CRITICAL SUCCESS FACTORS (CSFs) FOR AMPLIFYING THE INTEGRATION OF BIM AND SUSTAINABILITY PRINCIPLES IN CONSTRUCTION PROJECTS: A DELPHI STUDY

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ABSTRACT

In recent years, there have been significant calls for a more technologically driven construction sector which would not meet the expected standards in quality, time and cost but also integrate sustainable principles in delivering its final products. This research study aims at determining and prioritizing the key drivers that can enhance the integration of Building Information Modelling (BIM) and sustainable practices in construction projects. A two-stage Delphi survey technique involving the collection of data based on the perceptions and experiences of fourteen invited experts from both the academia and the industry. Statistical analyses such as mean score ranking technique and standard deviation and the Kendall's concordance test were applied to the data collated in each round. Altogether, 30 critical success factors (CSFs) were identified from extant literature, of which early involvement of project teams, more training programs for cross-field specialists in BIM and Sustainability, and technical competence of project staff, were ranked as the three most critical factors. Meanwhile, some recommendations were proffered to the construction project stakeholders including the government. The implementation of these key drivers would help the construction sector to implement sustainable practices and BIM while achieving the goal of sustainable urban city.

Keywords: BIM, construction projects, Delphi study, drivers, sustainability practices.

INTRODUCTION

The construction industry is a robust and complex environment wherein projects involving several processes and activities often take place simultaneously and also in recent years several technology tools and systems have been integrated to improve the design and construction of projects. Shi *et al.* (2012) pointed out that the activities and processes involved in construction projects and in the construction sector have significant impacts on the ecosystem and to the populace and that the construction industry is emerging as one of the key advocate of sustainability. More so, it is difficult to separate sustainable urban planning and the construction industry because they are closely related (Kocabas 2013; Shi *et al.* 2014) and involved the application of modern technology, software and tools (like BIM) (Olawumi *et al.* 2017).

Arayici *et al.* (2011) perceived that the drive behind the introduction and implementation of Building Information Modelling (BIM) in construction projects was to provide value for money, sustainable design and adaptable building construction. Extant literature (Olatunji *et al.* 2016a, 2016b; Olawumi and Ayegun 2016) described the construction industry as that which requires collaboration among the project stakeholders and the coordination of the processes. Arayici *et al.* (2011) further outlined the challenges faced in achieving sustainable development.

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BIM is described as a "digital technology" (Abanda *et al.* 2015) which could improve the efficiency of delivering construction projects and also could yield higher return on investment (Olatunji *et al.* 2017b). Meanwhile, sustainability is related to the lifecycle of facilities (Oti and Tizani 2015) and involves assessing the environmental, social and economic constructs of sustainable development. The concept of sustainability and sustainable development has its roots in the communique issued in 1987 after the World Commission on Environment and Development. Goodland (1995) discussed the concepts of social, economic and environmental sustainability in detail and argued that for a sustainable development, these three components of sustainability must be incorporated. However, most studies on sustainability issues have centered around environmental sustainability (Olawumi *et al.* 2017).

Several studies have been conducted to exemplify how BIM was implemented to enhance sustainability in the built environment. Oti and Tizani (2015) designed a prototype system linked with a BIM software to appraise steel structures designs for sustainability criteria. The basis of the model assessment developed by Oti and Tizani (2015) is to evaluate for the cost, carbon and ecological footprint which are important sustainability measures. They recommended for project stakeholders to be aware of sustainable design solutions and alternatives suitable for projects.

More so, a study by Kim *et al.* (2015) focused on applying a BIM-based decision support system to facilitate and simulate development trends and scenario for a large urban development, so as to assist project teams in interpreting and evaluating the impact of the development on sustainability of the environment. Nevertheless, according to Gan *et al.* (2015) there are still challenges facing the construction industry in undertaking projects in a responsible and sustainable manner due to what they term lack of "key drivers of urbanization".

Hence, this study attempts to identify and prioritize the significant drivers that would help enhance the integration of BIM and sustainable practices in construction projects towards the implementation of a sustainable urban development. More so, in achieving the aim of the study, the perception of project stakeholders was garnered using the Delphi survey methodology as explained in the next section. The deliverables of this research such as (i) identifying the drivers (CSFs) of integrating BIM and sustainable practices; and (ii) prioritizing such factors based on the level of importance, would serve as an essential source of knowledge and reference by project stakeholders and buildings owners in their decision-making process and strategies towards integrating technologies such as BIM and implementing sustainable practices at project sites. The study also contributes towards enhancing the drive for a sustainable urban development.

RESEARCH METHODOLOGY: DELPHI SURVEY TECHNIQUE

A two-stage Delphi survey was adopted in identifying and prioritizing the critical success factors (CSFs) of integrating BIM and sustainability practices at the design stage of construction projects. The Delphi survey technique is regarded as a "systematic and interactive" research approach to garner opinions and judgment of a panel of experts (Hallowell and Gambatese 2010; Chan and Chan 2012). Moreover, most research topics (Yeung *et al.* 2007, 2009; Chan and Chan 2012; Chan *et al.* 2015; Zahoor *et al.* 2017) that usually embrace this technique are areas that are either of a multidisciplinary in nature or relatively new concepts (or being carried out in a new region/country).

The study under consideration falls within both categories. Grisham (2009) further noted that it is useful for investigating "complex issues" and that it is useful in unearthing knowledge, however, the experts must be knowledgeable in the field(s) been considered. Meanwhile, this technique have found acceptance and usage in several disciplines (Czinkota and Ronkainen 1997; Grisham 2009).

The first stage of the Delphi survey was based on the invitation of 27 BIM and sustainability experts identified from both the academia and the industry to rank the CSFs of integrating BIM and sustainable practices at the design stage of construction projects. The 30 CSFs were determined based on a desktop literature review (see Table 1) and 14 experts out of the 27 invited experts responded to the invitation and participated in the survey. The summary of results of the first round of survey was then returned to the 14 experts to review or alter their original ratings to commence the second stage of the Delphi survey. Each expert was provided with their original rating for each factor to assist them in the review.

The results from both rounds of Delphi survey were analyzed statistically using the mean score ranking technique, standard deviation and Kendall's coefficient of concordance. Delphi survey being a self-validating technique, it is important for the researcher to ensure the right selection and composition of the expert panel. More so, the design of the questions and choice of the expert members is linked to the credibility a Delphi study (Chan *et al.* 2001, 2015; Chan and Chan 2012).

Hence, this study's Delphi panel members were constituted of expert members from both the industry and the academia with 7 members each using a purposive sampling technique. Also, for a Delphi panel the minimum size is 7 panel members (Linstone 1978; Mullen 2003; Thangaratinam and Redman 2005). The invited experts are those who have satisfied at least two of the following criteria: (1) experts with extensive experience in the construction industry; (2) experts who have participated in current/recent projects on both BIM and sustainability practices in the AEC industry; and (3) experts with sound knowledge and understanding of the concepts of BIM and sustainability practices.

Table 1: CSFs of integrating BIM and sustainability principles at the design stage of construction projects

Code	CSFs of integrating BIM and sustainability principles at the design stage of construction projects	Sources of reference
C1	Technical competence of staff	1, 2, 3, 5
C2	Greater awareness and experience level within the firm	4, 5, 6
C3	More training programs for cross-field specialists in BIM and Sustainability	7, 8
C4	Increased research in the industry and academia	7, 9
C5	Government establishment of start-up funding for construction firms to kick-start BIM initiatives	2, 10
C6	Adequate construction cost allocated to BIM	9, 11
C7	Availability of financial resources for BIM software, licenses and its regular upgrades	9, 11
C8	Information and knowledge-sharing within the industry	9, 12, 13
C9	Effective collaboration and coordination among project participants	9, 14
C10	Establishment of a model of good practice for BIM and sustainability implementation	13, 15
C11	Availability and a well-managed in-house database of information on similar projects	14, 16
C12	Development of appropriate legal framework for BIM use and deployment in projects	9, 13, 17

C13	Security of intellectual property and rights	11, 17
C14	Shared risks, liability, and rewards among project stakeholders	11, 13
C15	Establishment of BIM standards, codes, rules, and regulations	9, 13, 17, 15
C16	Appropriate legislation and governmental enforcement & credit for innovative performance	18, 17, 9, 13
C17	Increased involvement of project stakeholders in green projects	7, 14, 8
C18	Clarity in requirements and measures for achieving sustainable projects	14, 16
C19	Number of subcontractors experienced with BIM projects	14, 5, 11
C20	Client requirement and ownership	5, 9
C21	Early involvement of project teams	14, 1, 19
C22	Client satisfaction level on BIM projects	14, 4, 1
C23	Supportive organizational culture and effective leadership	6, 20
C24	Project complexity (regarding building shape or building systems)	3, 9, 21
C25	Availability and affordability of cloud-based technology	8, 9, 21
C26	Interoperability and data compatibility	8, 9, 11
C27	Standardization & simplicity of BIM and sustainability assessment software	22, 23
C28	Technical support from software vendors	17, 7, 14
C29	Availability of BIM and sustainability databases	16, 14, 23, 22
C30	Open-source software development	8, 17

Notes: Digits in the 'sources of reference' column are references from the review of extant literature.

1= Gu and London (2010); 2 = Abubakar *et al.* (2014); 3 = Yeomans *et al.* (2006); 4 = Kassem *et al.* (2012); 5 = Kassem *et al.* (2012); 6 = Saxon (2013); 7 = Wong and Fan (2013); 8 = Hope and Alwan (2012); 9 = Aibinu and Venkatesh (2014); 10 = Bin Zakaria *et al.* (2013); 11 = Kivits and Furneaux (2013); 12 = Wong *et al.* (2014); 13 = Azhar (2011); 14 = Antón and Díaz (2014); 15 = Lu *et al.* (2014); 16 = Adamus (2013); 17 = Redmond *et al.* (2012); 18 = Akanmu *et al.* (2015); 19 = Prins and Owen (2010); 20 = Boktor *et al.* (2014); 21 = Akinade *et al.* (2017); 22 = Aksamija (2012); 23 = Ahn *et al.* (2014)

DATA ANALYSIS AND RESULTS

This section discusses the analyses and findings of the data collected during the two-stage Delphi survey.

Reliability testing

The Cronbach's alpha (α) reliability test was used to test the reliability of the questionnaire and its associated Likert scale of measurement to ensure that they are measuring the required parameters (Olatunji *et al.* 2017a). A Cronbach's alpha reliability value of 0.70 and above is generally acceptable (Field 2009). The α-value for the first stage of the Delphi survey was 0.824 while the α-value of the second round of the Delphi survey was 0.808. This result is consistent and higher than the 0.70 threshold, hence it indicates a good internal consistency and reliability of measures.

Profile of the expert panel members

The fourteen panel members that accepted the invitation to participate in the Delphi survey consists of practitioners from both the academic and the industry. More so, there is a diversity in the countries of which the panel members reside, with four (4) of the experts from the United Kingdom, Hong Kong (3), the United States (2) and one (1) member each from South Korea, Mainland China, Australia, Germany and Sweden. It is important to note that BIM and sustainability adoption and implementation is quite high in some of these countries.

Moreover, more than two-third of the panel members have more than 11 years' experience working in the construction industry with sound knowledge of the concept and implementation of BIM or sustainability. Meanwhile, a sizable number of the experts have sound knowledge of both aspects. The knowledge and expertise of the expert panel members have enhanced the credibility of the data collected.

Ranking based on mean score

The 30 critical success factors were ranked based on their mean scores (MS) and standard deviations (SD) according to the data collated from the study's Delphi expert panel (Table 2). More so, extant literature (Lu *et al.* 2008; Olatunji *et al.* 2017a) regards factors with a mean score of 4 and above on a 5-point Likert scale as significant and important. Meanwhile, in cases where two or more items have the same MS, items with smaller SD are ranked higher, however, if they have the same MS and SD, they will be assigned the same rank (Olatunji *et al.* 2017a).

At the second stage of the Delphi survey, some members of the study's expert panel reviewed their original rating on some of the factors resulting in their different mean scores and item ranking for such factors (see Table 2). For example, factor 'C2' reduced in ranking from 4^{th} to 6^{th} ranked factor, likewise for factor 'C4' from 9^{th} to 10^{th}, factor 'C22' from 11^{th} to 13^{th} and factor 'C30' from 26^{th} to 28^{th} ranked item. However, factor 'C9' increased in its mean score and item rankings from 4.21 (6^{th}) to 4.29 (4^{th}) after the second round of Delphi survey. Meanwhile, some factors retained their mean ranking after the second round of the Delphi survey although their mean scores increased (or decreased). Factors such as factor 'C1' maintained the 3^{rd} mean rank although the mean score changes from MS=4.29 to MS=4.36, likewise, for factor 'C3' retained the 2^{nd} mean rank and factor 'C21' retained the 1^{st} mean rank. Meanwhile, although factor 'C7' maintained its 30^{th} mean rank after the second round of Delphi survey, its mean score reduces from MS=3.57 to MS=3.50 (see Table 2).

In total, there are 15 factors with a mean score, MS $\geq$ 4.00, however, all of the factors can be considered imperative for implementation by construction industry stakeholders as the factor with the lowest mean score "C7- Availability of financial resources for BIM software, licenses and its regular upgrades" has a MS=3.50 which is above the average mean score of 3.00. Noteworthy, that the top-four rated factors retained their mean rank after the second round of Delphi survey although there were increases in their mean scores. These factors are factor 'C21' ranked 1^{st} and increased in mean score from MS= 4.36 to MS= 4.43, likewise, factor 'C3' ranked 2^{nd}, factor 'C1' ranked 3^{rd} and factor 'C12' ranked 4^{th} from MS=4.21 to MS=4.29.

Kendall's coefficient of concordance (W)

The Kendall's coefficient of concordance was used to measure the consistency in the level of agreement among the experts across the two-stage of the Delphi survey (Chan and Chan 2012). The value of W ranges from 0 (perfect disagreement) to 1 (perfect agreement) and the value of W is to be considered with the p-value. The value of W for this study's Delphi survey increased slightly from W=0.110, $p<0.05$ (*first round*) to W=0.114, $p<0.05$ after the second stage of the Delphi survey. It can be concluded that there is a moderate level of consensus on the factors ranked by the experts.

Table 2: Mean score ranking for Round 1 and Round 2 from the expert panel

Factors	All Experts (Round 1)			All Experts (Round 2)		
	Mean	SD	Rank	Mean	SD	Rank
C1	4.29	.726	3	4.36	.745	3
C2	4.21	.426	4	4.21	.426	6
C3	4.29	.611	2	4.36	.633	2
C4	4.14	.663	9	4.14	.663	10
C5	3.86	.864	17	4.00	.877	14
C6	3.57	.756	27	3.64	.745	26
C7	3.57	1.342	30	3.50	1.286	30
C8	4.00	.555	10	4.14	.535	8
C9	4.21	.579	6	4.29	.469	4
C10	4.14	.535	8	4.14	.535	8
C11	3.86	.363	15	3.93	.475	16
C12	4.21	.426	4	4.29	.469	4
C13	3.79	.893	21	3.86	.864	21
C14	3.93	.616	13	4.00	.555	12
C15	4.00	.877	12	4.07	.829	11
C16	3.79	.802	20	3.86	.770	20
C17	3.86	.535	16	3.93	.475	16
C18	3.79	.579	18	3.86	.663	19
C19	3.79	.579	18	3.86	.363	18
C20	3.79	.893	21	3.86	.864	21
C21	4.36	.745	1	4.43	.646	1
C22	4.00	.784	11	4.00	.679	13
C23	3.71	.726	24	3.79	.699	24
C24	3.71	.726	24	3.79	.699	24
C25	3.57	.756	27	3.64	.745	26
C26	4.21	.579	7	4.21	.579	7
C27	3.93	1.072	14	4.00	1.038	15
C28	3.57	1.089	29	3.64	1.082	28
C29	3.79	0.975	23	3.86	1.027	23
C30	3.64	1.151	26	3.64	1.082	28

CONCLUSIONS AND RECOMMENDATIONS

The need for the adoption and implementation of BIM technologies has been emphasized in numerous academic literature, workshops and symposiums, likewise, the need for a sustainable urban development through the implementation of sustainable practices in the built environment. This study identified through desktop literature reviews, thirty (30) critical success factors can amplify the integration of BIM and sustainable practices in construction projects. More so, a list of these 30 drivers were dispatched to fourteen experts to rank the factors based on their perceived levels of importance using a two-stage Delphi survey technique.

The expert panel identified factor 'C21' – "Early involvement of project teams", factor 'C3' – "More training programs for cross-field specialists in BIM and Sustainability" and factor 'C1' – "Technical competence of staff" as the most critical drivers that could enhance the integration of both BIM and implementing sustainable practices in construction projects. The involvement of project teams and critical project stakeholders at the preliminary stage of every project would ensure that a more objective decision-making that could enhance the success of such projects and help in making sensible choices among alternative sustainable designs. More so, an increase in project stakeholders with knowledge and experience in both concepts of BIM and sustainability can enhance its implementation in a project. Meanwhile, the higher the capacity and ability of the project staff in handling the BIM software and its processes and their understanding of the various sustainable measures and indicators to assess in a project would increase the effectiveness of its implementation.

Hence, it is recommended that project stakeholders, notably, consultants and contactors keep track of the extensive list of key drivers that could enhance the implementation of BIM and sustainable practices in their projects and advise their clients on their benefits and significance. More so, there is a pressing need for more training and education in these two vital concepts relevant to the construction industry, hence, there is an urgent need for professional bodies, educational institutions and even government departments to organize regular training workshops, symposiums and seminars to keep their staff and workers abreast of the latest development in these two areas of concern and equip them with requisite professional skills necessary to manage the processes on construction sites.

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REFERENCES

Abanda, F. H., Vidalakis, C., Oti, A. H. and Tah, J. H. M. (2015) 'A critical analysis of Building Information Modelling systems used in construction projects', *Advances in Engineering Software*. THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, OXON, ENGLAND: ELSEVIER SCI LTD, 90, pp. 183–201. doi: 10.1016/j.advengsoft.2015.08.009.

Abubakar, M., Ibrahim, Y. M., Kado, D. and 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*, pp. 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.

Ahn, K., Kim, Y., Park, C., Kim, I. and Lee, K. (2014) 'BIM interface for full vs . semi-automated building energy simulation', *Energy & Buildings*. Elsevier B.V., 68, pp. 671–678. doi: 10.1016/j.enbuild.2013.08.063.

Aibinu, A. and 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), pp. 1–10. doi: 10.1061/(ASCE)EI.1943-5541.0000193.

Akanmu, A., Asfari, B. and Olatunji, O. (2015) 'BIM-Based Decision Support System for Material Selection Based on Supplier Rating', *Buildings*, 5, pp. 1321–1345. doi: 10.3390/buildings5041321.

Akinade, O. O., Oyedele, L. O., Ajayi, S. O., Bilal, M., Alaka, H. A. *et al.* (2017) 'Design for Deconstruction (DfD): Critical success factors for diverting end-of-life waste from landfills', *Waste Management*. Elsevier Ltd, 60, pp. 3–13. doi: 10.1016/j.wasman.2016.08.017.

Aksamija, A. (2012) 'BIM-Based Building Performance Analysis: Evaluation and Simulation of Design Decisions', *2012 ACEEE Summer Study on Energy*

Efficiency in Buildings, (Aksamija 2010), pp. 1–12.
Antón, L. Á. and Díaz, J. (2014) 'Integration of LCA and BIM for Sustainable Construction', *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 8(5), pp. 1378–1382.
Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. *et al.* (2011) 'Technology adoption in the BIM implementation for lean architectural practice', *Automation in Construction*. PO BOX 211, 1000 AE AMSTERDAM, NETHERLANDS: Elsevier B.V., 20(2), pp. 189–195. doi: 10.1016/j.autcon.2010.09.016.
Azhar, S. (2011) 'Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry', *Leadership and Management in Engineering*, 11(3), pp. 241–252.
Boktor, J., Hanna, A. and Menassa, C. C. (2014) 'State of Practice of Building Information Modeling in the Mechanical Construction Industry', *JOURNAL OF MANAGEMENT IN ENGINEERING*. 1801 ALEXANDER BELL DR, RESTON, VA 20191-4400 USA: ASCE-AMER SOC CIVIL ENGINEERS, 30(1), pp. 78–85. doi: 10.1061/(ASCE)ME.1943-5479.0000176.
Chan, A. P. C., Lam, P. T. I., Wen, Y., Ameyaw, E. E., Wang, S. *et al.* (2015) 'Cross-Sectional Analysis of Critical Risk Factors for PPP Water Projects in China', *Journal of Infrastructure Systems*, 21(1), p. 4014031. doi: 10.1061/(ASCE)IS.1943-555X.0000214.
Chan, A. P. C., Yung, E. H. K., Lam, P. T. I., Tam, C. M. and Cheung, S. O. (2001) 'Application of Delphi method in selection of procurement systems for construction projects', *Construction Management and Economics*, 19(7), pp. 699–718. doi: 10.1080/01446190110066128.
Chan, D. W. M. and 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), pp. 590–613. Available at: http://repository.lib.polyu.edu.hk/jspui/handle/10397/5364.
Czinkota, M. and Ronkainen, I. (1997) 'International Business and Trade in the Next Decade: Report from a Delphi Study', *Journal of International Business Studies*, 28(4), pp. 827–844. Available at: http://www.jstor.org/stable/155496.
Field, A. (2009) *Discovering Statistics Using SPSS*, *Sage Publication*. doi: 10.1234/12345678.
Gan, X., Zuo, J., Ye, K., Skitmore, M. and Xiong, B. (2015) 'Why sustainable construction? Why not? An owner's perspective', *Habitat International*. Elsevier Ltd, 47, pp. 61–68. doi: 10.1016/j.habitatint.2015.01.005.
Goodland, R. (1995) 'The Concept of Environmental Sustainability', *Annual Review of Ecology and Systematics*, 26(1), pp. 1–24. doi: 10.1146/annurev.es.26.110195.000245.
Grisham, T. (2009) 'The Delphi technique: a method for testing complex and multifaceted topics', *International Journal of Managing Projects in Business*, 2(1), pp. 112–130. doi: 10.1108/17538370910930545.
Gu, N. and London, K. (2010) 'Understanding and facilitating BIM adoption in the AEC industry', *Automation in Construction*. PO BOX 211, 1000 AE AMSTERDAM, NETHERLANDS: Elsevier B.V., 19(8), pp. 988–999. doi: 10.1016/j.autcon.2010.09.002.
Hallowell, M. R. and Gambatese, J. A. (2010) 'Qualitative Research: Application of the Delphi Method to CEM Research', *Journal of Construction Engineering and Management*, 136(1), pp. 99–107. doi: 10.1061/(ASCE)CO.1943-7862.0000137.
Hope, A. and Alwan, Z. (2012) 'Building the Future : Integrating Building Information

Modelling and Environmental Assessment Methodologies', *Northumbria Research Link*. Available at: https://core.ac.uk/download/pdf/8790178.pdf.
Kassem, M., Brogden, T. and 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), pp. 1–10.
Kim, J. I., Jung, J., Fischer, M. and Orr, R. (2015) 'BIM-based decision-support method for master planning of sustainable large-scale developments', *Automation in Construction*. PO BOX 211, 1000 AE AMSTERDAM, NETHERLANDS: ELSEVIER SCIENCE BV, 58, pp. 95–108. doi: 10.1016/j.autcon.2015.07.003.
Kivits, R. A. and Furneaux, C. (2013) 'BIM: Enabling sustainability and asset management through knowledge management', *The Scientific World Journal*, 2013. doi: 10.1155/2013/983721.
Kocabas, A. (2013) 'The transition to low carbon urbanization in Turkey: Emerging policies and initial action', *Habitat International*, 37(Supplement C), pp. 80–87. doi: https://doi.org/10.1016/j.habitatint.2011.12.016.
Linstone, H. A. (1978) *The Delphi technique. Handbook of Futures Research.* Greenwood: Westport, CT.
Lu, W., Shen, L., Asce, M., Yam, M. C. H. and Asce, M. (2008) 'Critical Success Factors for Competitiveness of Contractors : China Study', (December), pp. 972–983.
Lu, Y., Li, Y., Skibniewski, M. J., Wu, Z., Wang, R. *et al.* (2014) 'Information and Communication Technology Applications in Architecture , Engineering , and Construction Organizations : A 15-Year Review', *Journal of Management in Engineering*, 31(1), pp. 1–19. doi: 10.1061/(ASCE)ME.1943-5479.0000319.
Mullen, P. M. (2003) 'Delphi: myths and reality', *Journal of Health Organization and Management*, 17(1), pp. 37–52. doi: 10.1108/14777260310469319.
Olatunji, S. O., Olawumi, T. O. and Aje, I. O. (2017a) 'Rethinking Partnering among Quantity-Surveying Firms in Nigeria', *Journal of Construction Engineering and Management*, 143(11), pp. 1–12. doi: 10.1061/(ASCE)CO.1943-7862.0001394.
Olatunji, S. O., Olawumi, T. O. and 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), pp. 54–64.
Olatunji, S. O., Olawumi, T. O. and Odeyinka, H. A. (2016a) 'Nigeria's Public Procurement Law- Puissant Issues and Projected Amendments', *Public Policy and Administration Research- The International Institute for Science, Technology and Education (IISTE)*, 6(6), pp. 73–85.
Olatunji, S. O., Olawumi, T. O. and Ogunsemi, D. R. (2016b) 'Demystifying Issues Regarding Public Private Partnerships (PPP)', *Journal of Economics and Sustainable Development- The International Institute for Science, Technology and Education (IISTE)*, 7(11), pp. 1–22.
Olawumi, T. O. and 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), pp. 1–16.
Olawumi, T. O., Chan, D. W. M. and Wong, J. K. W. (2017) 'Evolution in the Intellectual Structure of BIM Research: A Bibliometric Analysis', *Journal of Civil Engineering and Management*, 23(8), pp. 1060–1081. doi: 10.3846/13923730.2017.1374301.
Oti, A. H. and Tizani, W. (2015) 'BIM extension for the sustainability appraisal of

conceptual steel design', *Advanced Engineering Informatics*. THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, OXON, ENGLAND: Elsevier Ltd, 29(1), pp. 28–46. doi: 10.1016/j.aei.2014.09.001.

Prins, M. and Owen, R. (2010) 'Integrated design and delivery solutions', *Architectural Engineering and Design Management*, 6(4), pp. 227–231.

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

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

Shi, L., Ye, K., Lu, W. and Hu, X. (2014) 'Improving the competence of construction management consultants to underpin sustainable construction in China', *Habitat International*, 41(Supplement C), pp. 236–242. doi: https://doi.org/10.1016/j.habitatint.2013.08.002.

Shi, Q., Zuo, J. and Zillante, G. (2012) 'Exploring the management of sustainable construction at the programme level: a Chinese case study', *Construction Management and Economics*. Routledge, 30(6), pp. 425–440. doi: 10.1080/01446193.2012.683200.

Thangaratinam, S. and Redman, C. W. (2005) 'The Delphi technique', *The Obstetrician & Gynaecologist*, 7, pp. 120–125. doi: 10.1576/toag.7.2.120.27071.

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

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

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

Yeung, J. F., Chan, A. P. C. and Chan, D. W. M. (2009) 'Developing a Performance Index for Relationship-Based Construction Projects in Australia: Delphi Study', *Journal of Management in Engineering*, 25(2), pp. 59–68. doi: 10.1061/(ASCE)0742-597X(2009)25:2(59).

Yeung, J. F. Y., Chan, A. P. C., Chan, D. W. M. and 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), pp. 1219–1237. doi: 10.1080/01446190701598673.

Zahoor, H., Chan, A. P. C., Gao, R. and 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), p. ECAM-01-2016-0027. doi: 10.1108/ECAM-01-2016-0027.

Bin Zakaria, Z., Mohamed Ali, N., Tarmizi Haron, A., Marshall-Ponting, A. and Abd Hamid, Z. (2013) 'Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach', *International Journal of Research in Engineering and Technology*, 2(8), pp. 384–395.