The following publication Chan, D.W.M., Olawumi, T.O. and Ho, A.M.L. (2019), "Critical success factors for building information modelling (BIM) implementation in Hong Kong", Engineering, Construction and Architectural Management, Vol. 26 No. 9, pp. 1838-1854 is published by Emerald and is available at https://dx.doi.org/10.1108/ECAM-05-2018-0204

CRITICAL SUCCESS FACTORS FOR BUILDING INFORMATION MODELLING (BIM) IMPLEMENTATION IN HONG KONG

Abstract

Purpose – Some initiatives have been proposed and implemented to facilitate successful project delivery and improve coordination and collaboration in the design, construction, and management phases of project development. Building Information Modelling (BIM) is one of those initiatives, though recent, however, has made a significant impact on the construction industry in some countries.

Design/methodology/approach – This paper aims to explore the critical success factors (CSFs) for BIM implementation in the Architecture, Engineering and Construction (AEC) industry of Hong Kong through a mixed research method (structured empirical questionnaire survey and expert interviews).

Findings – The most influential success factor relates to the client's acceptance with BIM projects, proper organizational structure to support BIM system within the company, and financial aid from the government to set up BIM system. The expert interviewees also stressed the need for willingness from project staff members to learn and utilize BIM.

Practical implications – This study has contributed to the establishment of more practical and effective strategies for ensuring full adoption of BIM in Hong Kong. Practical recommendations for enhancing BIM adoption in the construction industry were highlighted.

Originality/value – This study has established the key drivers leading to the success of BIM implementation in Hong Kong, as well as in the perspective of construction experts on how to enhance its uptake in construction projects.

Keywords: BIM implementation, Critical success factors (CSFs), Construction industry, Project stakeholders, Hong Kong

Introduction

The construction industry is a highly competitive industry; therefore for construction firms to make substantial progress and success, they have to be highly competitive and innovative. Ghafur and Nawi (2016) advocated that the Architecture, Engineering and Construction (AEC) industry is made of many and diverse players creating a "stiff and tough competition," although everyone has their peculiar qualities. Nevertheless, the advent and adoption of Building Information Modelling (BIM) in the AEC industry has promoted deeper collaboration and closer coordination among the diverse disciplines and stakeholders and has helped to reduce the enormous issues pervading the industry to manageable numbers.

BIM technology has been proved in some developed countries such as the United States, the United Kingdom, Australia and a few others of being reaped immense benefits when applied to engineering and construction projects whether small or large, with remarkable results. Abanda et al. (2015) described BIM as a tool for "*facilitating collaboration and improving delivery efficiency and project quality*" in the construction industry. However, when it is not well applied to the processes, there may be several difficulties and challenges. More so, issues affecting its applicability or suitability are mainly of two categories - external factors and internal factors.

External factors relating to BIM suitability to a project are that imposed by prevailing government regulations and incentives, unfavorable legal requirements, lack of enforcement of BIM standards (where it exists), issues with BIM development and support from the software vendors, among others. The internal factors are those related to consultants, contractors' organizations or sometimes the client's organizations. These internal factors mostly include the organization set up to support BIM use, collaboration and coordinating frameworks, training and technical competency, top management support and continuous investment.

Key issues in BIM implementation

Factors affecting the level of success of a project are categorized into technology, cash-flow management and quality management (Ghafur and Nawi, 2016). Building Information Modelling (BIM) is an innovative, dynamic and intriguing technology introduced into the construction industry for more than a decade. Since then, it has contributed a lot to the successful completion of several projects to schedule, within budget with reduced operational cost over time. Despite these perceived benefits, the level of its adoption and implementation is still low and not impressive in many countries. Only two countries to date have more than 50% adoption rate i.e. the United States with more than 75% adoption rate and the United Kingdom with more than 55% based on a desktop literature review of BIM adoption in several countries and regions carried out by Olawumi et al. (2017).

Critical success factors (CSFs) are of different descriptions as opined by several authors in scholarly journals. Sanvido et al. (1992) regarded them as “elements that foresee achievement instead of simply the unadulterated survival of a construction project.” Per Rockart (1982), CSFs are objects or agendas to be put in place for an organization or project to succeed. Meanwhile, Toor and Ogunlana (2008) intimated us that a CSF “denotes a certain element which significantly contributes to and is remarkably vital for the achievement of a project.” More so, according to Abu (2015), CSFs are the most significant factors to prevent delay in the project, increase project performance and assure success for construction projects.

Several research studies have examined the critical success factors for BIM’s adoption, application or implementation in several countries. Kim et al., (2016) considered the BIM level of acceptance in the South Korea AEC industry, and their findings revealed a positive interest to use BIM in South Korea and the necessity of its use, but there was no strong intent in its direction. The architects exhibited more positive interests compared to other project stakeholders. Mutai (2009) derived twelve (12) critical factors in the United States though data collected through surveys conducted with BIM users. The author identified top management support, staff training, and technical IT support as the most crucial factors. Davies and Harty (2013) discerned that ICT tools such as mobile tablets and personal computers etc. form the bedrock for the implementation of BIM on construction project sites. Meanwhile, Ruikar and Emmitt (2009) discussed the emerging trends and application of ICT in construction projects.

More so, another survey by Tsai et al. (2014) identified two most influential factors for BIM implementation in Taiwan as top management support and functionality of BIM tools. Both findings revealed top management support as the most crucial factor. However, a study by Huire et al. (2014) (as cited in Kim et al., 2016) in China puts more significance on the attitude of key stakeholders in the Chinese AEC industry to be influential to BIM adoption than support from top management as seen in Taiwan and the United States surveys. Oo (2014) assessed the CSFs for BIM implementation in Singaporean architectural firms using data collected via questionnaire surveys and expert interviews. His findings revealed top management support, staff training, and client acceptance as the three most crucial success factors in Singapore.

Ozorhon and Karahan (2016) examined the CSFs for BIM implementation in the Turkish construction industry and determined the three most important factors as availability of qualified staff, effective leadership, and availability of information and technology. Yaakob et al. (2016) also carried out a holistic review of CSFs for BIM implementation in the Malaysian construction industry. Table 1 lists the CSFs used in this study based on the extant literature review. To this intent, several efforts and initiatives have been carried out to facilitate effective BIM implementation in construction projects. Such studies include sharing of experiences on BIM application through case studies (Eastman et al., 2008; Epstein, 2012; Bryde et al., 2013), and its effects or suitability (Barlish and Sullivan, 2012). It also includes BIM maturity measurement (Succar, 2009; Succar et al., 2012), and significant challenges encountered during implementation (BIM Task Group, 2011; Eadie et al., 2013).

BIM Task Group (2011) and Eadie et al. (2013) identified issues affecting BIM implementation as that relating to technological and legal matters, and these include interoperability, data exchange schemas, business strategies, availability of relevant BIM standards and guides, training and education for users, and data ownership. Succar (2009) observed the need for a standardized BIM guide while Volk et al. (2014) discussed the need for standards for BIM data exchanges. More so, the need for refined strategies for BIM-process and work procedures is quite significant (Khemlani et al., 2007; Arayici et al., 2011). Furthermore, other issues affecting BIM implementation in extant literature include technical capability of BIM software and data exchanges (Azhar, 2011; Bryde et al., 2012; Howard and Björk, 2008); training and procurement of necessary BIM software and hardware (Gilligan & Kunz, 2007; Hartmann & Fischer, 2008), and legal issues such as data ownership and contractual terms (Wu and Wu, 2005; Olatunji, 2011; Thompson and Miner, 2006).

[Insert Table 1]

To improving the BIM acceptance level in Hong Kong, it is essential to evaluate the perception of diverse and key stakeholders in the Hong Kong AEC industry. To this end, this study aims to identify the critical success factors of BIM implementation by quantitatively analyzing the correlations between the perceptions of the major project stakeholders. The study applied several statistical tools to evaluate the data and opinions collected through structured questionnaire surveys and expert interviews as discussed in the next section. This study has contributed to the establishment of more practical and effective strategies for promoting full BIM adoption and implementation in Hong Kong.

Research methodology

Kim et al. (2016) noted that stakeholders' views and perceptions have a significant impact on the *"decision whether to adopt or reject a new technology before the technology is implemented"*. This study evaluated the perceptions of main project stakeholders about the critical success factors (CSFs) of BIM implementation in the Hong Kong construction industry. A mixed research method was employed which involved the use of structured questionnaire surveys and structured interview templates which were self-administered to the targeted respondents within Hong Kong. The key focus of the elicitation of this study's data is pertaining to clients, developers, main contractors and BIM / project consultants operating within Hong Kong and with practical BIM experience in their construction projects. The questionnaire items deduced through secondary means of a desktop literature review of academic journal papers, HKIBIM-CIC BIM Conference Proceedings 2014 produced by the Hong Kong Institute of Building Information Modelling (HKIBIM) and the Construction Industry Council (CIC), together with online reference materials. The survey forms the basis of assessing the respondents' perceptions and opinions. The respondents were obliged to identify and rank the perceived benefits and barriers of BIM implementation in Hong Kong on a five-point Likert-type scale, which was later used to measure their levels of agreement.

The questionnaire also solicited background information regarding the survey participants' working experience in the construction industry and the number of BIM projects that they have participated in. Other details include the type of organization which they are currently employed and their position within the organization. Meanwhile, regarding the expert interviews, three (3) respective interviewees from client/developer, main contractor and BIM consultant were selected from different organizations for a face-to-face structured interview session. The interview participants were not part of the survey respondents. They were invited to give their views on the barriers, benefits, and CSFs of BIM implementation in Hong Kong plus background information about their experience working in a BIM-enabled construction project. A total of 62 blank questionnaire survey forms were sent out with the help of colleagues to the target respondents who have been engaged in BIM projects. The return rate of the questionnaire survey was 44 completed and valid questionnaires after a month of survey period representing a response rate of 71%.

Summary of respondent demographics

This section describes and analyses the section A of the study's questionnaire survey form regarding the respondents' demographics and as depicted in Table 2. The majority of the survey participants are from the contractor's organizations (41%), with the remaining respondents from client's organizations (32%) and the consultant's organizations (27%). The diversity of the respondents' groups allows for the capture of differing views from different perspectives. Moreover, on average, the respondents have gained more than ten years of working experience in the construction industry. This result explains the fact that the respondents have not only theoretical knowledge of the operation of the AEC industry but also have over the years to bring such knowledge into practice.

The respondents chosen for the survey are those with at least one year experience in BIM-enabled projects. The majority of the respondents (66%) have participated in more than 5 BIM-enabled projects, 27% of them (in 3 – 4 BIM projects) and just 7% of the respondents involved in 1 – 2 BIM projects. Based on the above statistics, it can be deduced that the survey participants have a related knowledge of BIM and hands-on experience in using it in the construction projects and this gives reliability and credibility to the data and opinions collated.

[Insert Table 2]

Methods and statistical tools for data analysis

This study employed five statistical tools to analyze the various responses from the survey participants and to compare the views between different groups of respondents. These include the Cronbach's alpha reliability test, mean score ranking method, Kendall's concordance analysis, Spearman's rank correlation test, and Mann-Whitney U test.

Reliability testing

The Cronbach's alpha reliability test is mainly used to verify the internal consistency or reliability of the construct of the questionnaire items under the adopted Likert scale of measurement (Akinade et al., 2016; Chan et al., 2010). The range of the Cronbach's alpha reliability coefficient is from 0 to 1 (Olatunji et al., 2017; Olawumi and Chan, 2018a). The larger the α-value, the higher the reliability of the generated result or scale will be. If the α-value ≥ 0.7, the measurement scale is reliable (Santos, 1999; Field, 2009; Akinade et al., 2016). The Cronbach's alpha value for this study is 0.726 which was larger than the threshold value of 0.7. Therefore, the 5-point Likert scale used for measuring the CSFs for implementing BIM is reliable and the collected responses are internally consistent at the 5% significance level.

Kendall's coefficient of concordance (W)

The Kendall's coefficient of concordance (W) was employed to measure the agreement of different respondents on their rankings regarding barriers to BIM implementation based on mean values within a certain group (Olawumi et al., 2018; Olawumi and Chan, 2018d). The Kendall's coefficient of concordance measures the agreement of the various respondents based on mean values within a particular group (Legendre, 2004). The range of the value of Kendall's coefficient of concordance (W) is from 0 to 1. The higher the value of W, the higher the level of consensus among the survey respondents within the group will be (Chan et al., 2010). The value of W is as follows:

$$W = \frac{\sum_{i=1}^{n}(\bar{R}_i - \bar{R})^2}{n(n^2-1)/12}$$

Where n = Number of items ranked; R_i = Average of the ranks assigned to the ith item;

R = Average of the ranks assigned to all items

If the number of variables to be ranked is larger than 7, chi-square analysis should be applied instead. The rule is that if the calculated chi-square value equals or is higher than the critical value from the table, it shows a particular level of significance and value of degrees of freedom (Olawumi et al., 2018). The null hypothesis (H_0) which indicates the survey respondents' sets of rankings are unrelated or independent to each other within a study group will be rejected. In other words, there is a significant degree of agreement on the rankings of the items among the survey respondents within the group. The calculated chi-square value with (N-1) degrees of freedom is as follows: (Siegel and Castellan, 1988)

$$\Psi^2 = k(N-1)W$$

Where k = number of respondents ranking the items; N = number of items ranked.

Spearman's rank correlation test

The Spearman's rank correlation coefficient was adopted to test the strength of a relationship amongst two sets of rankings (Chen and Popovich, 2002). The range of the Spearman's rank correlation coefficient (r_s) is from -1 to +1 (Chan and Choi, 2015; Chan and Hung, 2015). The higher the positive/negative value of r_s, the stronger positive/negative linear correlation will be. If r_s = 0, there is no linear correlation at all (Chan et al., 2010). If r_s is statistically significant at a predetermined significance level (e.g. 5%), the null hypothesis (H_0) stating no significant correlation between the two groups on rankings can be rejected. In other words, there is no significant disagreement between the two groups on the ranking exercise. The following equation calculates the r_s:

$$r_s = 1 - \frac{6\sum d^2}{N(N^2-1)}$$

where d = difference in ranks of the two groups for the same item;

N = total number of responses regarding that item.

Mann-Whitney U test

The Mann-Whitney U test was adopted to determine any divergences in the median values of the same item among two selected respondent groups (Olawumi and Chan, 2018d). The Mann-Whitney U test is used to determine any statistically significant differences or divergences in the median values of the same item between any two selected respondent groups (Kasuya, 2001). The rule is that if the calculated p-value is less than the allowable significance level (e.g. 1%), the null hypothesis (H_0) stating no significant differences in the median values of the same item between the two survey groups can be rejected (Chan et al., 2010).

Discussion of research findings: CSFs for BIM implementation in Hong Kong

Ranking results

The survey results of the ranking of the critical success factors for implementing BIM in the Hong Kong AEC industry is as presented in Table 3. For the 11 CSFs identified, the mean (M) values range from the lowest mean score of M=3.16 "*Continuous investment/upgrade for BIM system within company*" to the highest mean value of M=4.57 "*Client's acceptance with BIM projects*." The three (3) most significant CSFs are hinged to the governmental support, organizational setup, and clients' support; and these include- *Client's acceptance with BIM projects* (M=4.57), *organizational structure to support BIM system within [the] company* (M=4.11), and *financial support from the government to set up BIM system* (M=3.91).

Most respondents concurred that the client plays a vital role in the future BIM adoption because their decisions can drive more designers or other professionals of various disciplines to apply BIM to their construction projects. Aibinu and Venkatesh (2014), Olawumi et al. (2018), and Olawumi and Chan (2018a) noted that the construction industry is currently plagued with lack of demand of innovative technologies such as BIM by clients. Furthermore, it is believed that changing an organizational structure to drive and support this technology for their work would help the staff to recognize BIM development as the focus of the company and drive them to learn and utilize it in real practice (Boktor et al., 2014). Also, they opined that the financial support from the government could be a great incentive to set up this costly system (Abubakar et al., 2014; Olawumi & Chan, 2018d, 2018b).

The three most significant CSFs are both included in the client group and contractor group. However, item #3 is not included in the top #3 ranking in the consultant group. It is reasonable because BIM consultants have already bought their BIM software and resources to do their business so the financial support from the government to set up a BIM system may not be too necessary for them. Therefore, the BIM consultant group view this factor as not too significant for their implementation of BIM. On the other side, the client group and contractor group believe that financial support is an excellent incentive to accelerate the adoption of BIM in Hong Kong.

[Insert Table 3]

Ranking agreement within each respondent group

The value of W of all respondents, client group, consultant group, and contractor group is 0.323, 0.308, 0.475 and 0.525, respectively. The levels of significance of all groups are 0.000 which are less than the allowable level of significance (5%), so the null hypothesis should be rejected. The Chi-square test was applied because there were 11 items involved (more than seven variables). The calculated Chi-square values of the client group, consultant group, and contractor group are 43.162, 56.970 and 94.436 which all of them are higher than the critical value of 18.307 so the *null hypothesis* should be rejected as well. From the results of these two tests, there is adequate evidence to conclude that the respondent's sets of rankings regarding the CSFs for BIM implementation are dependent on each other with a significant degree of agreement within each group.

Ranking agreement between the respondent groups

The Spearman's rank correlation coefficient (r_s) of rankings of the CSFs for BIM implementation: (1) between the client group and consultant group, (2) between the client group and contractor group, and (3) between the consultant group and contractor group, are 0.645, 0.600 and 0.573 with the calculated significance level of 0.032, 0.041 and 0.046 respectively which are lower than the allowable level of significance (5%).

Therefore, the null hypothesis should be rejected. In other words, there is a significant correlation between the client group and consultant group, between the client group and contractor group, and between the consultant group and contractor group, on the rankings of the CSFs for BIM implementation.

The significance of the statistical data

The first pair is the *client group versus the consultant group*, the second pair is the *client group versus the contractor group,* and the third pair is the *consultant group versus contractor group*. For the first pair (client group versus consultant group), all the actual calculated p-values are larger than 0.01; the null hypothesis should not be rejected. Therefore, there is no discriminating item identified in the first pair.

For the second pair (client group versus contractor group), only one discriminating item was identified which is item 4 – "*Willingness of staff to learn new technology*" (Olawumi et al., 2017; Wu & Issa, 2015). Compared with the contractors, the developers have more resources to develop or adopt the BIM system within their companies. The staff from the developers believed that the BIM development is a focus or trend in the industry, so they are willing to play a proactive role to learn this technology to increase their competitiveness in the market. However, contractors' staff perceived that the construction projects could be managed successfully without the adoption of BIM like in the old days. They perceive that this concept is mainly affecting their incentives to learn BIM, so the contractors put more emphasis on Item 4 to be a critical success factor for implementing BIM. The details of the test for the second pair are provided in Table 4.

[Insert Table 4]

For the third pair (consultant group versus contractor group), two discriminating items were identified including item 3 – "*Financial support from the government to set up BIM system*" (Bin Zakaria et al., 2013; Olawumi & Chan, 2018c); and item 4 – "*Willingness of staff to learn new technology*."

Regarding item #3, BIM consultants have their BIM software and resources to do their business so the financial support from the government to set up BIM system may not be too necessary to them. Therefore, BIM consultant group perceive it as not too critical for implementing BIM in the construction industry in Hong Kong. On the other side, the contractor group believes that the initial cost of BIM system is quite high so the financial support from the government is a good incentive to accelerate the adoption of BIM within their companies.

Regarding item #4, the main reason is like the second pair which the staff from the contractors' side opined that this concept is mainly affecting their incentives to learn BIM, so the contractors place more emphasis on item 4 to be a critical success factor for implementing BIM. On the other side, the staff working for BIM consultants have already known how to use BIM, so they do not think item #4 is too critical for them. The details of the test for the third pair are provided in Table 5.

[Insert Table 5]

Summary of interviewees' opinions

A total of three face-to-face structured interviews were conducted to collect valuable opinions for this research. The interviewees belong to different organizational setups: the developer/client, BIM consultant, and main contractor groups; and they did not participate in the initial round of questionnaire survey. They were invited to provide their views on the CSFs factors influencing implementation of BIM in Hong Kong based on their direct hands-on experience with BIM construction projects. The interviewees were also requested to provide some practical effective recommendations for facilitating the future BIM adoption in Hong Kong.

Profile of the study interview participants

The first interviewee (A) is an Assistant Manager of the Department of Cost and Quality Control in a developer firm. She has derived more than ten years of working experience in the construction industry and has been involved in three (3) BIM-enabled construction projects in Hong Kong. Her main responsibility is to take a check-and-balance role, so she needs to ensure that all decisions made by different project departments suit the internal policies and she also needs to balance between project's profit and company's policies to make commercial decisions. The second interviewee (B) is a Director of a BIM consultant company. He has gained more than nine years of working experience in the construction industry and has been participating in more than thirty (30) BIM-enabled construction projects in Hong Kong. He needs to manage the whole operation of the company and ensure that his teams provide excellent BIM services to the clients to fulfill their requirements or needs for their construction projects. Also, he needs to supervise the qualities of their services to see whether they are providing satisfactory added-values to their clients during the execution of BIM construction projects.

The third interviewee (C) is a Senior BIM Manager of the Department of Visual Design and Construction in a contractor firm. He has acquired more than 16 years of working experience in the construction industry and has managed more than 30 construction projects with the adoption of BIM in Hong Kong. He needs to supervise the whole operation of his department and provide professional services such as 3D printing, visualization rendering and BIM application for the specific projects. Also, he needs to cooperate with project managers to settle some technical issues of the BIM application for their projects. Sometimes his team may create cooperative tools or software for the colleagues to facilitate their work such as i720° tool.

Cross-synthesis of interviewees' perceptions on the CSFs for BIM implementation

Each interviewee was requested to pick up the three most significant critical success factors for implementing BIM among the 11 items elicited on the survey questionnaire. There is one common item: *item 7 - Organizational structure to support BIM system within the company* (Boktor et al., 2014; Olawumi and Chan, 2018b; Saxon, 2013) which these three interviewees have chosen (see Table 6). They agreed that if the top management is willing to prioritize the development of BIM system within their organizations; then the organizational structure should be changed to fit the use of BIM system, such as establishing a separate department for BIM personnel and putting efforts to promote and support its development.

Interviewees A and C perceived that *item 4 - Willingness of staff to learn new technology* (Olawumi and Chan, 2019) as important. Instances where project staff chooses to keep their traditional concepts, it implies that they are not willing to accept the innovative technology. Therefore, a change in their attitudes and willingness to spend time and efforts on learning new things will be a first step forward to learning BIM system. It is not necessary that all employees in the company must know the technical design operations of BIM, but at least it is imperative that they are aware of some applications of BIM. It includes how to generate useful data which can facilitate their daily work. For example, quantity surveyors may make use of the BIM system to output the quantities of materials used and then conduct the cost estimating or cost control.

Interviewee A identified *item 11 - Promotion from top management* (Ayegun et al., 2018; Rogers et al., 2015) as also very essential. Nowadays innovation is one of the principal competitive factors between companies, and BIM system is one of the recent innovative technologies. Therefore, the BIM implementation within the company will become smoother and more successful with the full support and promotion from the top management. Interviewee B stated that *item 3 - Financial support from the government to set up BIM system* (Abubakar et al., 2014; Bin Zakaria et al., 2013) and *item 9 - Professional BIM design team within the company* (Olawumi and Chan, 2018b; Tsai et al., 2014) are also dispensable.

It is because financial aid drives the private companies to use this system. Especially for the small-sized to middle-sized companies, financial assistance for the initial set-up cost is a key factor in adopting this innovative tool. Moreover, some skilled and experienced teams including design teams can better the operation of the company, so the top management is willing to spend money to support the BIM development in the company further. Interviewee C considered *item 5 - Client's acceptance with BIM projects* (Harding et al., 2014; Kassem et al., 2012) as also vital. For item 5, different clients have their concerns and needs. Therefore, a client who is confident in using BIM system to facilitate their projects and meet their requirements, they will be more willing to accept this innovative technology and put in more money to develop it within the company.

Overall, the interviewees selected six out of the eleven CSFs as highly significant to drive the implementation of BIM initiative in the construction industry. A closer look at these six CSFs reveals the notable contributions of key stakeholders such as construction organizations, the governments and even the project teams in the drive to enhance BIM adoption in the Hong Kong AEC industry. The interviewees highlighted the importance of an in-house BIM structure and management policy towards domesticating BIM adoption in such firms before its actual usage in construction projects (Chan, 2014; Saxon, 2013). An in-house BIM system implies that the activities (design, costing, energy assessment, etc. of buildings) of every unit in the construction firm is first seamlessly integrated and coordinated to ensure that the eventual deployment of BIM initiative in a project is carried out without a hitch.

Also, the interviewees believed that if there are incentives (such as bonuses, etc.) for staff in learning new technologies like BIM; it is capable of increasing their willingness to hone the BIM skills. More so, the top management of firms should consider organizing or sponsoring their staff for BIM training and workshops to ease the learning experience and enhance the BIM competencies of their staff. Meanwhile, the interviewees believed that the success rate of BIM projects such as its higher productivity, projects completed on schedule, budget and with required quality is critical in motivating more clients to adopt the use of BIM in their projects.

[Insert Table 6]

Cross-synthesis of the survey respondents' opinions and the interviewees' perceptions

This study explores the critical success factors (CSFs) for implementing BIM in the Hong Kong AEC industry. The survey participants identified client's acceptance with BIM projects, an organizational structure to support BIM system within the company and financial support from the government to set up BIM system as the three most significant CSFs for implementing BIM in Hong Kong. These CSFs relates to the three key project stakeholders involved in the construction industry, that is, the clients/government, consultants and contractors. For most projects, the clients seem to have the final say on the contract budget and the method through which such projects may be undertaken. BIM projects are costlier than the conventional ones, although the reaped benefits are numerous at the design, construction and facility management stages.

A client who had an unpleasant experience with the previous adoption of BIM in their projects may be unwilling to undertake such form of innovative technology in future projects; an opinion shared by Kassem et al. (2012). Therefore, it behooves the project team on BIM-enabled projects to ensure that they delivered such projects to the highest possible standards and satisfaction demanded by the clients to increase the clients' acceptance level of BIM projects. The interviewee from the contractor's side corroborated this assertion that project clients will become more inclined to adopt BIM in construction projects if there are verifiable benefits of such innovative technologies when implemented in their projects.

The need for related construction organizations (i.e. the clients' organizations, consultants, contractors or developers) to have a full-fledged BIM department as part of their organizational structure cannot be over-emphasized (Olawumi and Chan, 2019). The three interviewees unanimously selected this factor as quite significant to the success of BIM adoption in Hong Kong, and the same factor also ranked as the second by the survey respondents as crucial to BIM implementation. Although, some firms in Hong Kong have established BIM units in their organizations, the level of independence differs from firms to firms and some firms do not even have BIM personnel at all. Level of independence implies that the personnel engaged in the BIM department are solely and wholly working in the BIM unit, and not just deployed to the BIM unit when a project requires their urgent assistance or advisory service. The benefit of this independence will assist such staff to be adequately braced and equipped with the current trend of knowledge and application of this innovative technology. It will also enable and give them sufficient time and freedom to develop a best practice framework and specialized techniques which would facilitate the ease of utilizing BIM on their projects.

BIM as a new, modern and innovative technology comes with its attendant high cost of implementation (Kivits and Furneaux, 2013; Olawumi et al., 2018). These costs are associated with the BIM software, supporting hardware and operating system, yearly licenses and even the training of staff to utilize it. Therefore, any financial incentives by the governments downstream to firms and companies with the intention of utilizing BIM will facilitate its wider adoption and implementation in Hong Kong or elsewhere. The financial incentives may come in several forms like tax incentives, bonus credits, loans, access to subsided technical BIM support among others. The perception was also supported by the interviewee from the consultant's side. These financial initiatives and more will certainly enhance BIM implementation in near future.

Conclusions

The paper investigated the key issues pertaining to BIM implementation in Hong Kong and carried out a desktop literature review of BIM implementation in the leading economies of the world. More so, several factors were identified as critical success factors (CSFs) for BIM implementation in Hong Kong by a group of empirical survey respondents from the consultant, contracting and clients' organizations based in Hong Kong. The five most significant CSFs included: client's acceptance with BIM projects, organizational structure to support BIM system within the company, financial support from the government to set up BIM system, BIM standards for the industry, and BIM training programmes for staff.

Furthermore, the views of three senior expert interviewees involved in the Hong Kong AEC industry were gleaned, and they all agree on the factor- *organizational structure to support BIM system within the company*, being highly instrumental to the successful implementation of BIM in Hong Kong. Also, the willingness of staff to learn the innovative technology was perceived to be important by both the interviewees from the client's and contractor's organizations. Other factors suggested by the interviewees encompass: promotion from top management, financial support from the government to set up BIM system, the engagement/availability of a professional BIM design team, and client's acceptance with BIM projects.

Apart from the suggestions made by the interviewees, there is a need for a change in the approach to design submission for approval. Also, more encouragement to designers to adopt this software and the establishment of BIM industry standards, protocols, as well as legal frameworks are greatly conducive to its adoption. The need for financial support from the government will be a strong incentive for organizations to launch BIM. However, the incentive of the initial financial support may not be robust and attractive enough to drive the company to adopt this technology. Therefore, the government may consider whether it is feasible to develop a financial assistance scheme to support more for the running cost such as the free license of BIM software with the limited quota within the limited period of usage.

Areas for future studies may consider examining the critical success factors from the educational institutes and universities perspectives through a case study approach or perhaps a holistic review of BIM curriculum development standpoint. It is because BIM related subjects under different institutes may be offered only optional and so some students may not be too familiar and well-versed with the BIM development and usage.

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

Abu, Sudhakar, S. S. B. (2015). Critical success factors influencing performance of construction projects. *International Journal of Innovative Research in Science, Engineering and Technology*, 4(5), 3285–3292. doi:10.15680/IJIRSET.2015.0405048

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.

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 and Practice*, 140(3), 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. (2016). Design for Deconstruction (DfD): Critical success factors for diverting end-of-life waste from landfills. *Waste Management*. https://doi.org/10.1016/j.wasman.2016.08.017

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.

Arayici, Y., & Coates, P. (2012). "A system engineering perspective to knowledge transfer: A case study approach of BIM adoption." Virtual reality—Human computer interaction, X.-X. Tan, ed., InTech, Rijeka, Croatia, 179–206.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). "Technology adoption in the BIM implementation for lean architectural practice." *Automation in Construction*, Vol. 20, No. 2, pp. 189-195, DOI: 10.1016/j.autcon.2010.09.016.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). "BIM adoption and implementation for architectural practices." *Struct. Surv.*, 29(1), 7–25.

Ayegun, O. A., Abiola-falemu, J. O., & Olawumi, T. O. (2018). Assessment of Clients' Perception and Satisfaction with Project Quality Delivery in Nigeria. *Journal of Sustainable Construction Engineering and Project Management*, 1(1), 27–44. Retrieved from https://goo.gl/f3eu7T

Azhar, S. (2011). “Building Information Modeling (BIM): Trends, Benefits, risks, and challenges for the AEC industry.” *Leadership and Management in Engineering*, Vol. 11, No. 3, pp. 241-252, DOI: 10.1061/(ASCE)LM.1943-5630.0000127.

Baiden, B., Price, A., & Dainty, A. (2006). “The extent of team integration within construction projects.” *International Journal Project Management*, 24(1), 13–23.

Barlish, K. and Sullivan, K. (2012). “How to measure the benefits of BIM- A case study approach.” *Automation in Construction*, Vol. 24, pp. 149-159, DOI: 10.1016/j.autcon.2012.02.008.

BIM Task Group (2011). A report for the government construction client group from the BIM industry working group.

Bin Zakaria, Z., Mohamed Ali, N., Tarmizi Haron, A., Marshall-Ponting, A., & 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), 384-395.

Boktor, J., Hanna, A., & Menassa, C. C. (2014). State of Practice of Building Information Modeling in the Mechanical Construction Industry. *Journal of Management in Engineering*, 30(1), 78–85. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000176

Bryde, D., Broquetas, M., & Volm J. M. (2013). “The project benefits of Building Information Modelling (BIM).” *International Journal of Project Management*, Vol. 31, No. 7, pp. 971-980, DOI: 10.1016/ j.ijproman.2012.12.001.

BuildingSMART. (2011). BIM in the Middle East. buildingSMART ME.

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., & Choi, T. N. Y. (2015). Difficulties in executing the Mandatory Building Inspection Scheme (MBIS) for existing private buildings in Hong Kong. *Habitat International*, 48, 97–105. https://doi.org/10.1016/j.habitatint.2015.03.015

Chan, D. W. M., & Hung, H. T. W. (2015). An empirical survey of the perceived benefits of implementing the Mandatory Building Inspection Scheme (MBIS) in Hong Kong. *Facilities*, 33(5/6), 337–366. https://doi.org/10.1108/F-09-2013-0066

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.

Chen, P. Y. & Popovich, P. M. (2002). Correlation: Parametric and nonparametric measures. California: Sage Publications.

Davies, R., & Harty, C. (2013). Implementing `Site BIM': A case study of ICT innovation on a large hospital project. *Automation in Construction*, 30, 15–24. https://doi.org/10.1016/j.autcon.2012.11.024

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). "BIM implementation throughout the UK construction project lifecycle: An analysis." *Automation in Construction*, Vol. 36, pp. 145-151, DOI: 10.1016/j.autcon.2013.09.001.

Eastman C., Teicholz, P., Sacks, R., & Liston, K. (2008). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators, John Wiley and Sons, NJ.

Enegbuma, W. I. & Ali, K. N. (2011). A Preliminary Critical Success Factor (CSFs) Analysis of Building Information Modelling (BIM) Implementation in Malaysia. Proceedings of the Asian Conference on Real Estate (ACRE 2011): Sustainable Growth, Management Challenges

Epstein E. (2012). Implementing successful Building Information Modeling, Artech House, Norwood, M.A.

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

Ghafur, A., & Nawi, M. N. M. (2016). Critical success factors for competitiveness of construction companies: A Critical Review. In AIP Conference Proceedings (Vol. 20042, pp. 0–7). https://doi.org/10.1063/1.4960882

Gilligan, B. & Kunz, J. (2007). "VDC use in 2007: significant value, dramatic growth, and apparent business opportunity." Center for Integrated Facility Engineering, Report TR171.

Harding, J., Suresh, S., Renukappa, S., & Mushatat, S. (2014). Design Teams in Achieving BREEAM Accreditation? *Journal of Construction Engineering*. https://doi.org/http://dx.doi.org/10.1155/2014/390158

Hartmann, T. & Fischer, M. (2008). Applications of BIM and Hurdles for Widespread Adoption of BIM; AISC-ACCL eConstruction Roundtable Event Rep, CIFE Working Paper #WP105, Stanford University, Stanford, CA.

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

Howard, Rob & Bo-Christer Björk (2008). "Building information modelling–Experts' views on standardisation and industry deployment." *Advanced Engineering Informatics*, Vol. 22, No. 2, pp. 271-280, DOI: 10.1016/j.aei.2007.03.001.

Jung, Y., & Joo, M. (2011). “Building information modelling (BIM) framework for practical implementation.” *Automation of Construction*, 20(2), 126–133.

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.

Kasuya, E. (2001). Mann-Whitney U test when variances are unequal. *Animal Behaviour*, 61 (6), 1247-1249.

Khemlani, L. (2007). Top Criteria for BIM Solutions: AEC bytes Survey Results.

Kim, S., Park, C. H., & Chin, S. (2016). Assessment of BIM acceptance degree of Korean AEC participants. *KSCE Journal of Civil Engineering*, 20(4), 1163–1177. https://doi.org/10.1007/s12205-015-0647-y

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

Legendre, P. (2004). Species Associations: The Kendall Coefficient of Concordance Revisited., 3

McGraw Hill Construction. (2014). “The business value of BIM for construction in global markets: How contractors around the world are driving innovation with building information modeling.” Bedford, MA

Morlhon, R., Pellerin, R. & Bourgault, M. (2014). Building Information Modeling implementation through maturity evaluation and Critical Success Factors management. *Procedia Technology*, 16, 1126-1134.

Mutai A. K. (2009). Factors influencing the use of building information modeling within leading construction firms in the United States of America, Doctor of Philosophy, Indiana State University, Terre Haute, Indiana.

Olatunji, O. A. (2011). “Preliminary review on the legal implications of BIM and model ownership.” ITcon, Vol. 16, pp. 687-696.

Olatunji, S. O., Olawumi, T. O., & Aje, I. O. (2017). 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

Olawumi, T. O., & Chan, D. W. M. (2018a). Beneficial Factors of Integrating Building Information Modelling (BIM) and Sustainability Practices in Construction Projects. In *Proceedings of the Hong Kong International Conference on Engineering and Applied Science 2018 (HKICEAS 2018)*, 24-26 January 2018, Hong Kong: Higher Education Forum (pp. 141–152).

Olawumi, T. O., & Chan, D. W. M. (2018b). Critical Success Factors (CSFs) for Amplifying the Integration of BIM and Sustainability Principles in Construction Projects: A Delphi

Study. In *Proceedings of the RICS COBRA Conference 2018* 23-24 April 2018, London: RICS (Paper #127 in electronic format). Retrieved from https://goo.gl/eBfyVW

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

Olawumi, T. O., & Chan, D. W. M. (2018d). Identifying and prioritizing the benefits of integrating BIM and sustainability practices in construction projects: A Delphi survey of international experts. *Sustainable Cities and Society*, 40, 16–27. https://doi.org/10.1016/j.scs.2018.03.033

Olawumi, T. O., & Chan, D. W. M. (2019). Critical Success Factors for Implementing Building Information Modelling (BIM) and Sustainability Practices in Construction Projects: A Delphi Survey. *Sustainable Development*, (in press). https://doi.org/10.1002/sd.1925

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

Olawumi, T. O., Chan, D. W. M., Wong, J. K. W., & Chan, A. P. C. (2018). Barriers to the Integration of BIM and Sustainability Practices in Construction Projects: A Delphi Survey of International Experts. *Journal of Building Engineering*, 20, 60–71. https://doi.org/10.1016/j.jobe.2018.06.017

Oo, T. Z. (2014). Critical Success Factors for Application of BIM for Singapore Architectural Firms. School of the Built Environment, Heriot---Watt University. Heriott Watt University.

Ozorhon, B., & Karahan, U. (2016). Critical Success Factors of Building Information Modeling Implementation. *Journal of Management in Engineering*. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000505.

Peansupap, V. & Walker, D. (2005). Factors affecting ICT diffusion. A case study of three large Australian construction contractors, *Engineering Construction & Architectural Management*, 12 (1), Blackwell Publishing Limited, pp. 21–37

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

Rockart, J. F. (1982). The Changing Role of the Information Systems Executive : A Critical Success Factors Perspective. Sloan Management Review, 24(1), 3–13.

Rogers, J., Chong, H.-Y., & Preece, C. (2015). Adoption of Building Information Modelling technology (BIM) Perspectives from Malaysian engineering consulting services firms.

Engineering, Construction and Architectural Management, 22(4), 424–445. https://doi.org/10.1108/ECAM-05-2014-0067

Ruikar, E. K., & Emmitt, S. (2009). Emerging ICT Trends in Construction Project Teams: A Delphi Survey. *Journal of Information Technology in Construction*, 14(March), 81–97.

Santos, J. R. A. (1999). Cronbach's Alpha: A Tool for Assessing the Reliability of Scales. *Journal of Extension*, 37 (2), 1-5.

Sanvido, V., Grobler, F., Parfitt, K., Guvenis, M., & Coyle, M. (1992). Critical Success Factors for Construction Projects. *Journal of Construction Engineering and Management*. doi:10.1061/(ASCE)0733- 9364(1992)118:1(94)

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

Siegel, S. & Castellan, N. J. (1988). Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Inc

Succar, B. (2009). “Building information modelling framework: A research and delivery foundation for industry stakeholders.” *Automation in Construction*, Vol. 18, No. 3, pp. 357-375, DOI: 10.1016/j.autcon. 2008.10.003.

Succar, B., Sher, W., & Williams, A. (2012). “Measuring BIM performance: Five metrics.” *Architectural Engineering and Design Management*, Vol. 8, No. 2, pp. 120-142, DOI: 10.1080/17452007.2012.659506.

Succar, B., Sher, W., & Williams, A. (2013). “An integrated approach to BIM competency assessment, acquisition and application.” *Automation in Construction*, 35(1), 174–189.

Suermann, P., & Issa, R. (2009). “Evaluating industry perceptions of building information modeling (BIM) impact on construction.” ITcon, 4(1), 574–594.

Thompson, D. B. & Miner, R. G. (2006). Building information modeling-BIM: Contractual risks are changing with technology, [WWW document] URL http://www. aepronet. org/ge/no35. html.

Toor, S.-R., & Ogunlana, S. O. (2008). Critical COMs of Success in Large-Scale Construction Projects: Evidence from Thailand Construction Industry. *International Journal of Project Management*, 26(4), 420–430. doi:10.1016/j.ijproman.2007.08.003

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

Volk, R., Stengel, J., & Schultmann, F. (2014). “Building Information Modeling (BIM) for existing buildings-literature review and future needs.” *Automation in Construction*, Vol. 38, pp. 109-127, DOI: 10.1016/j.autcon.2013.10.023.

Won, J. & Lee, G. (2010). Identifying the consideration factors for successful BIM projects. *Proceedings of the International Conference on Computing in Civil and Building Engineering*, (72), 143-148.

Wu, I. L. & Wu, K. W. (2005). “A hybrid technology acceptance approach for exploring e-CRM adoption in organizations.” *Behaviour & Information Technology*, Vol. 24, No. 4, pp. 303-316, DOI: 10.1080/0144929042000320027.

Wu, W., & Issa, R. R. A. (2015). BIM Execution Planning in Green Building Projects: LEED as a Use Case. *Journal of Management in Engineering*, 31(1, SI), 1–18. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000314.

Yaakob, M., Athirah, W. N., Ali, W., Radzuan, K., Nur, W., & Ali, A. W. (2016). Identifying critical success factors (CSFs) of implementing building information modeling (BIM) in Malaysian construction industry. International Conference on Applied Science and Technology 2016 (ICAST), 19(10), 20105–15095. https://doi.org/10.1063/1.3452236

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