D., & Narkhede, B. (2018a). Modelling the challenges to sustainability in the textile and apparel (T&A) sector: A Delphi-DEMATEL approach. *Sustainable Production and Consumption*, *15*, 96–108. https://doi.org/10.1016/j.spc.2018.05.001

Gardas, B. B., Raut, R. D., & Narkhede, B. (2018b). Reducing the exploration and production of oil: Reverse logistics in the automobile service sector. *Sustainable Production and Consumption*, *16*, 141–153. https://doi.org/10.1016/j.spc.2018.07.005

GhaffarianHoseini, A., Tien Doan, D., Naismith, N., Tookey, J., & GhaffarianHoseini, A. (2017). Amplifying the practicality of contemporary building information modelling (BIM) implementations for New Zealand green building certification (Green Star). *Engineering, Construction and Architectural Management*, *24*(4), 696–714. https://doi.org/10.1108/ECAM-02-2016-0043

Giel, B., & Issa, R. R. A. (2016). Framework for Evaluating the BIM Competencies of Facility Owners. *Journal of Management in Engineering*, *32*(1). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000378

Gisev, N., Bell, J. S., & Chen, T. F. (2013). Interrater agreement and interrater reliability: key concepts, approaches, and applications. *Research in Social and Administrative Pharmacy*, *9*(3), 330–338.

Gourlis, G., & Kovacic, I. (2017). Building Information Modelling for analysis of energy efficient industrial buildings – A case study. *Renewable and Sustainable Energy Reviews*, *68*, 953–963. https://doi.org/10.1016/j.rser.2016.02.009

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, *19*(8), 988–999. https://doi.org/10.1016/j.autcon.2010.09.002

Gunhan, S., & Arditi, D. (2005). Factors affecting international construction. *Journal of Construction Engineering and Management - ASCE*, *31*(3), 273–282.

Guo, L., Qu, Y., Wu, C., & Gui, S. (2018). Evaluating Green Growth Practices: Empirical Evidence from China. *Sustainable Development*, *26*, 302–319. https://doi.org/10.1002/sd.1716

Hallowell, M. R., & Gambatese, J. A. (2010). Qualitative Research: Application of the Delphi Method to CEM Research. *Journal of Construction Engineering and Management*, *136*(1), 99–107. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000137

Hanna, A., Boodai, F., & El Asmar, M. (2013). State of Practice of Building Information Modeling in Mechanical and Electrical Construction Industries. *Journal of Construction Engineering and Management - ASCE*, *139*(10), 1–8. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000747

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*, *32*(4), 1008–1015. https://doi.org/10.1046/j.1365-2648.2000.t01-1-01567.x

Hollands, R. (2008). "Will the Real Smart City Stand Up? Creative, Progressive, or Just Entrepreneurial?,." *City*, *12*(3), 302–320.

Hon, C. K. H., Chan, A. P. C., & Chan, D. W. M. (2011). Strategies for improving safety performance of repair, maintenance, minor alteration and addition (RMAA) works. *Facilities*, *29*(13/14), 591–610. https://doi.org/10.1108/02632771111178391

Hope, A., & Alwan, Z. (2012). Building the Future : Integrating Building Information Modelling and Environmental Assessment Methodologies. *Northumbria Research Link*. Retrieved from https://core.ac.uk/download/pdf/8790178.pdf

Hyun, C., Cho, K., Koo, K., Hong, T., & Moon, H. (2008). Effect of delivery methods on design performance in multifamily housing projects. *Journal of Construction Engineering and Management - ASCE*, *134*(7), 468–482.

Jakhar, S. K. (2017). Stakeholder Engagement and Environmental Practice Adoption: The Mediating Role of Process Management Practices. *Sustainable Development*, *25*, 92–

110. https://doi.org/10.1002/sd.1644

Jalaei, F., & Jrade, A. (2015). Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings. *Sustainable Cities and Society*, *18*, 95–107. https://doi.org/10.1016/j.scs.2015.06.007

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, *20*(2), 126–133. https://doi.org/10.1016/j.autcon.2010.09.010

Kang, S. (2018). Communicating sustainable development in the digital age : The relationship between citizens ' storytelling and engagement intention. *Sustainable Development*, 1–12. https://doi.org/10.1002/sd.1905

Kang, T. W., & Hong, C. H. (2015). A study on software architecture for effective BIM/GIS-based facility management data integration. *Automation in Construction*, *54*, 25–38. https://doi.org/10.1016/j.autcon.2015.03.019

Kassem, M., Brogden, T., & Dawood, N. (2012). BIM and 4D planning: a holistic study of the barriers and drivers to widespread adoption. *Journal of Construction Engineering and Project Management*, *2*(4), 1–10.

Kivits, R. A., & Furneaux, C. (2013). BIM: Enabling sustainability and asset management through knowledge management. *The Scientific World Journal*, *2013*. https://doi.org/10.1155/2013/983721

Kovacic, I., Filzmoser, M., Kiesel, K., Oberwinter, L., & Mahdavi, A. (2015). BIM teaching as support to integrated design practice. *GRADEVINAR*, *67*(6), 537–546.

Lebreton, J. M., & Senter, J. L. (2008). Answers to 20 Questions About Interrater Reliability and Interrater Agreement. *Organizational Research Methods*, *11*(4), 815–852. https://doi.org/10.1177/1094428106296642

Lee, S., & Yu, J. (2016). Comparative Study of BIM Acceptance between Korea and the United States. *Journal of Construction Engineering and Management*, *142*(3). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001076

Li, T. H. Y., Ng, S. T., & Skitmore, M. (2013). Evaluating stakeholder satisfaction during public participation in major infrastructure and construction projects: a fuzzy approach. *Automation in Construction*, *29*, 123–135.

Lu, W., & Tam, V. W. (2013). Construction waste management policies and their effectiveness in Hong Kong: a longitudinal review. *Renewable & Sustainable Energy Reviews*, *23*, 214–223.

Ma, X., Xiong, F., Olawumi, T. O., Dong, N., & Chan, A. P. C. (2018). Conceptual Framework and Roadmap Approach for Integrating BIM into Lifecycle Project Management. *Journal of Management in Engineering*, *34*(6), 1–10. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000647.

Masdar Initiative. (2017). Sustainability. Retrieved July 20, 2017, from http://www.masdar.ae/en/masdar-city/ the-built-environment

MIGHT. (2014). Malaysia's Construction Industry Development Board is Partnering with Bayer Material Science to Build Two Prototype Houses at the Industrialized Building Show Village in Kuala Lumpur.

Milano Smart City. (2017). Smart Milano. Retrieved February 20, 2017, from www.milanosmartcity.org/joomla/

Mora, L., Bolici, R., & Deakin, M. (2017). The First Two Decades of Smart-City Research: A Bibliometric Analysis. *Journal of Urban Technology*, *24*(1), 3–27. https://doi.org/10.1080/10630732.2017.1285123

Morlhon, R., Pellerin, R., & Bourgault, M. (2014). Building Information Modeling Implementation through Maturity Evaluation and Critical Success Factors Management. *Procedia Technology*, *16*, 1126–1134. https://doi.org/10.1016/j.protcy.2014.10.127

Nanajkar, A., & Gao, Z. (2014). BIM Implementation Practices at India's AEC Firms. In *International Conference on Construction and Real Estate Management*. Kunming, China.

Olatunji, S. O., Olawumi, T. O., & Aje, I. O. (2017a). Rethinking Partnering among Quantity-Surveying Firms in Nigeria. *Journal of Construction Engineering and Management*, *143*(11), 1–12. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001394

Olatunji, S. O., Olawumi, T. O., & Awodele, O. A. (2017b). Achieving Value for Money (VFM) in Construction Projects. *Journal of Civil and Environmental Research- The International Institute for Science, Technology and Education (IISTE)*, *9*(2), 54–64.

Olatunji, S. O., Olawumi, T. O., & Ogunsemi, D. R. (2016). Demystifying Issues Regarding Public Private Partnerships (PPP). *Journal of Economics and Sustainable Development- The International Institute for Science, Technology and Education (IISTE)*, *7*(11), 1–22.

Olawumi, T. O., & Ayegun, O. A. (2016). Are Quantity Surveyors competent to value for Civil Engineering Works? Evaluating QSs' competencies and militating factors. *Journal of Education and Practice- The International Institute for Science, Technology and Education (IISTE)*, *7*(16), 1–16.

Olawumi, T. O., & Chan, D. W. M. (2017). Geospatial Map of the Global Research on Sustainability and Sustainable Development: Generating and converting KML files to Map. *Mendeley Data*, *1*(1). https://doi.org/10.17632/sv23pvr252.1

Olawumi, T. O., & Chan, D. W. M. (2018a). A Scientometric Review of Global Research on Sustainability and Sustainable Development. *Journal of Cleaner Production*, *183*, 231–250. https://doi.org/10.1016/j.jclepro.2018.02.162

Olawumi, T. O., & Chan, D. W. M. (2018b). Building Information Modelling and Project Information Management Framework for Construction Projects. *Journal of Civil Engineering and Management*, *(in press)*.

Olawumi, T. O., & Chan, D. W. M. (2018c). Development of a Benchmarking Model for BIM Implementation in Devloping Countries. *Benchmarking: An International Journal*, ((in press)). https://doi.org/10.1108/BIJ-05-2018-0138

Olawumi, T. O., Chan, D. W. M., & Wong, J. K. W. (2017). Evolution in the Intellectual Structure of BIM Research: A Bibliometric Analysis. *Journal of Civil Engineering and Management*, *23*(8), 1060–1081. https://doi.org/10.3846/13923730.2017.1374301

Oti, a. H., Tizani, W., Abanda, F. H., Jaly-Zada, a., & Tah, J. H. M. (2016). Structural sustainability appraisal in BIM. *Automation in Construction*, *69*, 44–58. https://doi.org/10.1016/j.autcon.2016.05.019

Raut, R. D., Narkhede, B., & Gardas, B. B. (2017). To identify the critical success factors of sustainable supply chain management practices in the context of oil and gas industries: ISM approach. *Renewable and Sustainable Energy Reviews*, *68*(September 2016), 33–47. https://doi.org/10.1016/j.rser.2016.09.067

Raut, R., Narkhede, B. E., Gardas, B. B., & Luong, H. T. (2018). An ISM approach for the barrier analysis in implementing sustainable practices: The Indian oil and gas sector. *Benchmarking*, *25*(4), 1245–1271. https://doi.org/10.1108/BIJ-05-2016-0073

Redmond, A., Hore, A., Alshawi, M., & West, R. (2012). Exploring how information exchanges can be enhanced through Cloud BIM. *Automation in Construction*, *24*, 175–183. https://doi.org/10.1016/j.autcon.2012.02.003

Reinhart, C. F., & Wienold, J. (2011). The daylighting dashboard - A simulation-based design analysis for daylit spaces. *Building and Environment*, *46*(2), 386–396. https://doi.org/10.1016/j.buildenv.2010.08.001

Sala, S., Ciuffo, B., & Nijkamp, P. (2015). A systemic framework for sustainability assessment. *Ecological Economics*, *119*, 314–325. https://doi.org/10.1016/j.ecolecon.2015.09.015

Saxon, R. G. (2013). *Growth through BIM. Construction Industry Council*. London.

Smart City Wien. (2017). Framework Strategy. Retrieved July 20, 2017, from https://smartcity.wien.gv.at/site/ en/

Tah, J. H. M., & Abanda, H. F. (2011). Sustainable building technology knowledge representation: Using Semantic Web techniques. *Advanced Engineering Informatics*, *25*(3), 547–558. https://doi.org/10.1016/j.aei.2011.02.006

Taylor Buck, N., & While, A. (2017). Competitive urbanism and the limits to smart city innovation: The UK Future Cities initiative. *Urban Studies*, *54*(2), 501–519.

Tsai, M.-H., Mom, M., Hsieh, S.-H., Tsai, M.-H., Hsieh, S.-H., Mom, M., … Hsieh, S.-H. (2014). Developing critical success factors for the assessment of BIM technology adoption: part I. Methodology and survey. *Journal of the Chinese Institute of Engineers*, *37*(7), 845–858. https://doi.org/10.1080/02533839.2014.888798

Turoff, M. (1970). The design of a policy Delphi. *Technological Forecasting and Social Change*, *2*, 149–171.

WCED. (1987). Our common future. In *Brundtland Report* (pp. 1–300). Brundtland: World Commission on Environment and Development- Oxford University Press. Retrieved from http://www.un-documents.net/our-common-future.pdf

Wong, J., Wang, X., Li, H., Chan, G., & Li, H. (2014). A review of cloud-based bim technology in the construction sector. *Journal of Information Technology in Construction*, *19*(August), 281–291.

Wong, K., & Fan, Q. (2013). Building information modelling (BIM) for sustainable building design. *Facilities*, *31*(3), 138–157. https://doi.org/10.1108/02632771311299412

Xue, L. (2018). Addressing policy challenges in implementing Sustainable Development Goals through an adaptive governance approach : A view from transitional China. *Sustainable Development*, *26*, 150–158. https://doi.org/10.1002/sd.1726

Yeomans, S. G., Bouchlaghem, N. M., & El-Hamalawi, A. (2006). An evaluation of current collaborative prototyping practices within the AEC industry. *Automation in Construction*, *15*(2), 139–149.

Yeung, J. F. Y., Chan, A. P. C., Chan, D. W. M., & Li, L. K. (2007). Development of a partnering performance index (PPI) for construction projects in Hong Kong: a Delphi study. *Construction Management and Economics*, *25*(12), 1219–1237. https://doi.org/10.1080/01446190701598673

Yusof, N., Zainul Abidin, N., Zailani, S. H. M., Govindan, K., & Iranmanesh, M. (2016). Linking the environmental practice of construction firms and the environmental behaviour of practitioners in construction projects. *Journal of Cleaner Production*, *121*, 64–71. https://doi.org/10.1016/j.jclepro.2016.01.090

Zahoor, H., Chan, A. P. C., Gao, R., & Utama, W. P. (2017). The factors contributing to construction accidents in Pakistan: their prioritization using the Delphi technique. *Engineering, Construction and Architectural Management*, *24*(3), ECAM-01-2016-0027. https://doi.org/10.1108/ECAM-01-2016-0027

Zhaojian, L., & Yi, J. (2006). Pondering over the situation of domestic generalized building energy consumption. *Architectural Journal*, *7*, 30–33.

Table 1: Drivers (CSFs) for BIM and sustainability practices in construction projects

Code	Factors	References
C1	Technical competence of staff	Gu and London (2010); Tsai et al. (2014)
C2	Greater awareness and experience level within the firm	Chan (2014); Kassem et al. (2012)
C3	More training programs for cross-field specialists in BIM and Sustainability	Wong and Fan (2013)
C4	Increased research in the industry and academia	Abdirad (2016)
C5	Government establishment of start-up funding for construction firms to kick-start BIM initiatives	Abubakar et al. (2014)
C6	Adequate construction cost allocated to BIM	Gu and London (2010); Kivits and Furneaux (2013)
C7	Availability of financial resources for BIM software, licenses, and its regular upgrades	Nanajkar and Gao (2014)
C8	Information and knowledge-sharing within the industry	Azhar (2011)
C9	Effective collaboration and coordination among project participants	Antón and Díaz (2014); Hanna et al. (2013)
C10	Establishment of a model of good practice for BIM and sustainability implementation	Jung and Joo (2011)
C11	Availability and a well-managed in-house database of information on similar projects	Adamus (2013); Antón and Díaz (2014)
C12	Development of appropriate legal framework for BIM use and deployment in projects	Aibinu and Venkatesh (2014); Becerik-gerber and Kensek (2010)
C13	Security of intellectual property and rights	Aibinu and Venkatesh (2014); Becerik-gerber and Kensek (2010)
C14	Shared risks, liability, and rewards among project stakeholders	Kivits and Furneaux (2013)
C15	Establishment of BIM standards, codes, rules, and regulations	Chan (2014)
C16	Appropriate legislation and governmental enforcement & credit for innovative performance	Redmond et al. (2012)
C17	Increased involvement of project stakeholders in green projects	Antón and Díaz (2014); Hope and Alwan (2012)
C18	Clarity in requirements and measures for achieving sustainable projects	Alsayyar and Jrade (2015)
C19	Number of subcontractors experienced with BIM projects	Aibinu and Venkatesh (2014)
C20	Client requirement and ownership	Chan (2014)
C21	Early involvement of project teams	Ahn et al. (2014)
C22	Client satisfaction level on BIM projects	Kassem et al. (2012)
C23	Supportive organizational culture and effective leadership	Ahn et al. (2014); Chan (2014)
C24	Project complexity (regarding building shape or building systems)	Yeomans et al. (2006)
C25	Availability and affordability of cloud-based technology	Hope and Alwan (2012); Kivits and Furneaux (2013)
C26	Interoperability and data compatibility	Adamus (2013); Saxon (2013)
C27	Standardization & simplicity of BIM and sustainability assessment software	Akinade et al. (2017); Aksamija (2012)
C28	Technical support from software vendors	Redmond et al. (2012)
C29	Availability of BIM and sustainability databases	Abolghasemzadeh (2013); Antón and Díaz (2014)
C30	Open-source software development	Hope and Alwan (2012)

Table 2: First round of Delphi survey- CSFs that amplify the integration of 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**
C1	4.29	.726	3	4.29	.756	11	4.29	.756	2	4.50	.756	2	4.00	.632	13
C2	4.21	.426	4	4.14	.378	12	4.29	.488	1	4.13	.354	9	4.33	.516	1
C3	4.29	.611	2	4.29	.488	8	4.29	.756	2	4.38	.518	3	4.17	.753	4
C4	4.14	.663	9	4.14	.690	13	4.14	.690	5	4.25	.707	7	4.00	.632	13
C5	3.86	.864	17	3.86	1.069	21	3.86	.690	14	3.88	1.126	15	3.83	.408	19
C6	3.57	.756	27	3.71	.951	28	3.43	.535	24	3.38	.916	27	3.83	.408	19
C7	3.57	1.342	30	4.14	1.069	16	3.00	1.414	30	3.25	1.669	30	4.00	.632	13
C8	4.00	.555	10	4.29	.488	8	3.71	.488	16	4.00	.756	10	4.00	.000	9
C9	4.21	.579	6	4.57	.535	1	3.86	.378	11	4.25	.707	7	4.17	.408	2
C10	4.14	.535	8	4.43	.535	3	3.86	.378	11	4.25	.463	5	4.00	.632	13
C11	3.86	.363	15	3.71	.488	22	4.00	.000	7	3.75	.463	17	4.00	.000	9
C12	4.21	.426	4	4.43	.535	3	4.00	.000	7	4.38	.518	3	4.00	.000	9
C13	3.79	.893	21	4.14	.900	15	3.43	.787	25	3.88	1.126	15	3.67	.516	27
C14	3.93	.616	13	4.29	.488	8	3.57	.535	20	4.00	.756	10	3.83	.408	19
C15	4.00	.877	12	4.43	.535	3	3.57	.976	22	4.00	1.069	13	4.00	.632	13
C16	3.79	.802	20	4.14	.690	13	3.43	.787	25	3.75	1.035	22	3.83	.408	19
C17	3.86	.535	16	3.57	.535	29	4.14	.378	4	3.75	.707	19	4.00	.000	9
C18	3.79	.579	18	3.71	.756	25	3.86	.378	11	3.75	.707	19	3.83	.408	19
C19	3.79	.579	18	4.00	.577	17	3.57	.535	20	3.75	.463	17	3.83	.753	25
C20	3.79	.893	21	4.00	.816	19	3.57	.976	22	4.00	.756	10	3.50	1.049	29
C21	4.36	.745	1	4.57	.535	1	4.14	.900	6	4.63	.744	1	4.00	.632	13
C22	4.00	.784	11	4.00	.577	17	4.00	1.000	10	3.88	.835	14	4.17	.753	4
C23	3.71	.726	24	3.71	.756	25	3.71	.756	17	3.75	.707	19	3.67	.816	28
C24	3.71	.726	24	3.71	.756	25	3.71	.756	17	3.63	.744	25	3.83	.753	24
C25	3.57	.756	27	3.71	.488	22	3.43	.976	27	3.63	.518	24	3.50	1.049	29
C26	4.21	.579	7	4.43	.535	3	4.00	.577	9	4.25	.463	5	4.17	.753	4
C27	3.93	1.072	14	4.43	.535	3	3.43	1.272	28	3.75	1.282	23	4.17	.753	4
C28	3.57	1.089	29	3.86	.690	20	3.29	1.380	29	3.38	1.188	28	3.83	.983	26

C29	3.79	.975	23	3.71	.488	22	3.86	1.345	15	3.50	1.195	26	4.17	.408	2
C30	3.64	1.151	26	3.57	.787	30	3.71	1.496	19	3.25	1.165	29	4.17	.983	8
Cronbach's α reliability coefficient		0.824			0.715			0.863			0.750			0.921	
Number of respondents (n)		14			7			7			8			6	
Kendall's coefficient of concordance (W)		0.110			0.215			0.188			0.184			0.134	
Calculated χ^2		44.605			43.549			38.091			42.792			**23.309	
χ^2- Critical value from statistical table (p=0.05)		42.557			42.557			42.557			42.557			42.557	
Degree of freedom (df)		29			29			29			29			29	
Significance level (p)		0.032			0.040			0.120			0.048			**0.762	

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

Table 3: Second round of Delphi survey- CSFs that amplify the integration of 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
C1	4.36	.745	3	4.29	.756	11	4.43	.787	1	4.63	.744	2	4.00	.632	11
C2	4.21	.426	6	4.14	.378	12	4.29	.488	3	4.13	.354	10	4.33	.516	1
C3	4.36	.633	2	4.29	.488	7	4.43	.787	1	4.50	.535	3	4.17	.753	3
C4	4.14	.663	10	4.14	.690	13	4.14	.690	8	4.38	.744	7	3.83	.408	16
C5	4.00	.877	14	3.86	1.069	21	4.14	.690	8	4.13	1.126	14	3.83	.408	16
C6	3.64	.745	26	3.71	0.951	29	3.57	.535	25	3.50	0.926	27	3.83	.408	16
C7	3.50	1.286	30	4.00	1.000	18	3.00	1.414	30	3.25	1.669	30	3.83	0.408	16
C8	4.14	.535	8	4.43	.535	3	3.86	.378	16	4.25	.707	9	4.00	.000	6
C9	4.29	.469	4	4.57	.535	1	4.00	.000	10	4.50	.535	3	4.00	.000	6
C10	4.14	.535	8	4.29	.488	7	4.00	.577	11	4.38	.518	6	3.83	.408	16
C11	3.93	.475	16	3.71	.488	25	4.14	0.378	5	3.88	.641	18	4.00	0.000	6
C12	4.29	.469	4	4.43	.535	3	4.14	0.378	5	4.50	.535	3	4.00	0.000	6
C13	3.86	.864	21	4.14	.900	15	3.57	.787	26	4.00	1.069	16	3.67	.516	27
C14	4.00	.555	12	4.29	.488	7	3.71	.488	20	4.13	.641	11	3.83	.408	16
C15	4.07	.829	11	4.43	.535	3	3.71	.951	21	4.13	.991	13	4.00	.632	11
C16	3.86	.770	20	4.14	.690	13	3.57	.787	26	3.88	.991	22	3.83	.408	16
C17	3.93	.475	16	3.71	.488	25	4.14	.378	5	3.88	.641	18	4.00	.000	6
C18	3.86	.663	19	3.71	.756	28	4.00	.577	11	3.88	.835	21	3.83	.408	16
C19	3.86	.363	18	3.86	.378	19	3.86	.378	16	3.88	.354	17	3.83	.408	16
C20	3.86	.864	21	4.00	.816	17	3.71	.951	21	4.13	.641	11	3.50	1.049	29
C21	4.43	.646	1	4.57	.535	1	4.29	.756	4	4.75	.463	1	4.00	.632	11
C22	4.00	.679	13	4.00	.577	16	4.00	.816	14	4.00	.756	15	4.00	.632	11
C23	3.79	.699	24	3.71	.756	23	3.86	.690	18	3.88	.641	18	3.67	.816	28
C24	3.79	.699	24	3.71	.756	23	3.86	.690	18	3.75	.707	25	3.83	.753	25
C25	3.64	.745	26	3.71	.488	22	3.57	.976	28	3.75	.463	24	3.50	1.049	29
C26	4.21	.579	7	4.43	.535	3	4.00	.577	11	4.25	.463	8	4.17	.753	3
C27	4.00	1.038	15	4.29	.488	7	3.71	1.380	23	3.88	1.246	23	4.17	.753	3
C28	3.64	1.082	28	3.86	.690	20	3.43	1.397	29	3.50	1.195	28	3.83	.983	26

C29	3.86	1.027	23	3.71	.488	25	4.00	1.414	15	3.63	1.302	26	4.17	.408	2
C30	3.64	1.082	28	3.57	.787	30	3.71	1.380	23	3.38	1.188	29	4.00	.894	15
Cronbach's α reliability coefficient		0.808			0.709			0.850			0.700			0.934	
Number of respondents (n)		14			7			7			8			6	
Kendall's coefficient of concordance (W)		0.114			0.209			0.173			0.194			0.143	
Calculated χ^2		46.308			42.454			35.094			44.963			24.938	
χ^2- Critical value from statistical table (p=0.05)		42.557			42.557			42.557			42.557			42.557	
Degree of freedom (df)		29			29			29			29			29	
Significance level (p)		0.022			0.051			0.201			0.030			0.681	

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

Factor coding	Round 1		Round 2		Round 1	Round 2
	$a_{wg(1)}$ score	Agreement level	$a_{wg(1)}$ score	Agreement level	Significance grade	Significance grade
C1	0.585	Moderate	0.525	Moderate	V. important	V. important
C2	0.867	Strong	0.867	Strong	V. important	V. important
C3	0.706	Moderate	0.657	Moderate	V. important	V. important
C4	0.699	Moderate	0.699	Moderate	V. important	V. important
C5	0.578	Moderate	0.527	Moderate	V. important	V. important
C6	0.713	Strong	0.714	Strong	V. important	V. important
C7	0.094	Lack	0.186	Lack	V. important	↓Important
C8	0.811	Strong	0.804	Strong	V. important	V. important
C9	0.755	Strong	0.827	Strong	V. important	V. important
C10	0.804	Strong	0.804	Strong	V. important	V. important
C11	0.925	Very strong	0.867	↓Strong	V. important	V. important
C12	0.867	Strong	0.827	Strong	V. important	V. important
C13	0.565	Moderate	0.578	Moderate	V. important	V. important
C14	0.777	Strong	0.811	Strong	V. important	V. important
C15	0.527	Moderate	0.555	Moderate	V. important	V. important
C16	0.649	Moderate	0.664	Moderate	V. important	V. important
C17	0.838	Strong	0.867	Strong	V. important	V. important
C18	0.817	Strong	0.751	Strong	V. important	V. important
C19	0.817	Strong	0.925	↑Very strong	V. important	V. important
C20	0.565	Moderate	0.578	Moderate	V. important	V. important
C21	0.525	Moderate	0.607	Moderate	V. important	V. important
C22	0.621	Moderate	0.716	↑Strong	V. important	V. important
C23	0.721	Strong	0.733	Strong	V. important	V. important
C24	0.721	Strong	0.733	Strong	V. important	V. important
C25	0.713	Strong	0.714	Strong	V. important	V. important
C26	0.755	Strong	0.755	Strong	V. important	V. important
C27	0.324	Weak	0.337	Weak	V. important	V. important
C28	0.404	Weak	0.398	Weak	V. important	V. important
C29	0.481	Weak	0.404	Weak	V. important	V. important
C30	0.318	Weak	0.398	Weak	V. important	V. important

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

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

Code	Factors	Ranking	Significance	Agreement level
C19	Number of subcontractors experienced with BIM projects	1	Very important	Very strong
C2	Greater awareness and experience level within the firm	2	Very important	Strong
C17	Increased involvement of project stakeholders in green projects	3	Very important	Strong
C18	Clarity in requirements and measures for achieving sustainable projects	4	Very important	Strong
C26	Interoperability and data compatibility	5	Very important	Strong
C11	Availability and a well-managed in-house database of information on similar projects	6	Very important	Strong
C9	Effective collaboration and coordination among project participants	7	Very important	Strong
C23	Supportive organizational culture and effective leadership	8	Very important	Strong
C10	Establishment of a model of good practice for BIM and sustainability implementation	9	Very important	Strong
C6	Adequate construction cost allocated to BIM	10	Very important	Strong
C8	Information and knowledge-sharing within the industry	11	Very important	Strong
C12	Development of appropriate legal framework for BIM use and deployment in projects	12	Very important	Strong
C14	Shared risks, liability, and rewards among project stakeholders	13	Very important	Strong
C22	Client satisfaction level on BIM projects	14	Very important	Strong
C24	Project complexity (regarding building shape or building systems)	15	Very important	Strong
C25	Availability and affordability of cloud-based technology	16	Very important	Strong
C21	Early involvement of project teams	17	Very important	Moderate
C3	More training programs for cross-field specialists in BIM and Sustainability	18	Very important	Moderate
C1	Technical competence of staff	19	Very important	Moderate
C4	Increased research in the industry and academia	20	Very important	Moderate
C5	Government establishment of start-up funding for construction firms to kick-start BIM initiatives	21	Very important	Moderate
C13	Security of intellectual property and rights	22	Very important	Moderate
C15	Establishment of BIM standards, codes, rules, and regulations	23	Very important	Moderate
C16	Appropriate legislation and governmental enforcement & credit for innovative performance	24	Very important	Moderate
C20	Client requirement and ownership	25	Very important	Moderate
C27	Standardization & simplicity of BIM and sustainability assessment software	26	Very important	Weak
C28	Technical support from software vendors	27	Very important	Weak
C29	Availability of BIM and sustainability databases	28	Very important	Weak
C30	Open-source software development	29	Very important	Weak
C7	Availability of financial resources for BIM software, licenses, and its regular upgrades	30	Important	Lack

Table 6: Mann-Whitney U test between the academics and practitioners' groups on the CSFs of BIM and sustainability integration in construction projects

Code	**Mean Rank**		**Mann-Whitney U**	**Z-value**	**p-value**	**Conclusion to H_0**
	Academics	**Practitioners**				
C1	7.07	7.93	21.500	-.421	.674	Accept
C2	7.00	8.00	21.000	-.628	.530	Accept
C3	6.86	8.14	20.000	-.643	.520	Accept
C4	7.50	7.50	24.500	.000	1.000	Accept
C5	7.07	7.93	21.500	-.415	.678	Accept
C6	8.07	6.93	20.500	-.574	.566	Accept
C7	9.14	5.86	13.000	-1.632	.103	Accept
C8	9.29	5.71	12.000	-2.015	.044	**Reject**
C9	9.50	5.50	10.500	-2.280	.023	**Reject**
C10	8.36	6.64	18.500	-.967	.334	Accept
C11	6.14	8.86	15.000	-1.693	.091	Accept
C12	8.50	6.50	17.500	-1.140	.254	Accept
C13	8.71	6.29	16.000	-1.172	.241	Accept
C14	9.21	5.79	12.500	-1.927	.054	Accept
C15	9.07	5.93	13.500	-1.578	.115	Accept
C16	8.79	6.21	15.500	-1.344	.179	Accept
C17	6.14	8.86	15.000	-1.693	.091	Accept
C18	6.64	8.36	18.500	-.862	.389	Accept
C19	7.50	7.50	24.500	.000	1.000	Accept
C20	8.00	7.00	21.000	-.482	.630	Accept
C21	8.21	6.79	19.500	-.714	.475	Accept
C22	7.50	7.50	24.500	.000	1.000	Accept
C23	7.07	7.93	21.500	-.421	.674	Accept
C24	7.07	7.93	21.500	-.421	.674	Accept
C25	7.79	7.21	22.500	-.287	.774	Accept
C26	8.79	6.21	15.500	-1.361	.174	Accept
C27	8.21	6.79	19.500	-.717	.473	Accept
C28	7.79	7.21	22.500	-.284	.777	Accept
C29	6.07	8.93	14.500	-1.425	.154	Accept
C30	6.71	8.29	19.000	-.739	.460	Accept

Table 7: Mann-Whitney U test between the West and East respondent groups on the CSFs of BIM and sustainability integration in construction projects

Code	**Mean Rank**		**Mann-Whitney U**	**Z-value**	**p-value**	**Conclusion to H_0**
	West	**East**				
C1	9.06	5.42	11.500	-1.770	.077	Accept
C2	6.88	8.33	19.000	-.906	.365	Accept
C3	8.25	6.50	18.000	-.866	.386	Accept
C4	8.88	5.67	13.000	-1.597	.110	Accept
C5	8.44	6.25	16.500	-1.049	.294	Accept
C6	6.75	8.50	18.000	-.870	.385	Accept
C7	7.31	7.75	22.500	-.215	.830	Accept
C8	8.25	6.50	18.000	-.977	.329	Accept
C9	9.00	5.50	12.000	-1.975	.048	**Reject**
C10	8.94	5.58	12.500	-1.873	.061	Accept
C11	7.13	8.00	21.000	-.540	.589	Accept
C12	9.00	5.50	12.000	-1.975	.048	**Reject**
C13	8.38	6.33	17.000	-.975	.330	Accept
C14	8.25	6.50	18.000	-.974	.330	Accept
C15	8.06	6.75	19.500	-.652	.514	Accept
C16	7.81	7.08	21.500	-.377	.706	Accept
C17	7.13	8.00	21.000	-.540	.589	Accept
C18	7.50	7.50	24.000	.000	1.000	Accept
C19	7.63	7.33	23.000	-.212	.832	Accept
C20	8.63	6.00	15.000	-1.253	.210	Accept
C21	9.38	5.00	9.000	-2.165	.030	**Reject**
C22	7.50	7.50	24.000	.000	1.000	Accept
C23	8.06	6.75	19.500	-.637	.524	Accept
C24	7.31	7.75	22.500	-.212	.832	Accept
C25	8.00	6.83	20.000	-.580	.562	Accept
C26	7.63	7.33	23.000	-.153	.879	Accept
C27	7.31	7.75	22.500	-.217	.828	Accept
C28	6.94	8.25	19.500	-.645	.519	Accept
C29	6.81	8.42	18.500	-.792	.429	Accept
C30	6.63	8.67	17.000	-.951	.342	Accept