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A COMPREHENSIVE BIM IMPLEMENTATION MODEL FOR DEVELOPING COUNTRIES

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ABSTRACT

BIM implementation in the construction industry can be used to build the quality and competitiveness of AEC practices in the construction industry. However, to ensure significant and sustained BIM implementation in developing countries, it becomes important to investigate the appropriate models for significant and sustained BIM implementation in developing countries. Therefore, this study investigated the strengths and shortcomings of the BIM implementation models in use in the developed countries so as to identify a comprehensive set of BIM implementation model that will bring about a significant and sustained BIM implementation in the developing countries. The study developed a comprehensive BIM implementation model based on a theoretical background that was built from a meta-synthesis of studies on BIM adoption and theoretical perspectives from Implementation Process Theory. The model features top management commitment strategies, motivation strategies, capacity development strategies, and application strategies as the constructs for achieving a successful and sustained BIM implementation. The findings of the study are useful for stimulating the growth and technological development of construction industries in developing countries.

Keywords: BIM; BIM in the developing countries; BIM implementation; BIM implementation model; BIM adoption; BIM implementation strategies.

1. INTRODUCTION

The efficient construction industry is a pre-requisite to effective national development (Oyewobi and Ogunsemi, 2010). However, construction industries in developing countries are not efficient and not globally competitive (Isa et al., 2013). This ineffectiveness is substantiated by the presence of international firms and expatriates who dominate over the indigenous construction firms and professionals in the developing countries. As a way to neutralize the negative effects of globalization and domination of indigenous construction firms and professionals, Mbamali and Okotie (2012) recommend that strategies should be developed for enhancing the global competitiveness of indigenous construction firms and professionals in the developing countries. BIM implementation provides the opportunity for the enhancement of global competitiveness of indigenous construction firms and professionals in the developing countries. According to Yori (2011) and Yussuf et al. (2016), BIM implementation determines the quality, efficiency, and competitiveness of a construction industry which makes it the best way to ensure quality works, workers efficiencies, and competitiveness of firms and professionals in the developing countries. In addition, the potentials of BIM in addressing the needs of construction industry has made BIM the international standard of project design, construction and management systems; and its implementation in a construction industry can be used to build the quality and competitiveness of architectural, engineering and construction practices in the construction industry (Bryde et al., 2013; Jung and Joo, 2011).

BIM implementation is the process of ensuring BIM adoption in the construction industry (that is, the process of mandating or making BIM a formal or acceptable working system in the construction industry) (Arayici et al., 2011; Eadie et al., 2013; Smith, 2014). While BIM adoption is an act carried out by organizations or construction project supply chain (CPSC) networks operating in particular construction industry, to take up or follow the provisions and guidelines of BIM as given in a BIM implementation requirement (Gu and London, 2010; Succar and Kassem, 2015). BIM adoption also refers to the formal acceptance of BIM by organizations and CPSC as a working system (technology, process, and management) in the construction industry (Newton and Chileshe, 2012).

BIM awareness is rapidly increasing in the developing countries on account of BIM implementation being touted as having the potentials to meet the needs of the construction industry (Rogers et al., 2015; Enshassi et al., 2016). Recently, pockets of BIM adoption have been reported among the large and international firms that are operating in the developing countries (Mehran, 2016; Gray et al., 2013). The pockets of BIM adoption for projects by large and international firms in developing countries is as a result of abundant resources and availability of BIM competent professionals in these firms, but it could suppress the growth of the indigenous firms in the developing countries (Mehran, 2016; Bensalah et al., 2018). Similarly, this form of BIM adoption is an apparition and unworthy of celebration because it doesn't translate to BIM implementation, nor does it give a true representation of the local market in the developing countries. Additionally, the adoption of BIM for projects by large and international firms in the developing countries, if not curbed may force the indigenous small and medium organizations to imitate the large and international organizations which could frustrate the growth of these small and medium organizations, as well as the growth and development of the construction industry (Olatunji, 2011). This implies that there are no significant BIM implementation initiatives in developing countries.

Nonetheless, several attempts have been made to investigate the current state of BIM implementation in the developing countries (Bui et al., 2016; Bensalah et al., 2018; Wong et al., 2010; Mohd-Nor and Grant, 2014; Rogers et al., 2015; Olugboyega and Aina, 2018; Gerges et al., 2017; Wang et al., 2015; Usman et al., 2016; Kekana et al., 2015; Hamma-adama et al., 2018; Akintola et al., 2017; Hosseini et al., 2016; Froise and Shakantu, 2014). Studies have also reported the barriers to BIM implementation in developing countries (Ahmed et al., 2014; Olugboyega and Aina, 2016; Kiani et al., 2015; Kekana and Aigbavboa, 2015; Saleh, 2015; Hamada et al., 2017) and the facilitators and benefits of BIM implementation in the developing countries (Mehran, 2016; Olugboyega and Aina, 2016; Ozorhon and Karahan, 2016; Masood et al., 2014; Enegbuma et al., 2014; Ezeokoi et al., 2016; Hatem et al., 2018). These previous studies have provided information on awareness, readiness, and BIM adoption efforts in developing countries. However, ensuring a significant and sustained BIM implementation in developing countries requires more than the investigation of BIM awareness and readiness for BIM adoption in developing countries. To ensure significant and sustained BIM implementation in the developing countries, it becomes important to investigate the appropriate models for significant and sustained BIM implementation in the developing countries (Nagalingam et al., 2013; Chan et al., 2018). Therefore, this study seeks to understand the strengths and shortcomings of the existing BIM implementation models and establish whether this will lead to the identification of a comprehensive set of BIM implementation model that will bring about a significant and sustained BIM implementation in the developing countries.

This study provides an important opportunity to advance BIM implementation in the developing countries because BIM implementation has become a necessity for any construction industry that wants to be effective, efficient and globally relevant (Arayici et al., 2011). However, BIM implementation becomes meaningless and onerous, if it is not successful and effective, hence it becomes imperative to investigate the strategies and theoretical approaches to BIM implementation models across the world with a view to drawing lessons and making recommendations for BIM implementation models in the developing countries. The strengths and shortcomings of the existing BIM implementation models serve as sources of recommendations for creating BIM implementation models in developing countries. This will enable the industry leaders and national policymakers in the developing construction industries to implement BIM for derivable benefits and development in their respective countries.

Developing a specific BIM implementation model for developing countries is important because of the strong urge to comply with the BIM implementation trends which might lead to the imitation of the BIM implementation initiatives that have been put in place in the developed countries. Imitation of BIM implementation initiatives of the developed countries is not a practical way of implementing BIM in developing countries because of the differences in the structure, culture and market context of developed and developing countries (Gu and London, 2010; Miller et al., 2013; Silva et al., 2016; Cao et al., 2017). In addition, it is important to learn from the strengths and shortcomings of the existing BIM implementation models because of the need to maximize the scarce resources in developing countries.

2. RESEARCH METHODOLOGY

Meta-synthesis of BIM implementation studies was selected for this study. This was done in order to achieve a better comprehension and interpretation of BIM implementation initiatives and strategies in the construction industry. The choice of meta-synthesis was informed by its usefulness in compiling qualitative evidence for achieving research objectives and gaining deeper insights into a phenomenon that might not be available in a single study (Walsh and Soo, 2005). According to Zimmer (2006), meta-synthesis research approach will generate a more complete understanding of the phenomenon because it offers an appropriate balance between a rigorous scientific approach to data analysis and the researcher's subjectivity. The meta-synthesis approach in this study consists of five main stages: (1) selecting of relevant journals and articles; (2) identifying key concepts and themes; (3) establishing relationships that exist between the identified concepts and themes; (4) categorising the identified concepts and themes into major themes; and (5) summarising and ensuring the credibility of the major themes. The meta-synthesis procedure used in this study is outlined in Figure 1.

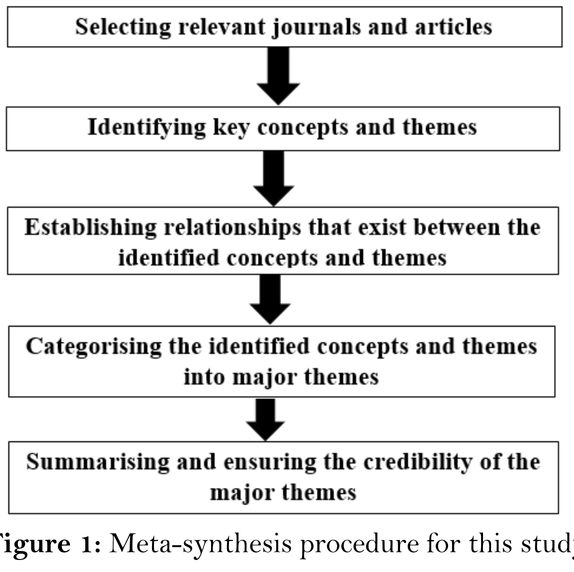

Figure 1: Meta-synthesis procedure for this study

2.1 Selecting relevant journals and articles

BIM implementation is a broad concept that includes a large number of related constructs and themes. Therefore, a robust search of database provided by Scopus, Google Scholar, JSTOR, EBSCO, Mendeley, Elsevier, PubMed, Science Open, and Springer was undertaken using the following combination of search terms to match the focus of the study to the literature search:

- BIM implementation/adoption in North America
- BIM implementation/adoption in Europe
- BIM implementation/adoption in South America
- BIM implementation/adoption in Asia
- BIM implementation adoption in Australia
- BIM implementation/adoption in Oceania
- BIM implementation/adoption in Africa
- BIM implementation strategies/initiatives/theories

The search generates 419 articles from the databases. Screening of the articles was done by reviewing their relevance using criteria such as the use of English Language, a reference to BIM implementation/adoption, and peer-reviewed articles and conference proceedings. At the end of this screening stage, 178 articles remained. Further screening of the articles for relevance was conducted by reviewing the titles and abstracts of these articles for specific relevance to the aim of this study. A total of 114 articles were screened out, which gives 64 relevant articles.

2.2 Identifying key concepts and themes

The aim of this study is to identify BIM implementation strategies and initiatives so as to develop a comprehensive BIM implementation model for developing countries. BIM implementation efforts have been initiated in the developed countries, and there are several studies that have reported these initiatives. At this stage, the objective of the meta-synthesis is to identify the key concepts and themes that relate to BIM implementation strategies and initiatives in these studies. This stage is important because different studies employ different theoretical perspectives and methodologies to explain and report their findings. The key concepts and themes relating to BIM implementation strategies were identified from the selected relevant studies by setting apart phrases, concepts, and ideas that describe BIM implementation efforts or initiatives.

2.3 Establishing relationships that exist between the identified concepts and themes

Meta-synthesis enables the understanding and identification of relationships among the concepts and themes in a group of similar studies (Lee, 2010). At this stage of the meta-synthesis, comparing and contrasting of the identified concepts and themes to each other was done in order to examine the relationships between them.

2.4 Categorising the identified concepts and themes into major themes

Major themes were determined by identifying and generating themes that apply to or explain two or more concepts. The major themes were generated by comprehending the similarities between the concepts and themes. Similar concepts and themes were linked so as to enable the generation of different categories or components for BIM implementation strategies. This procedure follows the recommendations by Jensen and Allen (1996) for capturing homogeneity among concepts.

2.5 Summarising and ensuring the credibility of the major themes

Dimensions were assigned to summarise the various categories of the major themes (BIM implementation strategies) for BIM implementation. The dimensions were defined based on new concepts that emerged from the categories. The summary of the synthesis is illustrated in Figure 2. The summary of the synthesis was reviewed independently by the authors in order to facilitate an accurate interpretation of the studies and ensure the credibility of the major themes.

3. MODELS OF BIM IMPLEMENTATION IN THE DEVELOPED COUNTRIES

3.1 motivation model for BIM adoption

Diffusion of Innovation (DOI) Theory is a popular approach to planning the adoption of Information Technology (IT) innovations. The theory predicts the diffusion phenomenon of IT innovations among IT innovations adopters by conceptualizing diffusion phenomenon as consisting of diffusion arena, diffusion forces, IT innovators and IT innovation adopters. IT innovation adopters are classified into forerunners and followers, while diffusion forces are classified into communicating force and imitative force. The postulation explains that IT innovators and IT innovation adopters interact in a homogeneous diffusion arena, where communicating force allows IT innovators to transfer new IT innovations to the forerunners. The transfer leads to the forerunners adopting the new IT innovations, while imitative force spreads the IT innovations to the followers (Lyytinen and Damsgaard, 2001; Miettinen and Paavola, 2014; Cao et al., 2015). Several countries have developed BIM implementation strategies based on the presumptions of DOI Theory (Succar and Kumar, 2015; Cao et al., 2015; Papadonikolaki, 2017). This model of BIM implementation relates to motivation strategies. Motivation strategies give reasons and inducements for BIM adoption by making use of imitative and coercive forces to set BIM adoption goals for the construction industry and to create internal competition among the organisations in the industry towards BIM adoption. According to Papadonikolaki (2017), this model of BIM implementation will create an institutional requirement that will provide a long-term inducement for BIM adoption and would contribute to the competitive advantage of the organisations in the construction industry. The general motivation strategies for BIM implementation include BIM pilot projects (Mihindu and Arayici, 2008; Sebastian et al., 2009; Silva et al., 2016; Cheng and Lu, 2015; McAuley et al., 2017), BIM guidelines and standards (Papadonikolaki, 2017; Wong et al., 2010; Silva et al., 2016; Cheng and Lu, 2015; McAuley et al., 2017; Shou et al., 2015), and mandatory requirement of BIM in contractor selection process and application for building permit (Silva et al., 2016; Cheng and Lu, 2015; McAuley et al., 2017; Ho and Rajabifard, 2016; Wong et al., 2010; Hermund, 2009; Adillah et al., 2015). However, the power of this model of BIM implementation in driving BIM adoption is limited due to the use of a theoretical perspective that treats BIM as technology and employs the use of imitation and coercion to drive its adoption (Miettinen and Paavola, 2014; Cao et al., 2017).

3.2 Motivation – Education model for BIM adoption

The principles of DOI theory are not adequate for the development of BIM implementation strategies because the theory did not put the characteristics of diffusion arena, IT innovators and IT innovation adopters into consideration (Cao et al., 2017). According to Lyytinen and Damsgaard (2001) diffusion arena, innovation, and adopter decisions are influenced by industry structure, cultural structures, economic (macro, meso, and micro) constraint, market context, technological constraints, and technical constraints. There are different kinds of activities, professionals, projects, clients, and firms in the construction industry that make the industry a complex arena for IT innovation diffusion. As a result of the inadequacy of

DOI Theory to drive BIM implementation, authors like Kassem and Succar (2017) and Cao et al. (2017) suggested the use of Institutional Theory or the combination of DOI Theory and Institutional Theory to extend the scope of BIM implementation strategies. Ho and Rajabifard (2016) describe Institutional Theory as the use of legal, social and cultural structures to control the thinking, actions, and behaviours of individuals, groups, and organizations. The compelling forces available in Institutional Theory include coercive, imitative and normative force. Coercive force compels individuals, groups, and organizations to act in line with the expectations spelt out in guidelines and regulations, imitative force makes small organizations to follow the examples of large firms; while normative force causes them to strive for identity, survival, and legitimacy in the society. The combination of DOI and Institutional theory pilots a BIM implementation model that features the blend of motivation strategies and education strategies for driving BIM adoption in the construction industry. This form of BIM implementation model employs the use of communicating force (BIM awareness), imitative force (adoption of BIM by large and international firms), coercive force (government institutions mandating the use of BIM), normative force (development of BIM guidelines and standards), and knowledge or literacy force (acquisition of BIM-related skills by ensuring the access to BIM knowledge and technologies) to drive BIM adoption in the construction industry (Forsythe et al., 2011; Wu and Issa, 2013; Chan, 2014; Yusuf et al., 2016). The main advantage of this form of BIM implementation model is that it has prompted some universities across the globe to update existing courses using BIM education or create discrete BIM education courses (Abbas et al., 2016; Abdirad and Dossick, 2016). However, the shortcoming is that the theoretical perspectives provided by the combination of DOI and Institutional Theory are inadequate for developing the strategies to address the legal, cultural, and social dimension of BIM implementation (Cao et al., 2014; Miettinen and Paavola, 2014; Succar and Kassem, 2015; Kassem and Succer, 2017; Cao et al., 2017). Hence, a theory that provides multi-dimensional perspectives to the implementation process is required for a comprehensive BIM implementation.

4. CONCEPTUALISING A COMPREHENSIVE BIM IMPLEMENTATION MODEL

4.1 Theoretical insights

This study employs the Implementation Process Theory modified with postulations on BIM adoption requirements and challenges to facilitate the understanding of the concepts and variables associated with ensuring a successful and sustained BIM implementation. Implementation Process Theory (IPT) describes the efforts required to initiate and sustain adoption decision by individuals and organizations that operate in an industry. These efforts are affected by the influence of the organizations' top management and cover the organizational and managerial resources to be expended to meet the implementation strategy requirements (Yetton et al., 1999; Al-Mashari and Zain, 1999; Jackson, 1997; Proctor et al., 2013). According to Klein and Knight (2005), achieving a successful and sustained implementation of innovation or practice, individuals and organisations that operate in the industry must possess the skills, competence, and training that are consistent with the innovation or practice. Fixsen et al. (2005), Aarons et al. (2011), Klein and Sorra (1996), and Khalfan et al. (2015) posit that while the skills, competence, and training will enable the adoption of an innovation or a practice by an individual; the adoption of an innovation or a practice in an organisation depends on the commitment and culture that will be established by the top management of the organisation towards the continued use of the innovation or the continuity of the practice.

Similarly, studies on BIM adoption have shown that BIM adoption in organisations requires hefty investments of time and money in technology, training, and structural change

(Andres et al., 2017; Usman et al., 2016; Bryde et al., 2013). In addition, a number of BIM-related studies have postulated that BIM implementation is a complex process and that the justification for and the effectiveness of BIM implementation strategies depend on their capabilities in addressing a wide range of issues (Gu and London, 2010; Barlish and Sullivan, 2012; Love et al., 2013; Eadie et al., 2013; Cao et al., 2017; Zhu and Mostafavi, 2017). The implication of this is that BIM implementation process will not be successful and sustainable without putting in place measures that will bring about motivations for BIM adoption (Ding et al., 2015; Hong et al., 2016), BIM-enabled competitive edge for organisations (Arayici et al., 2011; Olatunji and Sher, 2014), and efficiency and effectiveness in the application of BIM on construction projects (Arayici et al., 2012; Arayici et al., 2011). Based on these perspectives, it is clear that a multi-dimensional approach is required to conceptualise a model that will adequately explain the driving forces required for BIM implementation, strategies required to achieve the driving forces and the outcome of these strategies. This is important for ensuring a successful and sustained BIM implementation in the construction industry. The insights from these perspectives also highlights the importance of the following dimensions to the success and sustainability of BIM implementation in the construction industry: (1) commitment, (2) motivation, (3) culture, (4) education and training, (5) skills and competence, (6) competitiveness, (7) efficiency, and (8) effectiveness. The theoretical perspectives from IPT and postulations on BIM adoption requirements and challenges are summarised in Figure 2.

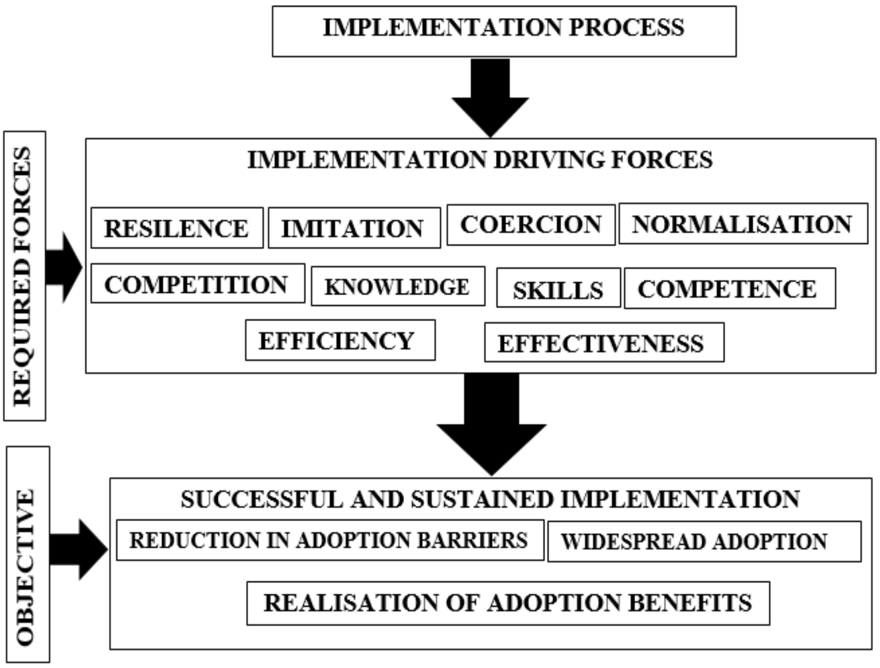

Figure 2: Theoretical framework for a successful and sustained BIM implementation

4.2 Theoretical grounding for a comprehensive BIM implementation

4.2.1 Strength of the BIM implementation models in the developed countries

In countries such as the United States, Canada, United Kingdom, Singapore, Spain, Portugal, and Sweden; BIM implementation models have manifested in form of the establishment of a national BIM program, mandatory use of BIM for spatial program validation of projects in 2007, development of a national BIM standard, development of BIM protocol and Integrated Project Delivery documents, and development of BIM guidelines (Cheng and Lu, 2015). BIM institute has been established, BIM guidelines and standards have been developed, and BIM has become a mandatory requirement in the contractor selection process (Powal and Hewage, 2013; Silva et al., 2016; Chew and Riley, 2013; Andres et al., 2017). BIM implementation initiatives in the United States and Canada relied heavily on BIM awareness, BIM adoption by government agencies, a mandatory requirement of BIM, BIM guidelines, and BIM standards to drive BIM adoption. The development of BIM library, the establishment of BIM centre and steering committee, mandatory BIM e-submissions for new projects, and BIM fund, with Industry Foundation Classes development and BIM classification standard initiatives.

In addition, BIM Task Group, BIM academic forum, and Construction Industry Council have been established to drive BIM implementation in some countries such as the United Kingdom, Finland, and Norway. These groups and committees have developed specification framework for BIM commissioning, BS 1192 for collaborative working, BS 1192-4 for interoperability, Uniclass 2015 for classification systems, PAS 1192-5 for security, and BIM use specifications (Cheng and Lu, 2015; Jensen and Johannesson, 2013; Lindblad and Vass, 2015). The use of these BIM implementation strategies has contributed significantly to BIM adoption in these countries based on the number of reports on the application of BIM on various types of projects in these countries (Gledson and Greenwood, 2016; Kiviniemi and Codinhoto, 2014).

4.2.2 Shortcomings of the BIM implementation models in the developed countries

The BIM implementation models in use in the developed countries are not all-inclusive and have brought about some setbacks such as non-realization of BIM benefits, lack of full-scale BIM projects, adoption bottlenecks, and economic liability to small and medium organizations (Porwal and Hewage, 2013; Kassem and Succar, 2017). The grounds for these shortcomings are discussed in the following sub-sections:

BIM implementation model must be multi-dimensional

A multi-dimensional BIM implementation approach is vital to ensuring the success of BIM implementation (Migilinskas et al., 2013; Miettinen and Paavola, 2014; Bui et al., 2016). BIM implementation model in use in the developed countries has been drawn primarily from the theoretical perspectives of Technology Acceptance and Diffusion of Innovation Theory. These theoretical perspectives provide strategies that are irrelevant to the capacity, macro and micro-economic dimensions of BIM implementation (Lyytinen and Damsgaard, 2001; Miettinen and Paavola, 2014; Cao et al., 2015; Cao et al., 2017). As noted by Succar et al. (2013) and Papadonikolaki (2017), capacity development and economic performance of organizations are key to the success of BIM implementation in the construction industry. Likewise, Jung and Joo (2011), Porwal and Hewage (2013), Morlhon et al. (2014), Cao et al. (2015), and Succar and Kumar (2015) concur that BIM implementation will be successful if BIM capability and applications, legal frameworks, as well as the macro, meso and micro-economy of the construction industry are considered in the BIM implementation strategies.

BIM implementation model must drive BIM adoption at the industry, organisation, and project level

The requirements for BIM implementation at the industry and organizational levels are not the same. There are three distinct levels in the construction industry, namely: macro, meso, and micro levels. The macro-level represents the industry level, meso level represents the organizational level, while project level is represented by the micro-level (Poirier et al.

(2015); Papadonikolaki, 2017). Poirier et al. (2015) noted that BIM implementation should be active at three levels. BIM implementation initiative is a national issue (Liu et al., 2015), therefore it depicts formal acceptance of BIM by the industry leaders and policymakers in order to be globally relevant and competitive. BIM adoption, on the other hand, depicts initiatives at the level of organizations or projects based on the expectations of the organizations or the clients and within the provisions of BIM implementation initiative. This shows that BIM implementation is a product of political will or legislation and it requires strategies, plans, decisions, regulations, and guidelines to bring it into effect; while BIM adoption is a product of requirements by clients or organizational vision. Without BIM implementation, BIM adoption is not legally binding on organizations or construction project supply chains (CPSC), except it was demanded by clients. Even with BIM implementation, BIM adoption is still not legally binding on organizations or CPSC if the clients (public or private) do not mandate it.

Mandatory BIM submission and development of national BIM standards, as found in the developed countries have provided the resources, authority, and control that are required to implement BIM at the industry level (Silva et al., 2016). However, this approach has limited the focus of BIM implementation to the industry level with little or no concerns for the cultural, structural, and economic impacts of mandatory BIM submission at the meso and micro levels. As a result, there are complications with BIM implementation strategies that are based on this approach. For example, Migilinskas et al. (2013) identified cost of investment, unavailability of BIM implementation framework, and structure of the industry as challenges of BIM implementation in Lithuania. In Sweden, Isaksson et al. (2016) reported a shortage of internal and external demands for BIM by team members and clients as obstacles to BIM implementation; and that reliance on coercive force alone won't drive BIM adoption among in the Swedish construction industry. Also, United Kingdom BIM implementation in the United Kingdom is experiencing complications such as resistance to change, BIM training and competency issues, BIM applications and tools problems, collaboration and integration issues, BIM workflow adaptation challenges, lack of client demand, cultural resistance, and reluctance of team members to share information (Arayici et al., 2011; Eadie et al., 2013).

BIM implementation model must cater to the small and medium construction organisations

The economic viability of small and medium firms is an important consideration in BIM implementation because the adoption of BIM by small and medium organizations is very important for the industry (Miller et al., 2013), and because not all the small and medium firms could survive economic liability of BIM adoption owing to poor financial base (Liu et al., 2017). This is because more than 96% of organizations in the industry are small and medium organizations which make the economic performances of small and medium firms vital to the macroeconomic performance of the construction industry (Olatunji, 2011; Miller et al., 2013). According to Barlish and Sullivan (2012), Miettinen and Paavola (2014), Isaksson et al. (2016), and Zhu and Mostafavi (2017), different organizations require different motivation for BIM adoption based on their respective organizational characteristics. However, nearly all the existing BIM implementation models lack supportive regulations, capacity development frameworks, and economic considerations such as financial support towards BIM adoption for small and medium firms in the construction industry. This has been a major challenge of BIM implementation in the developed countries (Yusuf et al., 2016; Cheng and Lu, 2015).

BIM implementation model must have contextual, theoretical and empirical justification.

A BIM implementation model becomes effective and provides multifaceted insights into BIM adoption when it has a contextual, theoretical and empirical justification. This will be achieved by incorporating considerations for organizational differences, culture, contingencies, commitment and capacities to sustain BIM adoption (Jung and Joo, 2011; Kim et al., 2005; Migilinskas et al., 2013; Miettinen and Paavola, 2014; Bui et al., 2016; Gu and London, 2010; Silva et al., 2016; Cao et al., 2017; Morlhon et al., 2014; Succar and Kumar, 2015; Cao et al. 2015; Zhu and Mostafari, 2017). It becomes important to justify the consensus of organizational perceptions of a BIM implementation model contextually, theoretically and empirically since the implementation process requires organizations to make adoption decisions; and since the willingness of the organizations to assume responsibilities for implementation strategies depend on their understanding and contributions to the choice of implementation strategies (Rapert et al., 2002).

The consensus of organizational perceptions is important in the choice of implementation strategies in order to ensure cooperation from the organizations and to ensure harmony between the requirements of implementation strategies, as well as the efforts of the organization towards adoption (Rapert et al., 2002; Zmud and Cox, 1979). In the same way, the consideration of organizational differences, culture, contingencies, commitment and capacities in developing BIM implementation strategies is vital to ensuring the success of BIM implementation owing to the complexity of BIM adoption barriers, the complexity of the construction projects, and the requirements of project participants (Proctor et al. 2013; Migilinskas et al. 2013; Miettinen and Paavola, 2014; Bui et al. 2016; Kassem and Succar, 2017). This will enable organisations and project participants to strategically plan (that is, address the issues of economic liability, BIM competency, BIM value, and BIM workflow adaptation challenges) BIM adoption on construction projects (Porwal and Hewage, 2013; Arayici et al., 2011; Eadie et al., 2013; Migilinskas et al., 2013; Isaksson et al., 2016; Enshassi and Abuhamra, 2017; Btoush and Harun, 2017; Yusuf et al., 2016; Smith, 2014; Cheng and Lu, 2015; Succar, 2009; Cao et al., 2014; Cao et al., 2015).

However, the BIM implementation strategies in use in the developed countries lack an operational structure that could strategically guide the utilization of BIM and the assessment of BIM performance on projects and in organisations in relation to the achievement of integration and collaboration as the ultimate benefit of BIM adoption, as well as economically justify investment in BIM and demand for BIM by clients on their projects (Aranda-Mena et al., 2009; Shusheng and Min, 2010; Barlish and Sullivan, 2012; Bryde et al., 2013; Succar et al., 2013; Miettinen and Paavola, 2014; Cao et al., 2015; Beaumont and Underwood, 2015; Abdirad and Dossick, 2016; Abbas et al., 2016; Ghaffarianhoseini et al. 2017; Sawhney et al., 2017; Liu et al., 2017).

4.3 Synthesis and Discussion: A comprehensive BIM implementation model

4.3.1 The driving forces required for a comprehensive BIM implementation model

The construction industry is a dynamic, diverse, complex sector owing to the interplay between market structure (macro, meso, and microstructures), socio-cultural structure, technical and legal contract structures (Tennant and Fernie, 2014). The complexity of the construction industry increases in developing countries because of the prevailing inefficiencies and ineffectiveness (Isa et al., 2013; Mbamali and Okotie, 2012). Hence, a comprehensive BIM implementation model is required for a successful and sustained BIM implementation in developing countries. A comprehensive BIM implementation model must complement the strengths and deficiencies of the existing BIM implementation models

(Porwal and Hewage, 2013; Miettinen and Paavola, 2014; Cao et al., 2015; Zhu and Mostafari, 2017; Cao et al., 2017). This implies that the BIM implementation model to be initiated in the developing countries must be multi-dimensional; must be capable of driving BIM adoption at the industry, organisation, and project level; must cater to the small and medium construction organisations; and must have contextual, theoretical and empirical justifications (Miettinen and Paavola, 2014; Bui et al., 2016).

A multi-dimensional approach to BIM implementation means that regulatory frameworks should be considered for economic viability of construction firms (small and medium firms in particular) to adopt BIM, BIM awareness and maturity, demand for BIM by both public and private clients, BIM standards and collaborative procurement guidelines, BIM capability of firms and professionals, BIM benefits and industry needs alignment. The demand for BIM by both public and private clients, most especially private clients is a function of the BIM value (that is, the business sense of BIM adoption on projects in relation to the cost implications of BIM adoption on projects) (Love et al., 2013; Lu et al., 2014. Eadie et al., (2013) observe that the fact that clients benefit the most from BIM adoption does not necessarily mean that clients should be made to bear the cost of BIM adoption alone; because BIM adoption also serves as competitive advantage and marketing opportunities for firms. Preferably, an acceptable BIM cost-benefit sharing framework should be developed as part of BIM implementation strategies (Liu et al., 2017). The BIM cost-benefit sharing framework must relate costs and benefits of BIM to BIM application levels, types and sizes of projects, and types and sizes of organizations; as this will provide flexibility in demands for BIM to suit the needs of the clients, project complexity and size, and BIM capacity of firms (Gu and London, 2010; Barlish and Sullivan, 2012; Love et al., 2013; Eadie et al., 2013).

4.3.2 BIM implementation strategies that are required to provide the driving forces for a comprehensive BIM implementation

The strengths and shortcomings of the existing BIM implementation models in the developed countries have shown that BIM implementation becomes impactful at the project level. This implies that a comprehensive BIM implementation model must entail strategies for motivating organisations, professionals, and clients to adopt BIM; strategies for developing the BIM capacity of the present and future construction professionals and organisations; strategies for applying BIM effectively and efficiently on construction projects; and strategies for securing the commitment of top management of construction organisations to BIM adoption. Based on the theoretical framework and theoretical grounding, this study presents a comprehensive BIM implementation model for ensuring a successful and sustained BIM implementation in developing countries. The detailed description of the constructs and sub-constructs of the model is provided in Figure 3, Table 1 - 4, and in the following sub-sections.

Capacity development strategies

BIM implementation strategies require more than BIM education at the higher institutions to develop the BIM capacity of the present and future construction professionals and organisations (Succar et al., 2013; Abdirad and Dossick, 2016; Liu et al., 2017; Eadie et al., 2013; Sawhney et al., 2017). This is because education merely develops knowledge and skills (Hiton, 2010); while capacity development deals with the development of knowledge, skills, competence, and competitive edge for the reason that it enables individuals and organisations to strengthen and maintain their education (Browne-Ferrigno and Muth, 2004). Butcher et al., (2011) concurs that capacity development is the process through which individuals and organisations obtain, strengthen, and maintain the capacities to set and achieve their own development objectives over time. Therefore, developing the BIM capacity of organisations and professionals towards a successful and sustained BIM implementation in the construction industry requires BIM education, BIM experience, and BIM training (Sawhney et al., 2017; Peterson et al., 2011; Becerik-Gerber et al., 2011; Succar et al., 2013; Miller et al., 2013; Abdirad and Dossick, 2016; Eadie et al., 2015; Liu et al., 2017; Eadie et al., 2013). The use of BIM education, BIM experience, and BIM training for BIM capacity development will ensure the availability of BIM competent construction professionals and organisations for the present and future needs of BIM implementation (Mahamadu et al., 2017). In addition, these strategies will reduce the cost of BIM adoption and increasing the benefits of BIM adoption (Azhar, 2011).

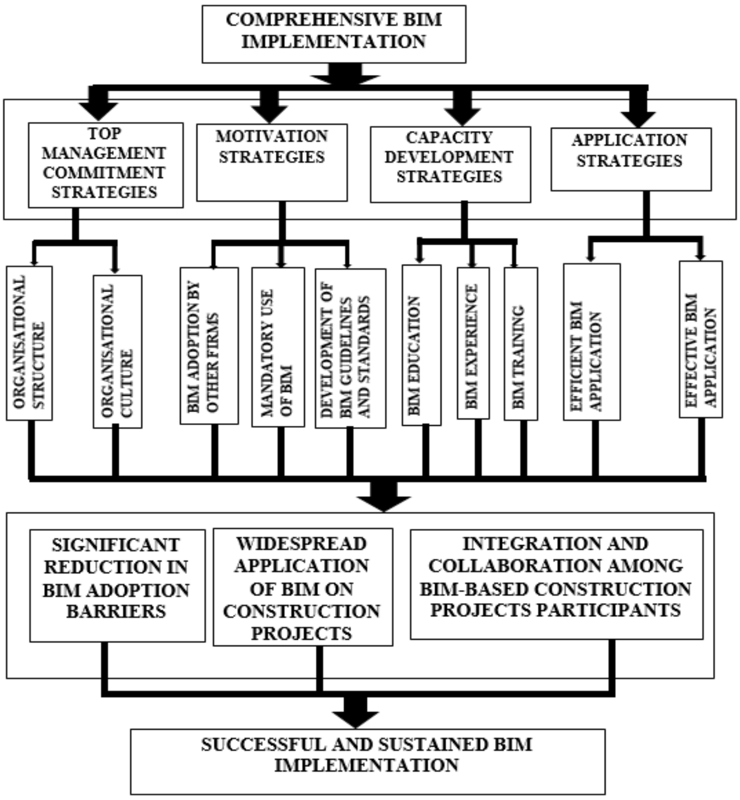

Figure 3: A comprehensive BIM implementation model

Table 1. Capacity development strategies for a comprehensive BIM implementation in the developing countries

BIM CAPACITY DEVELOPMENT STRATEGIES	
BIM EDUCATION	BIM TRAINING AND EXPERIENCE
2D and 3D CAD education in the secondary school	Upbringing by BIM proficient parents
BIM education at an undergraduate programme at the university	Pre-labour market-influenced BIM training
BIM technology educational programme in colleges, technical and vocational institutes	Self-initiated BIM training
BIM application and management programme at post-graduate level in the university	BIM workshops
	BIM seminars
	BIM research and development
	On-the-job BIM training for the employees
	Corporate BIM training partners
	Peer-group-influenced BIM training

Source: (Succar et al., 2013; Abdirad and Dossick, 2016; Peterson et al., 2011; Badrinath et al., 2016; Abbas et al., 2016; Miller et al., 2013; Becerik-Gerber et al., 2011; Hon et al., 2015)

Top management commitment strategies

Several studies have reported the importance of top management commitment regarding the initiation and sustenance of adoption decision in an organization (Mumford, 1995; Bashein et al., 1994; Al-Mashari and Zain, 1999; Jackson, 1997; Hammer and Stanton, 1995; El Sawy, 1997; Kettinger et al., 1997). For example, Al-Mashari and Zain (1999) suggest that top management is required to manage the transition, resistance, competency, organizational structure, and resources in the course of the implementation process. Mumford (1995) submits that top management are required to promote collaborative teamwork culture. Based on this understanding, it becomes clear that the total dedication of the top management of construction organisations to BIM adoption an adaptation is crucial to the success of BIM implementation (Chien et al., 2014). The implication of this is that the top management of construction organisations must be willing to allocate and commit organisational and managerial resources such as time, money, visions, culture, and structure to the process of BIM adoption in their organisations (Khosorowshahi and Arayici, 2012). The outcome of such a commitment is a successful and sustained BIM implementation.

Table 2. Top management commitment strategies for a comprehensive BIM implementation in the developing countries

TOP MANAGEMENT COMMITMENT STRATEGIES	
ORGANISATION STRUCTURE	ORGANISATION CULTURE
Coordination of the BIM process in the organization	Sanctions (queries & demotion) for resistance towards BIM usage
Provision of incentives (bonus & allowance) for BIM usage	Adaptation of BIM concepts to the organizational culture
Provision of incentives for BIM capacity development	Exploration of the usage of BIM on pilot projects
Provision of in-house BIM training	Provision of infrastructures (BIM environment) for BIM
Provision of technical support services in the organization	Incorporation of BIM into the vision of the organization
BIM consultant's engagement	Facilitate solutions to projects contingencies (incidents & challenges) brought about by BIM adoption
Revision of the reward system	Facilitate solutions to client's contingencies (incidents & challenges) brought about by BIM adoption
Revision of wage structure	Facilitate solutions to organizations contingencies (incidents & challenges) brought about by BIM adoption
Effective communication between stakeholders	Documentation of the proceedings of BIM-based projects
Stimulating BIM adoption with investments	Introduction of collaborative teamwork culture in the organization
Introduction of new roles and job titles	Educating staff on the potentials of BIM
Allowing staff members to participate in the work process redesign process	Development of new values
Increment in the staff development budget	Development of management processes
Creation of new organizational structure	Development of communication styles
Appointing BIM champions	Development of performance measures for BIM adoption
Appointing BIM managers	Identification of business opportunities in BIM adoption
Anticipating and planning for BIM adoption risk management	Ensuring effective use of BIM tools
	Adherence to BIM protocols
	Adherence to the BIM process

Source: (Ho and Rajabifard, 2016; Liu et al., 2017; Adillah et al., 2015; Cao et al., 2017; Hermund, 2009; Son et al., 2015; Jung and Joo, 2011)

Application strategies

The use of different construction management systems for project delivery will provide better project performance if the projects' characteristics are the basis for selecting the management systems. The selection of project process is determined by the project characteristics such as clients' expectations, project size, project complexity, team size and capability, and project expectations (Sauser et al., 2009; Howell et al., 2010). Several authors have argued that BIM is a construction management system and that its application on projects should be linked to projects characteristics and project expectations (Gu and London, 2010; Barlish and Sullivan, 2012; Porwal and Hewage, 2013; Miettinen and Paavola, 2014; Isaksson et al., 2016; Zhu and Mostafavi, 2017). The use of projects characteristics and project expectations in determining the extent of BIM application on construction projects describes a contingent and strategic BIM application and indicates an efficient and effective BIM application on construction projects (Lu et al., 2014).

Table 3. BIM application strategies for a comprehensive BIM implementation in the developing countries

BIM APPLICATION STRATEGIES	
EFFICIENT/STRATEGIC BIM APPLICATION	EFFECTIVE/CONTINGENT BIM APPLICATION
Sharing BIM cost and benefits between the client and the supply chain members	Determining the extent of BIM application based on the level of project complexity
Determining the appropriate level of development of building information models for different types of project complexities	Determining the appropriate types of professionals to form the construction project supply chain network
Assessing the performance of BIM adoption on construction projects	Determining the required BIM capacity of the construction project supply chain members based on the types of project
Determining the appropriate form of collaboration required for different types of project complexities	Determining the appropriate collaborative procurement system for different types of project complexities
Determining the appropriate intensity of collaboration required for different types of project complexities	Determining the appropriate import and export file format for different types of project complexities
Developing digital object identifiers for building materials manufacturers	
Developing digital object identifiers for supply chain	

Source: (Howard and Bjork, 2007; Son et al., 2015; Gerges et al., 2017; Lu et al., 2014; Linderoth, 2010; Barlish and Sullivan, 2012)

Motivation strategies

Motivation strategies are those initiatives that are targeted at stimulating the efforts and energy in construction professionals and organisations to adopt BIM (Coates et al., 2010; Memon et al., 2014). A number of initiatives that relate to motivation strategies for BIM adoption in the developed countries have been reported by studies such as Ho et al., (2016) and Ding et al., (2015). Table 4 provides a detailed description of motivation strategies for BIM implementation.

4.3.3 The outcomes of BIM implementation strategies

BIM implementation model with strategies that provide the driving forces that are required for BIM implementation will be useful in addressing the complexity of BIM implementation, the complexity of BIM adoption decisions, and the complexity of the construction industry. The adoption of a comprehensive BIM implementation model will free the developing countries from the bottlenecks that are being experienced in BIM implementation models in the developed countries (Succar, 2009; Cao et al., 2014; Cao et al., 2015; Gu and London, 2010; Miller et al., 2013; Lyytinen and Damsgaard, 2001; Miettinen and Paavola, 2014; Morlhon et al., 2014; Succar and Kumar, 2015).

Table 4. Motivation strategies for a comprehensive BIM implementation in the developing countries

MOTIVATION STRATEGIES FOR BIM ADOPTION/IMPLEMENTATION		
BIM ADOPTION BY OTHER FIRMS	MANDATORY USE OF BIM	DEVELOPMENT OF BIM GUIDELINES AND STANDARDS
Prevalent BIM adoption among the top and successful firms	BIM adoption as conformity to regulations and rules	Availability of legalities and copyright ownership of BIM
BIM adoption by rival firms	BIM adoption as part of clients' requirement	Availability of guidelines on BIM protocols
BIM adoption among peer firms	BIM adoption as part of project team requirement	Availability of fund to assist small and medium firms to adopt BIM
BIM adoption as a corporate social responsibility strategy	Government-sponsored BIM-based pilot projects	Availability of guidelines on BIM roles and responsibilities (BIM supply chain)
BIM adoption as a way of encouraging development in the construction industry	Mandatory requirement of BIM for building permit application	Availability of information on BIM concepts
BIM adoption as a marketing strategy	Mandatory requirement of BIM in the contractor selection process	Advocacy and campaign for BIM
Report of BIM usage on a widely acclaimed successful projects	BIM adoption as a requirement in the company's supply chain network	Advertisement and programs for BIM awareness
Marketing of BIM as professional services		Availability of national BIM standards
Availability of BIM proficient graduates		
Need to be seen as being up-to-date and technologically sophisticated		
Need to be socially acceptable to the clients		
Need to adapt to global best practices and trends		
Need to improve organizational performance and efficiency in short and long terms		
Need to improve competitiveness in project bidding		

Source: (Cao et al., 2017; Ciribini et al., 2016; Silva et al., 2016; Adillah et al., 2015; Cheng and Lu, 2015; McAuley et al., 2017; Ho and Rajabifard, 2016; Papadonikolaki, 2017; Shou et al., 2015)

5. CONCLUSIONS

The prevalent implementation of BIM all over the world makes it a revolution that construction industries in the developing countries cannot afford to abstain from, nor commit to the private sector. In the same way, BIM implementation in the developing countries must avoid the complications of the BIM implementation models in the developed countries by learning from the strengths and shortcomings of BIM implementation in the developed countries. The Complications that resulted from the BIM implementation models in the developed countries have shown that the models were not comprehensive enough as some dimensions of the construction industry were not accorded their due importance in these BIM implementation models. The complications have also shown that BIM implementation process is not a linear phenomenon but a complex one and that if the appropriate strategies are not employed, the process will further widen the gap between the large and small firms, will fail to provide the necessary support, legitimacy, incentives, resources, and guidelines for BIM implementation. One of the reasons why BIM implementation process is complex is because the Construction industry is not a homogeneous arena but a complex and multi-dimensional industry with complicated activities, characteristics, relationships, and management requirements. This makes it clear why the capacity development and economic performance of organizations in the industry, as well as the growth of the industry, are some of the important considerations that must be incorporated into the development of BIM implementation models.

The purpose of this study was to understand the strengths and shortcomings of the BIM implementation models in use in the developed countries and establish whether this will lead to the identification of a comprehensive set of BIM implementation strategies that will bring about a significant and sustained BIM implementation in the developing countries. The findings of the study informed the development of a comprehensive BIM implementation model based on the theoretical framework and theoretical background that come from Implementation Process Theory and postulations on BIM adoption. The model features four main constructs (top management commitment strategies, motivation strategies, capacity development strategies, and application strategies) and eleven sub-constructs (see Figure 3). In the model, the objective of the constructs is to achieve a successful and sustained BIM implementation. The model explains that a successful and sustained BIM implementation will be achieved when there is a significant reduction in BIM adoption barriers, a widespread application of BIM on construction projects, and integration and collaboration among construction project participants. The strategies to achieve a successful and sustained BIM implementation are illustrated in Figure 3 and outlined in Table 1. Top management commitment explains that change in organisation structure and culture are required in order to adopt and adapt BIM to the organisational work process. Motivation strategies are associated with efforts by industry regulators and leaders such as mandatory use of BIM in the industry and development of BIM guidelines and standards. The availability of these strategies will create an enabling environment and impetus for BIM adoption in the industry. Capacity development strategies as a construct define the capabilities that are required to function in a BIM environment or to participate effectively in a BIM-based construction project. As illustrated in the model, BIM-related capabilities of an organisation or a professional entail the skills, knowledge, and competence to participate on BIM-based projects, as well as bestow a competitive edge on the organisation and the professionals. Application strategies explain that an efficient and effective application of BIM on construction projects is important to the success of BIM implementation in the construction industry.

Implications of this study include the possibility of developing the financial and production capabilities of the indigenous small and medium firms to reach the level of the large and international firms that are operating in the developing countries through the use of appropriate motivation strategies for BIM adoption. Furthermore, the evidence from this study has suggestions for stimulating the growth and technological development of construction industries in the developing countries. Further research needs to contextualize and investigate the applicability of the model to the needs and peculiarities of each of the developing countries.

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7. REFERENCES

Aarons, G. A., Hurlburt, M., & Horwitz, S. M. (2011). Advancing a conceptual model of evidence-based practice implementation in public service sectors. Administration and Policy in Mental Health and Mental Health Services Research, 38(1), 4-23.

Abbas, A., Din, Z. U., & Farooqui, R. (2016). Integration of BIM in construction management education: an overview of Pakistani Engineering universities. Procedia Engineering, 145, 151-157.
Abdirad, H., & Dossick, C. S. (2016). BIM curriculum design in architecture, engineering, and construction education: a systematic review. Journal of Information Technology in Construction (ITcon), 21(17), 250-271.
Adillah, N. A. I., Owen, R. L., & Drogemuller, R. (2015). Cost estimating practice incorporating building information modelling (BIM): Malaysian quantity surveyors perspectives. In Proceedings of the 7th International Conference on Sustainable Development in Building and Environment. The University of Reading.
Ahmed, S. M., Emam, H. H., & Farrell, P. (2014). Barriers to BIM/4D implementation in Qatar. Smart, Sustainable and Healthy Cities, 533.
Akintola, A., Root, D., & Venkatachalam, S. (2017). Key constraints to optimal and widespread implementation of BIM in the South African construction industry. Management, 25, 34.
Al-Mashari, M., & Zairi, M. (1999). BPR implementation process: an analysis of key success and failure factors. Business process management journal, 5(1), 87-112.
Andrés, S., del Solar, P., de la Peña, A., & Vivas, M. D. (2017). Implementation of BIM in Spanish construction industry. Building & Management, 1(1), 1.
Anker Jensen, P., & Ingi Jóhannesson, E. (2013). Building information modelling in Denmark and Iceland. Engineering, Construction and Architectural Management, 20(1), 99-110.
Aranda-Mena, G., Crawford, J., Chevez, A., & Froese, T. (2009). Building information modelling demystified: does it make business sense to adopt BIM?. International Journal of managing projects in business, 2(3), 419-434.
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, 20(2), 189-195.
Arayici, Y., Egbu, C. O., & Coates, S. P. (2012). Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. Journal of Information Technology in Construction, 17, 75-92.
Arayici, Y., Kiviniemi, A. O., Coates, S. P., Koskela, L. J., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). BIM implementation and Adoption Process for an Architectural Practice.
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.
Badrinath, A. C., Chang, Y. T., & Hsieh, S. H. (2016). An overview of global research trends in BIM from analysis of BIM publications. In The 16th International Conference on Computing in Civil and Building Engineering, Osaka, Japan.
Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM—A case study approach. Automation in construction, 24, 149-159.
Bashein, B. J., Markus, M. L., & Riley, P. (1994). Preconditions for BPR success and how to prevent failures. Information System Management, 11(2), 7-13.
Beaumont, W., & Underwood, J. (2015). Data Management for Integrated Supply Chains in Construction. In: Supply Chain Management and Logistics in Construction, Kogan Page, 91-119.
Becerik-Gerber, B., Jazizadeh, F., Li, N., & Calis, G. (2011). Application areas and data requirements for BIM-enabled facilities management. Journal of construction engineering and management, 138(3), 431-442.
Bensalah, M., Elouadi, A., & Mharzi, H. (2018). Integrating BIM in railway projects Review & perspectives for Morocco and MENA. International Journal of Recent Scientific Research, 9(1), 23398-23403.
Browne-Ferrigno, T., & Muth, R. (2004). Leadership mentoring in clinical practice: Role socialization, professional development, and capacity building. Educational administration quarterly, 40(4), 468-494.
Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). International journal of project management, 31(7), 971-980.
Btoush, M., & Harun, A. T. (2017, November). Minimizing delays in the Jordanian construction industry by adopting BIM technology. In IOP Conference Series: Materials Science and Engineering 271 (1) 012041.

Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). A review of Building Information Modelling for construction in developing countries. Procedia Engineering, 164, 487-494.
Butcher, J., Bezzina, M., & Moran, W. (2011). Transformational partnerships: A new agenda for higher education. Innovative Higher Education, 36(1), 29-40.
Cao, D., Li, H., & Wang, G. (2014). Impacts of isomorphic pressures on BIM adoption in construction projects. Journal of Construction Engineering and Management, 140(12), 04014056.
Cao, D., Li, H., Wang, G., & Huang, T. (2017). Identifying and contextualising the motivations for BIM implementation in construction projects: An empirical study in China. International journal of project management, 35(4), 658-669.
Cao, D., Wang, G., Li, H., Skitmore, M., Huang, T., & Zhang, W. (2015). Practices and effectiveness of building information modelling in construction projects in China. Automation in Construction, 49, 113-122.
Chan, A. P. C., Darko, A., Olanipekun, A. O., & Ameyaw, E. E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. Journal of cleaner production, 172, 1067-1079.
Chan, C. T. (2014). Barriers of implementing BIM in the construction industry from the designers' perspective: A Hong Kong experience. Journal of System and Management Sciences, 4(2), 24-40.
Cheng, J. C., & Lu, Q. (2015). A review of the efforts and roles of the public sector for BIM adoption worldwide. Journal of Information Technology in Construction (ITcon), 20(27), 442-478.
Chew, A. N. D. R. E. W., & Riley, M. E. R. E. D. I. T. H. (2013). What is going on with BIM? On the way to 6D. The International Construction Law Review, 253.
Chien, K. F., Wu, Z. H., & Huang, S. C. (2014). Identifying and assessing critical risk factors for BIM projects: Empirical study. Automation in Construction, 45, 1-15.
Ciribini, A. L. C., Caratozzolo, G., Bolpagni, M., Ventura, S. M., & De Angelis, E. (2016). The Implementation of Building Information Modelling within an Integrated Public Procurement Approach: The Main Contractor's Perspective. Building up business operations and their logic Shaping materials and technologies, 3, 417.
Coates, P., Arayici, Y., Koskela, K., Kagioglou, M., Usher, C., & O'Reilly, K. (2010). The key performance indicators of the BIM implementation process.
Ding, Z., Zuo, J., Wu, J., & Wang, J. Y. (2015). Key factors for the BIM adoption by architects: a China study. Engineering, Construction and Architectural Management, 22(6), 732-748.
Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. Automation in construction, 36, 145-151.
Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2015). A survey of the current status of and perceived changes required for BIM adoption in the UK. Built Environment Project and Asset Management, 5(1), 4-21.
El Sawy, O. (1997). Business process reengineering – do software tools matter? Conference in Information Systems in Florida, Internet: [http://hsb.baylor.edu/ramsower/ais.ac.97/papers/elsaw.htm].
Enegbuma, W. I., Dodo, Y. A., & Ali, K. N. (2014). Building information modelling penetration factors in Malaysia. International Journal of Advances in Applied Sciences (IJAAS), 3(1), 47-56.
Enshassi, A., & AbuHamra, L. (2017). Challenges to the Utilization of BIM in the Palestinian Construction Industry. In ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction (Vol. 34). Vilnius Gediminas Technical University, Department of Construction Economics & Property.
Enshassi, A., Ayyash, A., & Choudhry, R. M. (2016). BIM for construction safety improvement in Gaza strip: awareness, applications, and barriers. International Journal of Construction Management, 16(3), 249-265.
Ezeokoli, F. O., Okoye, P. U., & Nkeleme, E. (2016). Factors Affecting the Adaptability of Building Information Modelling (BIM) for Construction Projects in Anambra State Nigeria. Journal of Scientific Research & Reports, 11(5), 1-0.
Fixsen, D. L., Naoom, S. F., Blase, K. A., & Friedman, R. M. (2005). Implementation research: a synthesis of the literature. Research on social work practice, 19(5), 531-540.
Forsythe, P. J., Jupp, J. R., & Sawhney, A. (2011). BIM in tertiary construction project management education: A program-wide strategy. In Australian Universities Building Education Association Annual Conference. Institute of Sustainable Development & Architecture, Bond University.

Gerges, M., Austin, S., Mayouf, M., Ahiakwo, O., Jaeger, M., Saad, A., & Gohary, T. E. (2017). An investigation into the implementation of Building Information Modeling in the Middle East. Journal of Information Technology in Construction (ITcon), 22(1), 1-15.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks, and challenges. Renewable and Sustainable Energy Reviews, 75, 1046-1053.

Gledson, B., & Greenwood, D. (2016). Surveying the extent and use of 4D BIM in the UK. Journal of Information Technology in Construction (ITcon), 21, 57-71.

Gray, M., Gray, J., Teo, M., Chi, S., & Cheung, Y. K. F. (2013). Building information modelling: an international survey.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. Automation in construction, 19(8), 988-999.

Hamada, H. M., Haron, A., Zakiria, Z., & Humada, A. M. (2017). Factor Affecting of BIM Technique in the Construction Firms in Iraq. In MATEC Web of Conferences (Vol. 103, p. 03003). EDP Sciences.

Hamma-adama, M., Galadima, Y. K., & Kouider, T. (2018). Building information modelling: a tool for the diffusion of information in Nigeria.

Hammer, M. and Stanton, S. (1995), "The reengineering revolution", HarperCollins, New York, NY.

Hatem, W. A., Abd, A. M., & Abbas, N. N. (2018). Testing a Measurement Model of BIM Potential Benefits in Iraqi Construction Projects. Civil Engineering Journal, 3(12), 1349-1365.

Hermund, A. (2009). Building information modeling in the architectural design phases: And why compulsory BIM can provoke distress among architects.

Hilton, M. (2010). Exploring the Intersection of Science Education and 21st Century Skills: A Workshop Summary. National Academies Press.

Ho, S., & Rajabifard, A. (2016). Towards 3D-enabled urban land administration: Strategic lessons from the BIM initiative in Singapore. Land Use Policy, 57, 1-10.

Hon, C. K., Utiome, E., Drogemuller, R., Owen, R. L., Nepal, M. P., Gray, J., & Coffey, V. (2015, July). Gearing up academics for collaborative Building Information Modelling (BIM) education. In Proceedings International Conference on Innovative Production and Construction 2015 (IPC 2015) (pp. 23-26). IPC2015 Organizing Committee.

Hong, Y., Sepasgozar, S. M., Ahmadian, A. F. F., & Akbarnezhad, A. (2016). Factors influencing BIM adoption in small and medium-sized construction organizations. In ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction (Vol. 33, p. 1). Vilnius Gediminas Technical University, Department of Construction Economics & Property.

Hosseini, M Reza, Azari, Ehsan, Tivendale, Linda, Banihashemi, Saeed and Chileshe, Nicholas 2016, Building Information Modeling (BIM) in Iran: An exploratory study, Journal of engineering, project, and production management, 6, 2, 78-89.

Howard, R., & Bjork, B. C. (2007). Building information models–experts' views on BIM/IFC developments. In Proceedings of the 24th CIB-W78 Conference (pp. 47-54).

Howell, D., Windahl, C., & Seidel, R. (2010). A project contingency framework based on uncertainty and its consequences. International Journal of Project Management, 28(3), 256-264.

Isa, R. B., Jimoh, R. A., & Achuenu, E. (2013). An overview of the contribution of the construction sector to sustainable development in Nigeria. Net Journal of Business Management, 1(1), 1-6.

Isaksson, A., Linderoth, H., Bosch, P., & Lennartsson, M. (2016). BIM use in the production process among medium-sized contractors: A survey of Swedish medium-sized contractors. In 16th International Conference on Computing in Civil and Building Engineering, ICCCBE2016, Osaka, July 6-8, 2016. (pp. 687-694).

Jackson, N. (1997). BPR'96-A report on the Business Process Re-engineering conference organised by Business Intelligence and held at the end of October in London. Management Services, 41(2), 34-37.

Jensen, L. A., & Allen, M. N. (1996). Meta-synthesis of qualitative findings. Qualitative health research, 6(4), 553-560.

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. Automation in construction, 20(2), 126-133.

Kassem, M., & Succar, B. (2017). Macro BIM adoption: Comparative market analysis. Automation in Construction, 81, 286-299.

Kekana, G., Aigbavboa, C., & Thwala, W. D. (2015). Understanding Building Information Modelling in the South Africa construction industry.
Kekana, T. G., & Aigbavboa, C. O. (2015). A literature review on the barriers to the adaptation and implementation of Building Information Modelling in the South Africa Construction Industry.
Kettinger, W. J., Teng, J. T., & Guha, S. (1997). Business process change: a study of methodologies, techniques, and tools. MIS quarterly, 55-80.
Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. Engineering, Construction and Architectural Management, 19(6), 610-635.
Kiani, I., Sadeghifam, A. N., Ghomi, S. K., & Marsono, A. K. B. (2015). Barriers to implementation of Building Information Modeling in scheduling and planning phase in Iran. Australian Journal of Basic and Applied Sciences, 9(5), 91-97.
Kim, Y., Lee, Z., & Gosain, S. (2005). Impediments to successful ERP implementation process. Business process management journal, 11(2), 158-170.
Kiviniemi, A., & Codinhoto, R. (2014). Challenges in the implementation of BIM for FM—Case Manchester Town Hall complex. In Computing in Civil and Building Engineering (pp. 665-672).
Klein, K. J., & Knight, A. P. (2005). Innovation implementation: Overcoming the challenge. Current directions in psychological science, 14(5), 243-246.
Klein, K. J., & Sorra, J. S. (1996). The challenge of innovation implementation. Academy of management review, 21(4), 1055-1080.
Lee, J. (2010). 10-year retrospect on stage models of e-Government: A qualitative meta-synthesis. Government Information Quarterly, 27(3), 220-230.
Lindblad, H., & Vass, S. (2015). BIM implementation and organisational change: A case study of a large Swedish public client. Procedia Economics and Finance, 21, 178-184.
Linderoth, H. C. (2010). Understanding the adoption and use of BIM as the creation of actor networks. Automation in construction, 19(1), 66-72.
Liu, H., Al-Hussein, M., & Lu, M. (2015). A bim-based integrated approach for detailed construction scheduling under resource constraints. Automation in Construction, 53, 29-43.
Liu, Y., Van Nederveen, S., & Hertogh, M. (2017). Understanding the effects of BIM on collaborative design and construction: An empirical study in China. International Journal of Project Management, 35(4), 686-698.
Love, P. E., Simpson, I., Hill, A., & Standing, C. (2013). From justification to evaluation: Building information modeling for asset owners. Automation in construction, 35, 208-216.
Lu, W., Fung, A., Peng, Y., Liang, C., & Rowlinson, S. (2014). Cost-benefit analysis of Building Information Modeling implementation in building projects through demystification of time-effort distribution curves. Building and Environment, 82, 317-327.
Lyytinen, K., & Damsgaard, J. (2001, April). What's wrong with the diffusion of innovation theory?. In Working Conference on Diffusing Software Product and Process Innovations (pp. 173-190). Springer, Boston, MA.
Mahamadu, A. M., Mahdjoubi, L., & Booth, C. A. (2017). Critical BIM qualification criteria for construction pre-qualification and selection. Architectural Engineering and Design Management, 13(5), 326-343.
Masood, R., Kharal, M. K. N., & Nasir, A. R. (2014). Is BIM adoption advantageous for the construction industry of Pakistan?. Procedia Engineering, 77, 229-238.
Mbamali, I., & Okotie, A. (2012). An assessment of the threats and opportunities of globalization on building practice in Nigeria. American International Journal of Contemporary Research, 2(4).
McAuley, B., Hore, A., & West, R. (2017). BICP Global BIM Study-Lessons for Ireland's BIM Programme.
Mehran, D. (2016). Exploring the Adoption of BIM in the UAE Construction Industry for AEC Firms. Procedia Engineering, 145, 1110-1118.
Memon, A. H., Rahman, I. A., Memon, I., & Azman, N. I. A. (2014). BIM in the Malaysian construction industry: status, advantages, barriers, and strategies to enhance the implementation level. Research Journal of Applied Sciences, Engineering, and Technology, 8(5), 606-614.
Miettinen, R., & Paavola, S. (2014). Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. Automation in construction, 43, 84-91.
Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2013). The benefits, obstacles, and problems of practical BIM implementation. Procedia Engineering, 57, 767-774.

Mihindu, S., & Arayici, Y. (2008, July). Digital construction through BIM systems will drive the re-engineering of construction business practices. In 2008 international conference visualisation (pp. 29-34). IEEE.

Miller, G., Sharma, S., Donald, C., & Amor, R. (2013, July). Developing a building information modelling educational framework for the tertiary sector in New Zealand. In IFIP International Conference on Product Lifecycle Management (pp. 606-618). Springer, Berlin, Heidelberg.

Mohd-Nor, M. F. I., & Grant, M. P. (2014). Building information modelling (BIM) in the Malaysian architecture industry. WSEAS Transactions on Environment and Development, 10, 264-273.

Morlhon, R., Pellerin, R., & Bourgault, M. (2014). Building information modeling implementation through maturity evaluation and critical success factors management. Procedia Technology, 16, 1126-1134.

Mumford, E. (1995). Creative chaos or constructive change: business process reengineering versus socio-technical design. Examining Business Process Re-engineering: Current Perspectives and Research Directions, Kogan Page, 192-216.

Nagalingam, G., Jayasena, H. S., & Ranadewa, K. A. T. O. (2013, June). Building information modelling and future quantity surveyor's practice in Sri Lankan construction industry. In Second World Construction Symposium (pp. 81-92).

Newton, K., & Chileshe, N. (2012). Awareness, usage, and benefits of building information modelling (BIM) adoption–the case of the South Australian construction organisations. Management, 3, 12.

Olatunji, O. A. (2011). Modelling the costs of corporate implementation of building information modelling. Journal of Financial Management of Property and Construction, 16(3), 211-231.

Olatunji, O. A., & Sher, W. (2014). Perspectives on modelling BIM-enabled estimating practices. Construction Economics and Building, 14(4), 32-53.

Olugboyega, O., & Aina, O. O. (2016). Analysis of Building Information Modelling Usage Indices and Facilitators in the Nigerian Construction Industry. Journal of Logistics, Informatics and Service Sciences, 3(2).

Olugboyega, O., & Aina, O. O. (2018). Examination of the Levels of Development of Building Information Models in the Nigerian Construction Industry. Journal of Construction Business and Management, 2(2), 1-14.

Oyewobi, L. O., & Ogunsemi, D. R. (2010). Factors influencing reworks occurrence in construction: A study of selected building projects in Nigeria. Journal of Building Performance, 1(1).

Ozorhon, B., & Karahan, U. (2016). Critical success factors of building information modeling implementation. Journal of Management in Engineering, 33(3), 04016054.

Papadonikolaki, E. (2017, June). Aligning BIM Adoption with Implementation In Loosely Coupled construction systems. In Proceedings of the EPOC-MW Conference. Engineering Project Organization Society.

Peterson, F., Hartmann, T., Fruchter, R., & Fischer, M. (2011). Teaching construction project management with BIM support: Experience and lessons learned. Automation in Construction, 20(2), 115-125.

Poirier, E., Staub-French, S., & Forgues, D. (2015). Embedded contexts of innovation: BIM adoption and implementation for a specialty contracting SME. Construction Innovation, 15(1), 42-65.

Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. Automation in construction, 31, 204-214.

Proctor, E. K., Powell, B. J., & McMillen, J. C. (2013). Implementation strategies: recommendations for specifying and reporting. Implementation Science, 8(1), 139.

Rapert, M. I., Velliquette, A., & Garretson, J. A. (2002). The strategic implementation process: evoking strategic consensus through communication. Journal of Business Research, 55(4), 301-310.

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.

Saleh, M. A. D. (2015). Barriers and Driving Factors for Implementing Building Information Modelling (BIM) in Libya (Master's thesis, Eastern Mediterranean University (EMU)-Doğu Akdeniz Üniversitesi (DAÜ)).

Sauser, B. J., Reilly, R. R., & Shenhar, A. J. (2009). Why projects fail? How contingency theory can provide new insights–A comparative analysis of NASA's Mars Climate Orbiter loss. International Journal of Project Management, 27(7), 665-679.

Sawhney, A., Singh, M. M., & Ahuja, R. (2017). Worldwide BIM Overview. Integrated Building Information Modelling, 1.
Sebastian, R., Haak, W., & Vos, E. (2009, November). BIM application for integrated design and engineering in small-scale housing development: a pilot project in The Netherlands. In International symposium CIB-W096 future trends in architectural management (pp. 2-3).
Shakantu, W., & Froise, T. (2014). Diffusion of innovations: an assessment of building information modelling uptake trends in South Africa. Journal of construction project management and innovation, 4(2), 895-911.
Shou, W., Wang, J., Wang, X., & Chong, H. Y. (2015). A comparative review of building information modelling implementation in building and infrastructure industries. Archives of computational methods in engineering, 22(2), 291-308.
Shusheng, S. and Min, Z. (2010). Construction Supply Chain System. Proceedings of the 7th International Conference on Innovation & Management, 1649 – 1656.
Silva, M. J. F., Salvado, F., Couto, P., & e Azevedo, Á. V. (2016). Roadmap proposal for implementing building information modelling (BIM) in Portugal. Open Journal of Civil Engineering, 6(03), 475.
Smith, P. (2014). BIM implementation–global strategies. Procedia Engineering, 85, 482-492.
Son, H., Lee, S., & Kim, C. (2015). What drives the adoption of building information modeling in design organizations? An empirical investigation of the antecedents affecting architects' behavioral intentions. Automation in construction, 49, 92-99.
Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in construction, 18(3), 357-375.
Succar, B., & Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. Automation in construction, 57, 64-79.
Succar, B., Sher, W., & Williams, A. (2013). An integrated approach to BIM competency assessment, acquisition, and application. Automation in construction, 35, 174-189.
Tennant, S., & Fernie, S. (2014). Theory to practice: A typology of supply chain management in construction. International Journal of Construction Management, 14(1), 56-66.
Usman, N., Abubakar, M., & Ibrahim, M. A. (2016). Assessment of some key issues that affect the acceptance of Building Information Modelling (BIM). ATBU Journal of Environmental Technology, 9(2), 40-52.
Walsh, D., & Downe, S. (2005). Meta-synthesis method for qualitative research: a literature review. Journal of advanced nursing, 50(2), 204-211.
Wang, C., Adetola, S. H., & Abdul-Rahman, H. (2015). Assessment of BIM implementation among MEP firms in Nigeria. International Journal of Advances in Applied Sciences, 4(3), 73-81.
Wong, A. K., Wong, F. K., & Nadeem, A. (2010). Attributes of building information modelling implementations in various countries. Architectural Engineering and Design Management, 6(4), 288-302.
Wu, W., & Issa, R. R. (2013). BIM education and recruiting: Survey-based comparative analysis of issues, perceptions, and collaboration opportunities. Journal of professional issues in engineering education and practice, 140(2), 04013014.
Yetton, P., Sharma, R., & Southon, G. (1999). Successful IS innovation: the contingent contributions of innovation characteristics and implementation process. Journal of Information Technology, 14(1), 53-68.
Yori, R. (2011). The cost of not doing BIM: Education and professional development. Journal of Building Information Modelling, 66-67.
Yusuf, B. Y., Ali, K. N., & Embi, M. R. (2016). Building Information Modeling as a Process of Systemic Changes for Collaborative Education in Higher Institution. Procedia-Social and Behavioral Sciences, 219, 820-827.
Zhu, J., & Mostafavi, A. (2017). Discovering complexity and emergent properties in project systems: A new approach to understanding project performance. International journal of project management, 35(1), 1-12.
Zimmer, L. (2006). Qualitative meta-synthesis: a question of dialoguing with texts. Journal of advanced nursing, 53(3), 311-318.
Zmud, R. W., & Cox, J. F. (1979). The implementation process: A changing approach. MIS quarterly, 35-43.