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Adoption and Implementation of Building Information Modelling (BIM) in Small and Medium-Sized Enterprises (SMEs): A Review and Conceptualization

Purpose: Despite the SMEs representing a large percentage of firms in the construction industry, there has been an under-representation of SMEs perspective in BIM research studies. This paper aims to systematically review the few extant studies with a view of synthesising the findings.

Design/methodology/approach: Hermeneutic philosophy using the interpretivist epistemology approach with a touch of metasynthesis was adopted to critically review and analyse extant studies published over the last decade.

Findings: The findings revealed a scarcity of BIM studies in SMEs, the status of adoption, identified barriers, benefits and drivers. A conceptual model was then developed based on the literature review and theoretical lenses of innovation diffusion model, technology-organisation-environment framework and institutional theory. The paper presents pertinent propositions to drive BIM in the SMEs.

Originality/value: This paper holistically reviews extant BIM studies from the perspective of SMEs that are the backbone of the construction industry. It synthesizes extant studies and set scenes for further studies.

Keywords: Building Information Modelling (BIM), Adoption, Implementation, Small and Medium-sized Enterprises (SMEs), review, conceptualization.

1.0 Background of Study

The Construction Industry is a complex industry with many stakeholders and many activities. This complexity coupled with the nature of the industry has led to low productivity compared to other industries such as the manufacturing industry. Latham (1994) attributed this to the fragmentation of the industry and this was corroborated by Egan (1998). Thus, a more integrated industry has been said to be one of the solutions to the low productivity of the industry.

Over the years, there has been emerging technologies, processes that have been channelled towards the aim of improving productivity and adding value to the construction industry. The Building Information Modelling (BIM) is one of such technologies and it has been changing the way the Architecture, Engineering and Construction Industry (AEC) operates over the last decade. Singh *et al.* (2011) viewed it as Information Technology (IT) oriented approach that enables access and sharing of building data for various functionalities. Succar (2009) opined that it is a mix of policies, processes, and technologies for the management of the building from inception to demolition in digital format.

Building Information Modelling has been seen as a tool and process that could solve the major challenges facing the construction industry, especially low productivity and fragmentation in the industry. It breaks the silo effect among the various participating organisations in a construction supply chain and connects fragmented processes in a more integrated manner efficiently (Wang *et al.*, 2017). Consequently, there have been many studies on BIM in the construction industry at the context of industry, organisation and projects level. These studies have focused on adoption, challenges & benefits, application and implementation strategies. Benefits such as improved productivity and efficiency, early integration of stakeholders, improved communications, saves time and cost, better contract documentation, clash detection, improved design quality/visualization, reduced design errors/rework, positive return on investment, life-cycle cost data management, cost estimating, higher sustainability and competitive edge have been reported in extant studies (Chan *et al.*, 2019a, 2019b). These benefits and many more have prompted organisations, governments/institutions to embark on BIM implementation in their construction Industries (Saka & Chan, 2019a).

However, the BIM that is meant to serve as an integrator in the already fragmented construction industry is creating a 'digital divide' between the large firms and the small firms, although they both belong to the same industry (Ayinla & Adamu, 2018; van Dijk, 2006). The large firms are seen to be 'BIM compliant' while the small and medium (SMEs) firms are perceived to be 'BIM complaint' (Dainty *et al.*, 2017b; Hosseini *et al.*, 2018b; Saka & Chan, 2019b). The large and SMEs firms are faced with different economic and social challenges leading to different organisation structure and behaviour. The SMEs have been reported to be lagging the large firms in the adoption of BIM in the construction industry (Poirier *et al.*, 2015a). This has been ascribed to the fact that SMEs are slow to adopt innovation and are always reluctant with innovation that involves much investment, and that may not benefit the firm in a short time(Sexton & Barrett, 2004). Despite the lag by the SMEs, the SMEs stand to benefit more from BIM implementation than the large firms because of some of their unique characteristics such as a flexible structure that can make change easy, small project and shorter duration that can make a high level of implementation possible (Arayici *et al.*, 2011b; Hosseini *et al.*, 2016). The SMEs are the backbone and cornerstone of economic prosperity (Love & Irani, 2004). 98.2% of firms in the US, 99% in the UK, 97% in Malaysia, 97% in Nigeria, 99.7% in Japan, 97% in China and India, 97.8% in Australia, and 99% of firms in the European Union (EU). They also dominate the construction market at the global scale (Shelton *et al.*, 2016). For a major change such as the integration of the industry to be possible, the SMEs are the cornerstone to its achievement. Thus, for the proliferation of the BIM in the Construction Industry, the SMEs must be BIM compliant (Lam *et al.*, 2017). This is not only necessary but unavoidable for the SMEs in the AEC to survive and to be competitive, as SMEs that are not BIM compliant would lose out of business share (Harris *et al.*, 2013; Kouch *et al.*, 2018). Thus, there have been studies of BIM in SMEs, although these studies are still lagging the large firm (Hosseini *et al.*, 2016; Lam *et al.*, 2015).

Extant reviews have presented the status quo of BIM research development using bibliometric (Olawumi *et al.*, 2017; Oraee *et al.*, 2017; Santos *et al.*, 2017), scientometric(He *et al.*, 2017; Saka & Chan, 2019a; Saka & Chan, 2019b; Zhao, 2017), latent semantic analysis and manual review(Ghaffarianhoseini *et al.*, 2017; Volk *et al.*, 2014). Despite these reviews being important to the understanding of BIM in the AEC Industry, they are majorly about general BIM development. They adopted a singular review of both large and SMEs firms, even thou the development differs and a single view of these two types of firms is not realistic (Ayinla & Adamu, 2018). Poirier *et al.* (2015a) noted that the growing trend in the extant studies on BIM reflects the underrepresentation of SMEs and their perspective on BIM adoption and implementation. The extant reviews of BIM studies are often reflective of the large firms that are leading the BIM adoption and implementation and not representative of the SMEs that are still lagging and facing challenges. Lam *et al.* (2017) reflected that there has been no systematic effort to date to bring together the result of research in SMEs' BIM adoption. Thus, this study will review the extant studies on BIM adoption in SMEs to reveal the status of adoption, the challenges/barriers, benefits, drivers/motivations, and influencing contexts and existing gaps. Also, it will conceptualize and synthesize the review using related theoretical lenses to present BIM in SMEs. This study will contribute to the growing studies on BIM in SMEs and provide a clear status of the adoption and implementation of BIM in SMEs for the researchers, policymakers and practitioners alike.

The paper is structured into eight sections: the first section provides the background of the study, the second section defines terminologies, the third part provides the research methodology adopted, the fourth section presents a concept-centric analysis of the papers, the fifth section provides a critical assessment of the papers, the sixth section conceptualizes and synthetizes the review with theoretical lenses, the seventh section draw inferences and discussion of findings and the last section is the conclusion.

2. Definitions of Small and Medium-Sized Enterprises (SMEs)

Definition of SMEs varies across different boundaries. However, regardless of the definition, they have similar characteristics. They are characterised by a small number of employees, and turnover as shown in Table 1. These give them unique reflexes compared to large firms and the two firms often operate in two different technological worlds. The differences between the SMEs and large firms make a singular approach to BIM unrealistic. As the SMEs are the backbone of economies and will continue to dominate the construction industry landscape (Shelton *et al.*, 2016), studying BIM in SMEs is thus important for its proliferation in the industry and integration (Dainty *et al.*, 2017a). Construction SMEs also differs from one another, however, regardless of the differences in their business formation, similar outcomes can be achieved when strategies are applied to drive the business interest in the new direction (Olatunji, 2011).

Insert Table 1.

It is also necessary to define BIM adoption and BIM implementation as they are often used interchangeably in extant studies (Ahmed & Kassem, 2018).

a) BIM Adoption: This is the decision by the SMEs to either adopt or reject BIM innovation in their organisation. So many factors (drivers and barriers) can affect this decision from the external environment to the internal environment and the characteristics of the BIM itself. This is per the innovation diffusion theory of Rogers (2003).

b) BIM Implementation: This follows the decision to adopt BIM by the SMEs and it involves implementing the BIM in the organisation. The implementation can occur in different stages such as object-based modelling, model-based modelling, and network-oriented integration (Succar, 2009), Adhoc, linear and distributed (Papadonikolaki *et al.*, 2016), level 0, level 1, level 2, and level 3 (NBS, 2014).

3. Research Methodology

Creation of new knowledge from existing knowledge is an established approach in existing literature (Ahmed & Kassem, 2018; Boell & Cecez-Kecmanovic, 2014; Webster & Watson, 2002). This study adopted a systematic literature review and viewed it as a 'hermeneutic enterprise' using an interpretivist epistemology approach (Antwi-Afari *et al.*, 2018; Boell & Cecez-Kecmanovic, 2014) with a touch of metasynthesis. Hermeneutic philosophy which originated from the interpretation and understanding of biblical texts has been extended to all text or linguistic material (Boell & Cecez-Kecmanovic, 2014). It involves an iterative interaction with text to interpret, understand and develop context. Boell and Cecez-Kecmanovic (2014) corroborated that '…*In such a way the fusion of horizons may assist unfolding of a broader whole or a body of relevant literature which can open new horizons for understanding the research problem or puzzle. The new understanding of a body of literature in turn enables identification of new texts relevant to this understanding and a renewed dialogue with individual texts.*' Thus, the hermeneutic framework by Boell and Cecez-Kecmanovic (2014) was refined and adopted as shown in Figure 1. This approach enables the researchers to interprete extant studies whilst bringing their own experience to shape the narration. The approach is divided into three parts.

a) Data Collection: Search engines such as Web of Science (WOS) which is a database that consists of important and influential journals in the world (Olawumi & Chan, 2018; Song *et al.*, 2016; Zhao, 2017), Scopus which has a wider range of coverage (Hong *et al.*, 2012; Hosseini *et al.*, 2018a), Science Direct and Google Scholar were used in collecting the research articles. No limitation was set on the publication type as done by Hosseini et al (Hosseini *et al.*, 2018a) to avoid 'publication bias' (Hopewell *et al.*, 2007; McAuley *et al.*, 2000). This is also necessary for this type of review in growing research area such as BIM in SMEs as against the established BIM in large firm research areas. Search inputs such as *"BIM" and "SME"* and *"BIM" and "Small firm"* were used for title, keyword and abstract search on these search engines. The initial output generated was then sorted by the language and field as this is the practice in related studies (Hong *et al.*, 2012; Hong & Chan, 2014; Lu *et al.*, 2017; Olawumi & Chan, 2018; Santos *et al.*, 2017). The refined papers were then compiled and repetition was eliminated. Also, citation tracking as per Randolph (2009) was adopted to ensure the literature search near 'critical saturation'. The citation tracking involves using the reference lists of all the gleaned research articles to search for more related articles until no new articles are found (i.e 'critical saturation') (Randolph, 2009)

b) Analysis: This involves analysing the collected papers by three processes
    a. Mapping and Classifying: This involves analysing the paper publication trend, methodologies adopted, theoretical lens, area of study, and the scope of the study.

b. Critical assessment: This involves identifying the status of BIM adoption with a touch of metanalysis, the challenges, benefits, drivers/motivation, and barriers of BIM in SMEs
c. Conceptualization and Synthetization: This involves identifying related theories/lens to synthesize the review and conceptualize BIM in SMEs

c) Inference and Conclusion: This involves concluding the analysis and synthetization.

Insert Figure 1.

4. Analysis of Review

51 final papers (refined) were used as shown in Table 2, and this corroborated Lam *et al.* (2017) that there is a limited number of publications that directly referenced BIM in SMEs.

Insert Table 2.

4.1 Annual Publication Trends of BIM in SMEs

The annual distribution of the papers on Building Information Modelling (BIM) in Small and Medium-Sized Enterprises (SMEs) is as shown in Figure 2. Despite an increase in BIM studies as reported in extant literature (Saka & Chan, 2019a), there is a dearth of studies on BIM in SMEs. However, over the last years, there has been an increase in this area. This area will continue to grow as the SMEs will continue to dominate the construction industry and the adoption/implementation of BIM is necessary for the proliferation of BIM (Shelton *et al.*, 2016).

Insert Figure 2.

4.2 Area of Study (Country) on BIM in SMEs

Level of BIM awareness and implementation varies from country to country, thus, studies on BIM are often context-based with regards to the area of study. The area of study of the selected papers is as shown in Figure 3. The UK has the highest number of papers on BIM in SMEs, this can be related to the attention given to BIM in SMEs in recent years in the country coupled with the increase in the level of awareness and implementation of BIM in the UK. This is followed by Australia, France, Canada and Malaysia. Most of these countries are countries with high BIM awareness and are majorly developed countries.

Insert Figure 3.

4.3 Theme of the Study

The papers themes vary from awareness to adoption and implementation as shown in Table 3. The themes are focused on three aspects of BIM in SMEs which are awareness, adoption and implementation. The awareness involves surveys about the readiness and awareness of the SMEs as regards BIM. The adoption, on the other hand, includes areas such as factors affecting decisions of the SMEs, barriers and drivers with regards to BIM. The implementation consists of studies on factors affecting implementation in SMEs; studies on the implementation of BIM in SMEs and these usually adopt case studies; studies on BIM functionalities i.e applications of BIM in SMEs; studies on risk with BIM implementation in SMEs; empirical studies on BIM benefits in SMEs; studies on software; and studies on the cost of BIM implementation in SMEs.

Insert Table 3.

4.4 Theoretical Lens

The selected papers conceptualize BIM from innovation/technology lens, knowledge lens and others as shown in Table 4. A large percentage of the papers are not theory-driven and most of the recent papers are theory-driven based on innovation/technology theoretical lens. Using theories to conceptualize innovation studies is very important to benefit from the robust knowledge on which the theories were built on (Hosseini *et al.*, 2015).

Insert Table 4.

5. Critical Assessment of BIM in SMEs

5.1 Status of BIM Adoption and Implementation in SMEs

Extant studies have pointed out the low level of adoption of BIM in SMEs and this is coupled with the few research studies in this area. McGraw Hill's (2014) reported that most of the non-adopting firms are small and medium-sized (SMEs). Many of the surveys on BIM are carried out without regards to the difference in size (Dainty *et al.*, 2017a) and an exception is the National Federation of Builders (NFB) surveys. In 2012, NFB (NFB, 2012) reported that 73% of SMEs have never used BIM before and only 57% have a positive view of its adoption. In 2014, NFB (NFB, 2014) added that there has been no significant change in the level of adoption and implementation of BIM in SMEs.

Papers that considered the status of BIM in SMEs were then reviewed with a light touch of metasynthesis and presented in Table 5.

Insert Table 5.

All the papers adopted a survey method to assess the level of awareness, adoption and implementation of BIM in SMEs. From Table 5, most of the surveys on BIM in SMEs originated from Australia and it can be said that the level of BIM usage in SMEs is slightly above 40%. Similarly, the level of awareness in Indonesia is above 40%, thus, the level of adoption/implementation would be below 40%. In the UK, the percentage of non-adopters is around 75% compared to 85% in France. It is worthy of note that the level of awareness would be higher than the level of adoption and implementation. Also, the level of awareness/adoption/implementation varies from one SME context (e.g. architectural or contractor) to another (e.g. mechanical or quantity surveying etc). Lastly, there is a significant difference between the level of awareness/adoption/implementation of BIM in SMEs and that of a country survey which is often not representative of the SMEs.

5.2 Challenges of BIM Adoption and Implementation in SMEs

The SMEs are facing myriads of challenges with BIM adoption. These problems are significantly different from that of large firms because they operate in different organisation structure and context. The papers were reviewed, and the challenges were grouped as 'Technology-related barriers', 'Process/people-related barriers' and 'Economic-related barriers' (Saka *et al.*, 2019a) as shown in Table 6. It is noteworthy that there are often differences between perceived challenges and actual challenges. Perceived challenges are often a survey-based approach and from the perspective of non-adopters and adopters. The perceived challenges are often more of their perception and may be unfounded. Actual challenges, on the other hand, are the challenges facing adopters.

Insert Table 6.

5.3 Benefits of BIM Adoption and Implementation in SMEs

Most of the benefits of BIM in SMEs in extant studies are often survey-based and are perceived benefits from stakeholders/organisation. Few studies have adopted a case study approach (Arayici *et al.*, 2011b; Arayici *et al.*, 2009; Hochscheid *et al.*, 2016; Poirier *et al.*, 2015b, 2015c) to study BIM implementation and benefits. Perceived benefits are often survey-based and from the perspective of non-adopters whilst benefits are the actual benefits as regards BIM and are often case study based on the perspective of adopters. Perceived benefits may be exaggerated compared to the actual benefits. Lack of actual BIM benefits evaluation is one of the major challenges of BIM implementation in SMEs. Both perceived benefits and actual benefits from the refined papers are shown in Table 7. The benefits are mostly intangible, and the tangible ones may take time to leverage the cost of BIM implementation in SMEs. Also, most reported benefits are BIM functionalities such as 3D visualization, clash detection, quantity takeoff, cost estimation and cost planning.

Insert Table 7.

5.4 Drivers and Motivation of BIM Adoption and Implementation in SMEs

There is no clear compartmentalization between drivers and motivations of BIM adoption and implementation in SMEs. Perceived benefits can serve as drivers and motivations; similarly, solutions of perceived challenges can serve as drivers. Drivers and Motivations of BIM adoption and Implementation is SMEs is shown in Table 8.

Insert Table 8.

5.5 Influencing Context (IC) of BIM Adoption and Implementation in SMEs

Studies of BIM are context-based and varies from one context to another. The following are some of the influencing context identified:

a) Area of study (IC1): This depends on the area of study or location of the SMEs. This varies from location to location as reflected in the different status of BIM at a different location. Thus, studies from developed countries with a high level of awareness of BIM, technological infrastructure and government support would be different to that of emerging markets with a low level of awareness and no clear government policy as regards BIM.

b) Type of the SME (IC2): There are different SMEs with respect to their professions such as contracting, architectural, civil engineering, and quantity surveying etc. The level of awareness and adoption varies across these professions. With a high level of awareness and adoption often recorded in consultancy firms because of their familiarity with CAD. Also, their function differs, and this would influence the study of BIM in the SMEs.
c) Level of BIM Implementation (IC3): Study of BIM is influenced by the level of implementation in the organisation. The implementation can occur in different stages such as object-based modelling, model-based modelling, and network-oriented integration; Adhoc, linear and distributed.
d) The position of the SMEs (IC4): This is the position of the SMEs on the supply chain; SMEs can be contractor or subcontractors.
e) Organisational structure (IC5): There are different organisation structures in SMEs. Each of these structures reacts differently to BIM innovation. Olatunji (2011) identified Networked organizations, Functional organizations, Matrix model and Divisional organization structure.

5.6 BIM in Construction SMEs

The BIM implementation, BIM mandate for construction SMEs, and perceived benefits of adopting BIM in SMEs are discussed:

BIM Implementation: The implementation process is difficult for the SMEs with limited resources and lack of organisational slack. The process goes beyond mere software installation but involves a total change in the practice of the firm. Arayici *et al.* (2011a) present the implementation of BIM in SME architectural firms through action-based research using a set of steps to ease the process. The steps adopted for successful implementation of BIM are a review of current status and potential BIM gain; design of action plans and knowledge management database; taking action by implementing BIM from a socio-technical perspective through piloting it on projects, improving company's capability and staff development; and evaluation step which involves review and sustaining of the process. The study revealed that BIM could be easily implemented through learning by doing for the SMEs and with strong top management support. Also, the focus should not be on the technological aspect of BIM only but a more balanced social-technical view. Similarly, Hochscheid and Halin (2018) adopted 4 stepwise methods that consist of studying the context, setting goals, execution of plans, and use of BIM on real projects. Similarly, Joseph Garcia *et al.* (2018) developed a framework for the adoption and implementation of BIM for small building businesses in the US. The framework identified three important phases in the process as the initiation stage, the stabilization stage, and the progression stage. The initiation stage includes getting internal support from the top management and low-level staff, setting time and cost objectives, and hiring of BIM experts. The stabilization phase is where the small businesses focus on retaining their BIM experts and solidifying their BIM business practice; the progression phase involves learning from other business networks around them. Summarily, these implementation processes of BIM in SMEs includes: preliminary planning, execution and evaluation.

BIM Mandate: BIM mandate have often been pushed as a major driver of BIM, but does this have expected effect on the SMEs? Dainty *et al.* (2017b) presented a critical commentary on the BIM policy which cast shadows on the effectiveness of the BIM policies to underpin the cultural differences as regards to the size in the construction industry. Dainty *et al.* (2017b) opined that the current BIM mandate might be reinforcing digital divide in the construction industry because the SMEs do not have the same BIM implementation opportunities compared to the large firms. Loveday *et al.* (2016) corroborated the assertion by conducting interviews with some firms of varying discipline and sizes. It emerged that the BIM mandate is effective to drive the large firms because they work on public projects, but its effect on the SMEs that often work on private projects is minimal. The study reinforced the belief that the mandate might be leading to more divide as the SMEs would be unwilling to work on projects where they might be forced to make use of BIM because of the cost and lack of trained personnel in their firms. However, Caroll and McAuley (2017) investigated the pillars of establishing a successful BIM strategy in the Irish construction SMEs. The study concluded that there is a need for government mandate for BIM use, however, incentives should be provided for the SMEs and caution should be taken in order not to alienate them in the already fragmented construction industry. Thus, the SMEs must be taken into consideration when making BIM policy in order not to widen the current digital divide in the industry.There is a need for more studies on BIM, SMEs and government policies.

BIM Benefits: Studies have highlighted benefits of BIM, however, there is a need to move beyond anecdotal and faith as evidence to drive BIM in SMEs (Poirier *et al.*, 2015a). Poirier *et al.* (2015b) revealed that that BIM has a positive impact over time on project cost and labour cost, whilst there is no effect on project scope and quality in a small speciality enterprise mechanical contracting firm in Canada that expended less than 1% of their yearly sales volume of BIM implementation. Poirier *et al.* (2015c) focused on the impact of BIM on labour productivity by conducting action-based research in a small speciality firm. The labour productivity of modelled area (areas where BIM was used) was compared to areas that were not modelled and this revealed an increase in productivity ranging from 75% to 241% over the areas that were not modelled. However, the firm is a speciality mechanical firm and only one project was considered for the evaluation. Similarly, Arayici *et al.* (2009) reported benefits such as improved lean design process, improved information management and improved design quality in SME architectural firms. Lastly, Poirier *et al.* (2015a) highlighted improved efficiency, improved sub trades integration, and rework reduction on SME projects where BIM was adopted. More empirical studies are needed to show the observability of BIM in SMEs to encourage implementation.

6. Conceptualizing BIM in SMEs

Extant studies often conceptualized BIM as an innovation (Brewer & Gajendran, 2012; Cao *et al.*, 2014; Hosseini *et al.*, 2016; Poirier *et al.*, 2015a). Murphy *et al.* (2014) recommended dealing with BIM through the lens of innovation. The SMEs spend around 3% of their turnover on innovation (O'Regan & Ghobadian, 2005) which is smaller compared to that of large firms. Thus, innovation transfer is not always successful in SMEs especially when such innovation is viewed to involve too much investment, too much risk and far away from their comfort zone (Sexton *et al.*, 2006).

Sexton *et al.* (2006) discussed technology in small firms and highlighted the inter-organizational network, knowledge characteristics and organization direction & capability as the three elements of 'technology transfer system'. The first part which is the inter-organizational network includes other close firms (e.g clients and supply chain), other firms (e.g competitors) and institutional network (e.g professional bodies and government institutions). These influence the successful transfer of technology (innovation) in SMEs, however, the main focus is the organisation/SMEs itself. As they have the capability to develop from internal change and reaction. The second element is the knowledge characteristics, and this refers to the type of knowledge: tacit (hard to communicate and transfer) or explicit knowledge (easy to communicate). The last part which is the organizational direction and capability relates to the internal environment of the firm and the lens with which they view innovation. The lens could be as enabling technologies (technologies that are necessary for the business to function), or as critical technologies (technologies that give firms advantage over other firms) or as strategic technologies (technologies that are anticipated to be critical to the firm's future). Similarly, Slaughter (2000) identified 5 different types of innovation in the construction industry as incremental, architectural, modular, system and radical innovation. This study conceptualizes Building Information Modelling as a system innovation in SMEs of which the knowledge characteristic is a mixture of tacit and explicit knowledge (Murphy *et al.*, 2014). It views it as enabling technologies because they are available for all competitors in the construction industry; and at the same time as strategic technologies because they are anticipated to become critical technologies in the future (i.e by adopting and leveraging on BIM, early SMEs adopters can have an advantage over non-adopters in the future).

6.1 Synthetization

This study then adopted three theoretical lenses to synthesize the studies of BIM in SMEs. The Technology-Organisation-Environment Framework, Innovation Diffusion Theory and Institutional theory are adopted. These three theoretical lenses are well suited because they are organisational level theories and complement each other.

a) **Innovation Diffusion Theory:** Rogers (2003) innovation diffusion theory (IDT) is adopted to explain the phases/stages of BIM innovation in SMEs. The stages start from awareness to intention to decision to adoption to implementation and to confirmation. Innovation diffuse by information through communication channels to presents *knowledge* to the interested parties who may then be persuaded (*persuasion*) to make the *decision* either to adopt or reject the innovation. The *implementation* follows the adoption decision and involves using the innovation for a period before *confirmation* (Rogers, 2003). For this study, the BIM adoption and Implementation differentiation of IDT theory are adopted. The main elements of the DOI are innovation, communication channel, time, and social system. The communication channel is the means through which individual pass information to one another such as mass media and interpersonal channels. The time relates to the duration it takes to adopt or reject, the relative duration of adoption as regards earliness or lateness and the duration for a specified number of adopters. While the social system is a set of interrelating units working together to achieve an objective(s). The theory conceptualizes innovation to be in different phases and influenced by characteristics of the innovation, adopters' characteristics and the surrounding social system. The innovation characteristics are identified as relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). The relative advantage 'is the degree to which an innovation is perceived as better than the idea it supersedes', compatibility is 'the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters'. The complexity of the innovation is 'the degree to which an innovation is perceived as difficult to understand and use.', trialability is 'the degree to which an innovation may be experimented with on a limited basis' and Observability is 'the degree to which the results of an innovation are visible to others'. These are contextualized as perceived BIM usefulness/benefits (relative advantage and observability), the perception of BIM (compatibility) and ease of use (complexity and trialability).

Hosseini *et al.* (2016) adopted the innovation diffusion model to conceptualized BIM adoption within the Australian SMEs and argued that the theory is appropriate for BIM adoption process (Cao *et al.*, 2014; Davies & Harty, 2013). However, the theory has been criticized for its focus on technological context with little attention to the social structure of the system (Ifinedo, 2012; Ishak & Newton, 2016). Bayer and Melone (1989) criticized the oversimplicity of the theory and the representation of adoption as a binary function which fails to show the use divide. The study added that there are no justifications for the categorization of the adopters according to innovativeness, lack of representation of innovation discontinuance by the adopters, effects of government mandate on innovation and there is no specification for the interaction between various social systems. Regardless of the criticisms, it is well established that IDT is useful for innovation studies, however, the theory needs to be modified to cover for the identified lapses to be useful in complex technologies such as BIM.

b) **Technology-Organisation-Environment Framework (TOE):** The framework is an organization level theory developed by Tornatzky *et al.* (1990) which postulates that three context influence adoption decision. The three contexts are the technological, organizational, and environmental context which provide complimentary adoption determinants (Chen *et al.*, 2019). This is contextualized in this study as BIM (technology), SMEs' Organisation (Organisation) and external environment (environment). Baker (2012) asserted that the TOE framework has been tagged as a more generic theory, consequently, there has been little additional constructs and criticism over the years. The framework provides contexts that would subsume the determinants of adoption. It has been said to be similar or related to other theories such as the IDT (Oliveira & Martins, 2011). The IDT postulates top management characteristics and internal organizational characteristics which are related to the organizational context of the TOE. External characteristics of IDT are similar to environment context of the TOE and the innovation characteristics are similar to technological context. The framework is also similar to that of Iacovou *et al.* (1996) which identified characteristics that influence firms' decision to adopt EDI and concluded that they are the perceived benefits, organizational readiness and external pressure.

TOE has been used in BIM studies such as Ahuja *et al.* (2016) and Chen *et al.* (2019) to conceptualize BIM adoption at the organization level in India and China respectively. The TOE framework is well suited for BIM adoption at the organization level as it permits the inclusion of specific innovation adoption determinants. Oliveira and Martins (2011) suggested that for complex technology adoption, it would be important to combine more than one theoretical lens.

c) **Institutional Theory:** Meyer and Rowan (1977) and DiMaggio and Powell (1983) emphasized the critical roles of the institutional environment in driving organisations towards making significant changes. There are three basic institutional isomorphic pressures which are coercive pressure, mimetic pressures and normative pressures. Coercive isomorphism refers to formal and informal pressure on the organization by organizations that they are dependent on in the same context. This could either be in the form of force, persuasion or invitation to join collusions which can be glaring or less explicit (DiMaggio & Powell, 1983). Mimetic isomorphism relates to mimicking or modelling other firms or competitors as a result of certainty. The proponents posit that organizations often model other organizations that they considered more legitimate or successful in their environment. The modelling could be indirect, or involuntary like employee transfer or more explicit in the form of consulting firms. Normative isomorphism takes root from professionalization which is the 'collective struggle of members of an occupation to define conditions and methods of their work' (DiMaggio & Powell, 1983) and could be better represented as dictating tune to the piper. The two main sources of professionalization are the formal education training and professional training institutions which give rise to homogenous professionals occupying the position in different organizations. This is contextualized in this study as pressures from the inter-organisational network and institutional network (coercive pressures) as noted by Sexton *et al.* (2006); pressures of imitation of other SMEs to adopt and implement BIM (Mimetic pressures) and pressures of norms and values of related SMEs (Normative pressures). Although the INT is a useful theoretical lens, it majorly explains the homogeneity of organizations. Consequently, it has often been synthesized with other theoretical lenses such as IDT or TOE framework in innovation studies. Cao (2016) combined the INT with resource dependence theory to investigate BIM implementation on Chinese construction projects. Ahmed and Kassem (2018) used the INT to provide constructs for external environment context in a study to determine drivers of BIM in the UK architectural firms.

Table 9 shows the mapping of the theories with regards to BIM adoption and implementation

Insert Table 9.

6.2 Synthetization of the Review with the Theoretical Lenses

Constructs are adopted from the three theoretical lenses with regards to the review for synthetization. The stages of innovation and characteristics of innovation are adopted and contextualized from the innovation diffusion theory, coupled with the three elements from the TOE framework and the three isomorphic pressures. This is as shown in Figure 4 and Table 10.

Insert Figure 4.

Insert Table 10.

7.0 Discussion of Review Findings

Despite the SMEs accounting for a larger percentage of the firms in the construction industry, there has been a dearth of research studies on the adoption and implementation of BIM in SMEs. The adoption and proliferation of BIM in SMEs is a necessity for the integration of the fragmented industry and the survival of the SMEs. An emerging trend in the extant studies is to generalize the findings without attention to the size of the firms. The dearth of BIM studies that specifically focus on SMEs is reflected in the total number of papers that were available during the search and the few that were later adopted for this study. A total of 51 journal papers were adopted for this study compared to close to a thousand papers that are available for the large firms. Over the years, there has been an increase in the number of studies, albeit slowly. The increase in the number of publications on BIM in SMEs would continue because the SMEs would continue to dominate the construction industry and there will be a need for their adoption and implementation.

There are a few of the publications from developing countries, despite the SMEs been more important in these countries (Saka & Chan, 2020). This can be related to the fact that the level of BIM awareness, adoption and implementation is still low compared to that of developed countries. This is in agreement with the findings of Saka *et al.* (2019b) and Bui *et al.* (2016). There is still a large number (X) of SMEs that are still unaware of BIM. The number of SMEs that are aware of BIM is increasing, however, not all informed SMEs would adopt the BIM and not all SMEs would implement and later confirm BIM innovation in their organisation as depicted in Figure 5. 'A' SMEs are aware but not adopting BIM, 'B' accepted BIM but are not implementing it, 'C' implement but later did not confirm BIM usage on the long run, only 'D' confirm the implementation of BIM in their organisation. This is in per the Innovation Diffusion Theory (Rogers, 2003) and reflected in Table 5.

Insert Figure 5.

The focus of the publication ranges from awareness, adoption to implementation of BIM in SMEs. However, there are limited papers on empirical evidence of BIM benefits in SMEs, risk, cost and legal issue related to BIM implementation in SMEs. Similarly, few of the papers are through theoretical lenses of innovation and knowledge; most of the papers have none. Hosseini *et al.* (2015) opined that neglecting theoretical lenses which have been built upon the robust of knowledge from sociology, psychology, and communication by studies aiming at investigating any aspect of innovation seem irrational.

A critical review of the papers revealed the benefits, challenges, drivers/motivations and influencing contexts. The barriers were grouped into process/people-related barriers, technology-related barriers and economic-related barriers. The process/people-related barriers are the most severe and this can be related to the fact that BIM is as 'much about people and processes as it is about technology' (Arayici *et al.*, 2011a). This is consistent with the findings of Saka and Chan (2019b) which asserted that process/people-related barriers are often the severest for the SMEs. Barriers such as lack of implementation strategies/guides; lack of clients' demand for BIM; shortage of experts; lack of awareness of the stakeholders; and resistance to change are the most severe. The high cost of software; lack of technical know-how, interoperability and legal issues are the severe technology-related barriers(Saka & Chan, 2020). Similarly, the lack of clear BIM benefits is a major challenge debarring SMEs from adoption and implementation. There is a wrong misconception that BIM is only meant for large firms and that it is not applicable in small building projects. Although these barriers facing SMEs are numerous, strategies such as more empirical studies on BIM benefits, cost, risk can help; coupled with increased awareness and studies on implementation strategies and guides.

Most of the identified benefits from the review are non-tangible such as improves project collaboration, improves stakeholders' understanding, improves project information management etc. Oftentimes most of the studies of BIM benefits are perceived benefits based on survey approach and not case study-based approach. This approach of perceived benefits may not be representative of the actual benefits and this applies to the perceived challenges. The perceived challenges from the view of non-adopters are often exaggerated and do not depict the actual challenges. It is also worthy of note that 3D visualization is one of the most reported functionalities coupled with cost estimating, and auto quantity takeoff. This point to the fact that the level of implementation of BIM in SMEs is still low.

The drivers and motivations of BIM adoption and implementation were also reviewed, and these can be from the external environment, internal environment or the characteristic of the BIM. Flexible organisation structure needs for competitiveness and survival, top management support, and clients demand are some of the internal environment drivers Perceived benefits of BIM, the perception of BIM, and ease of use are some of the BIM characteristics that can serve as drivers. The external environment consists of the inter-organizational network, and these are the stakeholders that are directly related to the SMEs; other stakeholders and these are stakeholders that are not directly related to the SMEs, and lastly, the institutional networks that consist of the government institutions and professional bodies. These can provide drive and motivation for the SMEs to adopt and implement BIM. This corroborates the findings of Saka *et al.* (2020) in SMEs of developing countries.

Influencing contexts were also influence the BIM studies in SMEs and these are the location of study, level of BIM implementation, type of SMEs, the position of the SME on the supply chain and the organisation structure. These would influence the result of the studies and studies in these different contexts would be different. The type of SME relates to the profession e.g architecture, mechanical, quantity surveying, contractor, etc while the position of the SME on the supply chain relates to whether it is a main contractor or subcontractor. It was noted that level of awareness of architecture firms is higher compared to that of other SMEs; the level of implementation in developed countries is higher than that of developing countries; organisation structure reacts to structural changes differently. Thus, special attention should be given to these influencing contexts in the study of BIM in SMEs. This further support the idea of Papadonikolaki (2017) that BIM study is highly contextual.

Innovation diffusion theory, technology-organisation-environment framework and institutional theory were then contextualized in the study and synthesized. The result gives a conceptual framework for the study of BIM in SMEs that could also serve as an additional area of further study. The conceptual framework developed is in tandem with the view of Straub (2009) that opined that the underlining contexts in most theories are the internal environment, external environment, and the innovation characteristics. Whetten (1989) opined that the 'What', 'How' and 'Why' are essential elements of a model. The 'What' relates to which factors should be included and measured based on the criteria of comprehensiveness and parsimony. The developed conceptual framework was built based on the review of extant studies to meet the criteria of comprehensiveness, and it is also partitioned into three contexts of technology, organization and environment to depict the simplest explanation. The 'How' and 'Why' relate to the relationship between the identified constructs and the rationale for the relationships. These were deduced based on logic in the reviewed extant studies and the established theoretical lenses adopted. A conceptual framework with all the relationships tested and already established in the literature is of little or no use. The conceptual framework sheds light on relationships that are not explicit in the literature, and relationships that are not well established. Consequently, a couple of propositions can be deduced from the model which are grounded in logic:

Ha: This proposition relates to the effect of BIM characteristics on the different stages of BIM innovation. How does compatibility/relative advantage/observability of BIM affect BIM awareness, adoption, implementation and confirmation in SMEs? Studies such as Ahmed and Kassem (2018), Chen *et al.* (2019), Ahuja *et al.* (2016), and Son *et al.* (2015) have contradicting submission on the relationships in large firms.

Hb: This proposition relates to the effect internal environment on the different innovation phase. How does top management support/organisation/financial resources/motivation affect BIM awareness, adoption, implementation and confirmation in SMEs? Studies (Ahmed & Kassem, 2018; Ahuja *et al.*, 2016; Chen *et al.*, 2019) have reported the significance of top management support on the BIM adoption decision, whereas, Ding *et al.* (2015) asserted that management support is not significant in large firms.

Hc: This proposition relates to the effect of the external environment on the different BIM diffusion stage. How does coercive/normative/mimetic pressure affect BIM awareness, adoption, implementation and confirmation in SMEs? Does it make sense to mandate BIM for the SMEs? What is the right combination of pressure needed to drive BIM in SMEs? Results of this proposition would be useful for policymaking to drive BIM adoption in the SMEs.

Lastly, meaning is derived from context (Whetten, 1989) and influencing contexts such as type of SMEs, location of the SMEs, level of BIM implementation, and organisation structure are identified to set boundaries of generalizability. For instance: BIM diffusion in consulting firms such as architecture firms and engineering firms would differ when compared to contracting firms because of the prior exposure to CAD of consulting firms; SMEs in developing countries where the level of BIM awareness is low would react differently when compared those in developed countries. Would the BIM Mandate have an effect on SMEs in developing countries/developed countries? These are some of the instances that show the highly contextual nature of BIM studies.

8.0 Conclusions

It was established that there is a dearth of BIM studies with a focus on SMEs and there is also a low level of awareness, adoption and implementation. Most of the papers reviewed were from developed countries with a higher level of awareness and government support. Thus, there would be a need for more studies from developing countries/emerging markets as the SMEs are the backbone of the economy; and implementation of BIM in the BIM 'complaints' SMEs is a necessity for integration and survival of the SMEs. Challenges, benefits, and drivers of BIM in SMEs were identified in this study. This is important because the identification of the challenges would lead to the identification of the solutions. Similarly, one of the identified challenges is the lack of BIM benefits evaluation, thus, empirical studies on BIM benefits in SMEs is necessary for the BIM proliferation.

The paper also identified the area of focus of the extant studies and this revealed that there is a need for more BIM studies on BIM benefits to provide empirical evidence for the SMEs that are sceptical about it. Also, the SMEs are characterised with limited resources and the high cost of implementation of the BIM is a major bottleneck for the SMEs. There is a need for more studies on the cost of BIM implementation in SMEs and similarly, there is a need for more studies on implementation strategies and guides. BIM studies in SMEs on risk and legal issues are also few and there is a need for more studies in this area as the SMEs considered the risk associated with adoption and implementation as high.

A conceptual framework was then developed based on the theoretical lenses of innovation diffusion theory, technology-organisation-environment framework and institutional theory. Also, this paper presents a systematic review of BIM studies with a specific focus on SMEs and has provided the status, benefits, challenges and drivers of BIM in SMEs which is of benefits to the SMEs, researchers and policymakers; it has set a scene for further studies on BIM in SMEs.

Lastly, the keyword search may have served as a limitation for the outputs of the articles, however, citation tracking was adopted to search for other related articles using the reference lists of the research outputs. Also, the developed conceptual framework may not have covered all the likely constructs, however, the generated framework is regarded as a generic framework that provides various contexts in which other constructs can be easily subsumed.

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Figure 1: Hermeneutic Research Outline (Adapted from Boell and Cecez-Kecmanovic (2014))

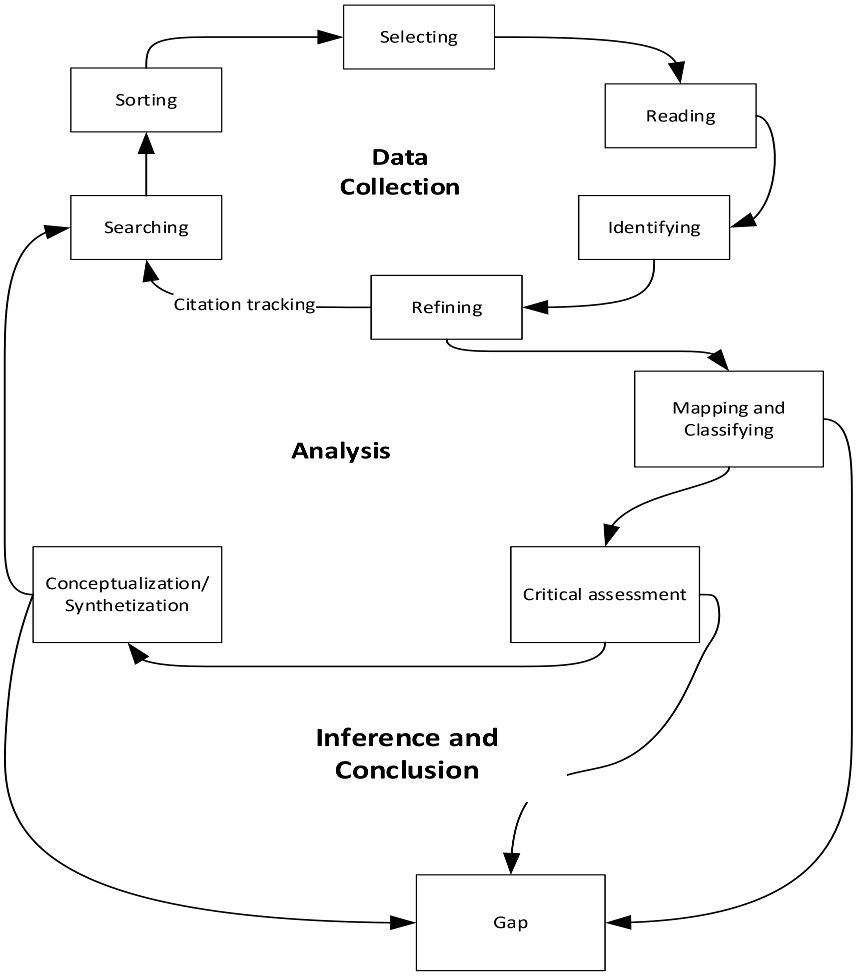

Figure 2: Annual distribution of the selected research papers on BIM in SMEs

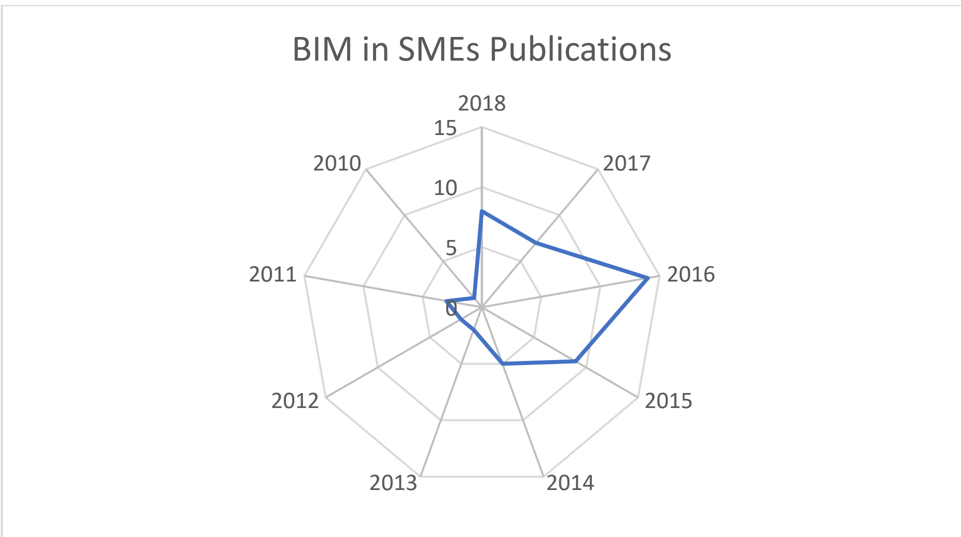

Figure 3: Country of the selected research papers on BIM in SMEs

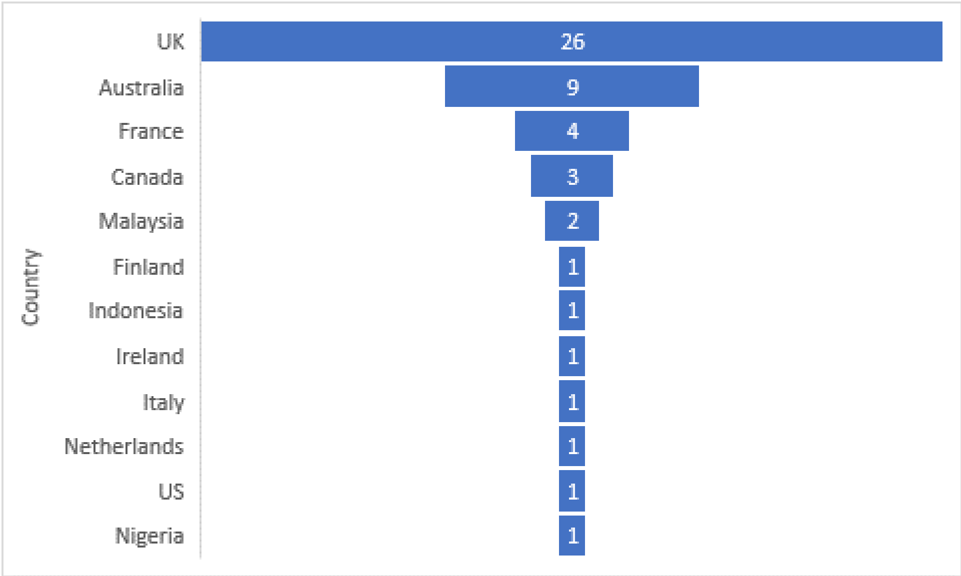

Figure 4: Conceptualizing and Synthetization of BIM in SMEs

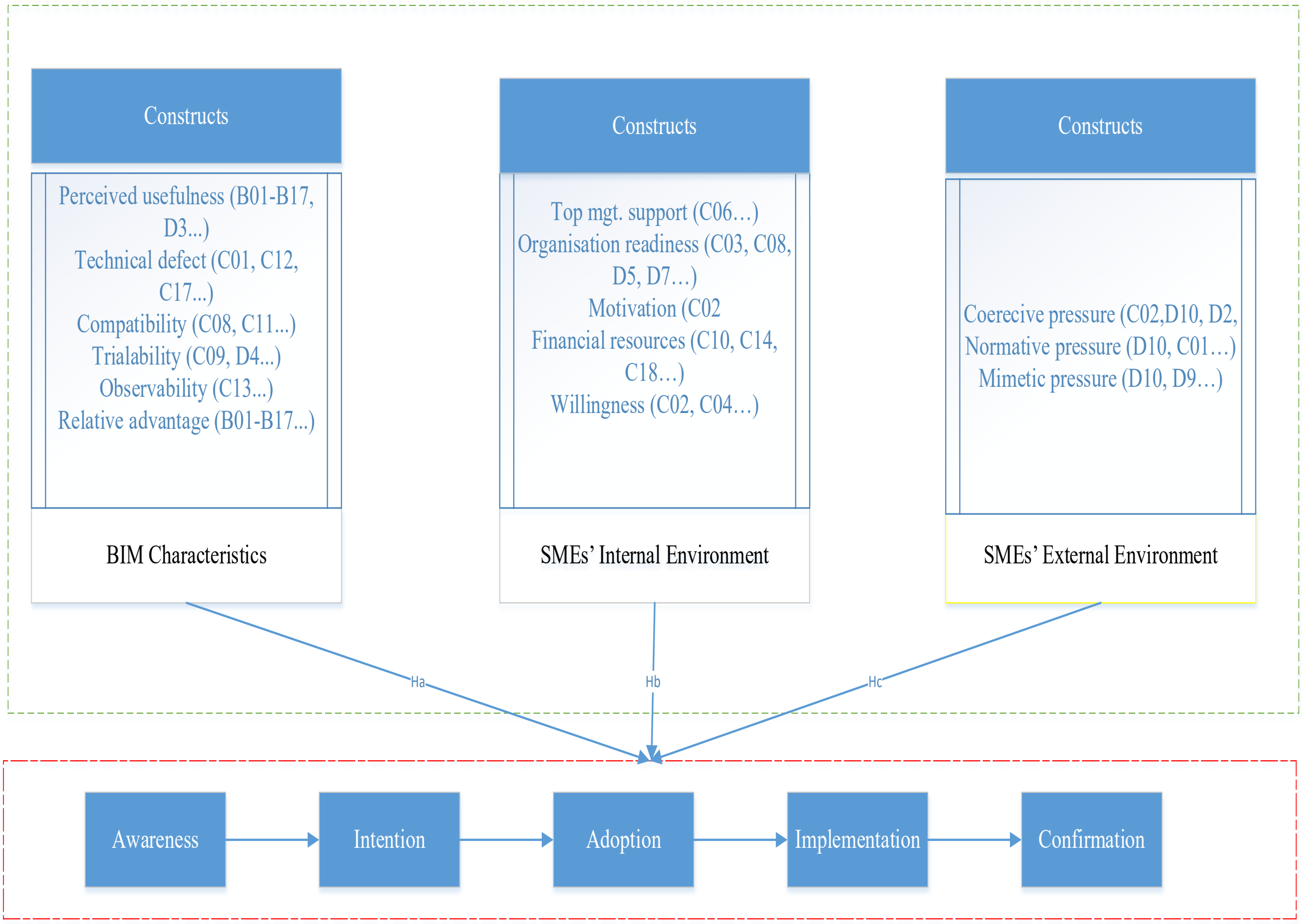

Figure 5: BIM in SMEs (Awareness = A+B+C+D, Adoption = B+C+D, Implementation = C+D and Confirmation = D)

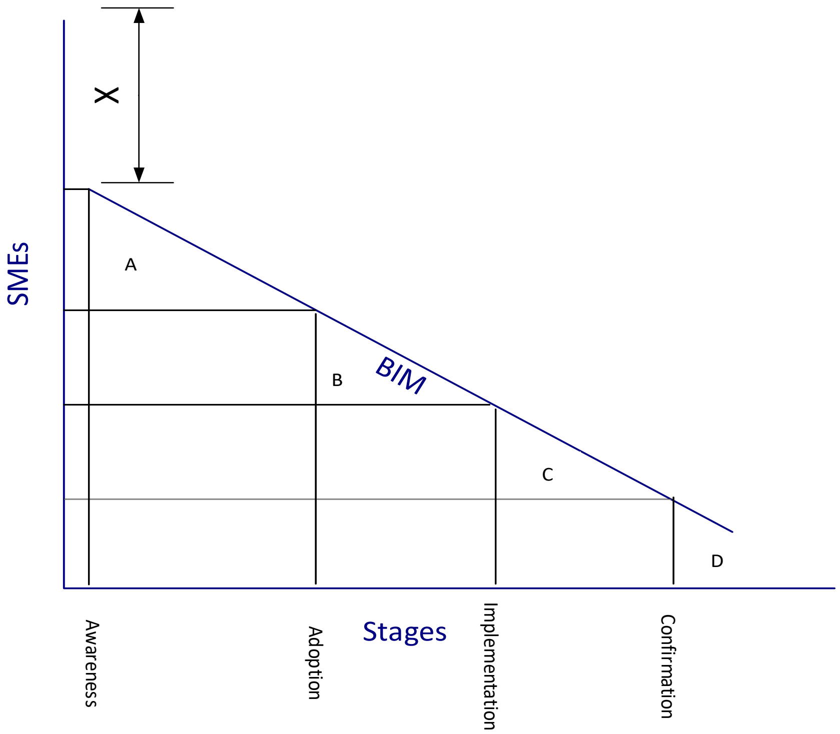

Table 1: Summary of definitions of SMEs

Country	SMEs	Size of employees	Annual turnover	Sources
Australia	98%	< 200		(Hosseini *et al.*, 2016a; Shelton *et al.*, 2016)
Canada	98%	< 499	< $5 million	(Poirier *et al.*, 2015a; Rispoli *et al.*, 2011)
France	98%	< 250	< €50 million	
Indonesia	96%	< 100		(Furry *et al.*, 2017)
Italy	98%	< 250		(Statista, 2018)
Malaysia	98.5%	≤ 200	≤ RM50 million	(SMEinfo, 2019)
The Netherlands	99%	< 250	< €40 million	(OECD, 2017)
Nigeria	96%	< 200	< ₦ 499 million	(Oyelaran-Oyeyinka, 2007; SMEDAN, 2005)
UK	98%	< 250		(Lam *et al.*, 2017)
US	98%	< 500		(USITC, 2010)

Table 2: Highlights of reviewed papers on BIM in SMEs

S/N	**Year**	**SMEs**	**Lens**	**Country**	**Methodology**	**Area of focus**	Author(s)
1	2018	Architectural firm	Knowledge-Based Innovation	Nigeria	Mixed approach	BIM adoption	Kori *et al.* (2019)
2	2018	All	Competitive Dynamics Perspective	Australia	Survey	BIM implementation	Hosseini *et al.* (2018)
3	2018	Architectural firm	Innovation Diffusion Model	France	Qualitative	BIM implementation	Hochscheid and Halinb (2018)
4	2018	Contractor	Innovation Diffusion Model and Technology Acceptance Model	Australia	Survey	BIM adoption	Hong *et al.* (2018)
5	2018	Contractor	-	Italy	Case study	Scheduling functionalities	Malacarne *et al.* (2018)
6	2018	All	-	UK	Survey	Collaboration environment	Abuelmaatti and Ahmed (2018)
7	2018	Contractor	-	Finland	Literature review	BIM implementation	Kouch *et al.* (2018)
8	2018	Contractor	Project-Based Learning	UK	Literature review	BIM team	Udomdech *et al.* (2018)
9	2017	All	-	UK	Mixed approach	Risk	Lam *et al.* (2017)
10	2017	Contractor	Digital divide	UK	Qualitative	BIM implementation	Dainty *et al.* (2017)
11	2017	Contractor	-	France	Qualitative	BIM implementation	Joblot *et al.*
12	2017	All	-	France	Survey	Awareness	Tranchant *et al.* (2017)
13	2017	Contactor and Sub Contractor	-	Ireland	Qualitative	BIM adoption	Caroll and McAuley (2017)
14	2017	Architect	-	Indonesia	Survey	BIM adoption	Furry *et al.* (2017)
15	2017	Contractor	-	US	Qualitative	BIM implementation	Joseph Garcia *et al.* (2018)
16	2016	All	-	Australia	Mixed approach	BIM adoption	Rodgers *et al.* (2016)
17	2016	All		Australia	Survey	BIM adoption	Hosseini *et al.* (2016b)

18	2016	All	Innovation Diffusion Model	Australia	Survey	BIM adoption	Hosseini *et al.* (2016a)
19	2016	All	-	Australia	Mixed approach	BIM adoption	Monozam *et al.* (2016)
20	2016	Designer	-	UK	Mixed approach	Reality Capture functionalities	Craggs *et al.* (2016)
21	2016	Contractor	Technology Acceptance Model	Australia	Mixed approach	BIM adoption	Hong *et al.* (2016)
22	2016	Designer and Contractor	-	UK	Qualitative	BIM implementation	Loveday *et al.* (2016)
23	2016	All	-	UK	Qualitative	BIM implementation	Mellon and Kouider (2016)
24	2016	All	-	UK	Mixed approach	BIM adoption	Ghaffarianhoseini *et al.* (2016b)
25	2016	All	-	UK	Literature review	BIM implementation	Ghaffarianhoseini *et al.* (2016a)
26	2016	Design and Carpentry firm	Theory planned Behaviour, Technology Acceptance Model and the Lazy Person Theory	France	Case study	BIM implementation	Hochscheid *et al.* (2016)
27	2016	Construction firm	-	Malaysia	Qualitative	BIM implementation	Mahdzir and Khuzzan (2016)
28	2016	Architectural firm	-	UK	Case study	BIM implementation	Jaradat and Sexton (2016)
29	2016	Design, Manufacture and Fit out	-	UK	Case study	BIM implementation	Machado *et al.* (2015)
30	2015	Mechanical Contracting	-	Canada	Case study	BIM implementation	Poirier *et al.* (2015a)
31	2015	Architect	-	UK	Case study	Visualization functionalities	Stojanovic *et al.* (2015)
32	2015	Civil Engineering	Technology Acceptance Model	UK	Literature review	BIM implementation	Longwe *et al.* (2015)
33	2015	All	-	UK	Literature review	Risks	Lam *et al.* (2015)
34	2015	Mechanical Contracting	-	Canada	Case study	Benefits	Poirier *et al.* (2015c)
35	2015	Mechanical Contracting	-	Canada	Case study	Benefits	Poirier *et al.* (2015b)

36	2015	All	-	UK	Literature review	Coordination functionalities	Muñoz and Arayici (2015)
37	2015	Designer	Situational Awareness	UK	Mixed approach	Collaboration/Functionalities	Adamu *et al.* (2015)
38	2015	Contractor	-	Malaysia	Survey	BIM implementation	Anuar and Abidin (2015)
39	2014	All	-	UK	Casestudy	Readiness/Awareness	Mellon and Kouider (2014)
40	2014	All	-	Australia	Qualitative	BIM implementation	Forsythe (2014)
41	2014	Civil Engineering	-	UK	Mixed approach	BIM implementation	Bataw *et al.* (2014)
42	2014	Designer	-	UK	Qualitative	BIM implementation	Kouider and Paterson (2014)
43	2014	All	-	UK	Case study and literature review (Qualitative)	Risks	Charlson and Oduoza (2014)
44	2013	All	-	UK	Literature review	BIM implementation	Tah and Zhou (2013)
45	2013	Consulting Civil and Structural Engineers	-	UK	Qualitative	BIM implementation	Fereday and Potter (2013)
46	2012	Contractors	-	UK	Qualitative	BIM implementation	Gledson *et al.* (2012)
47	2012	Quantity Surveying	-	UK	Case study	Readiness/Awareness	Zhou *et al.* (2012)
48	2011	All	-	Australia	Qualitative	Cost	Olatunji (2011)
49	2011	Architectural firms	-	UK	Case study	BIM implementation	Arayici *et al.* (2011a)
50	2011	Architectural firms	-	UK	Case study	BIM implementation	Arayici *et al.* (2011b)
51	2010	All	-	The Netherlands	Qualitative	BIM implementation	Sebastian (2011)

Table 3: Themes of the selected papers on BIM in SMEs

Topic	**Subtopics**	**Research Studies**	**Per cent**
Awareness	*Awareness* *Readiness*	(Rodgers *et al.*, 2016; Tranchant *et al.*, 2017) (Ghaffarianhoseini *et al.*, 2016b; Mellon & Kouider, 2014; Zhou *et al.*, 2012)	9.8%
Adoption	*Factors affecting adoption* *Barriers* *Drivers*	(Caroll & McAuley, 2017; Forsythe, 2014; Gledson *et al.*, 2012; Hong *et al.*, 2018; Hong *et al.*, 2016; Hosseini *et al.*, 2016a; Longwe *et al.*, 2015; Mahdzir & Khuzzan, 2016) (Anuar & Abidin, 2015; Bataw *et al.*, 2014; Furry *et al.*, 2017; Hosseini *et al.*, 2016b; Machado *et al.*, 2015) (Anuar & Abidin, 2015; Rodgers *et al.*, 2016)	29.4%
Implementation	*Factors affecting Implementation* *Implementation* *Functionalities* *Success factors* *Risks* *Benefits* *Software* *Cost*	(Dainty *et al.*, 2017; Hosseini *et al.*, 2018; Kouch *et al.*, 2018; Loveday *et al.*, 2016; Mellon & Kouider, 2016) (Arayici *et al.*, 2011a, 2011b; Ghaffarianhoseini *et al.*, 2016a; Ghaffarianhoseini *et al.*, 2016b; Hochscheid & Halinb, 2018; Hochscheid *et al.*, 2016; Jaradat & Sexton, 2016; Joseph Garcia *et al.*, 2018; Kouider & Paterson, 2014; Machado *et al.*, 2015; Poirier *et al.*, 2015a; Udomdech *et al.*, 2018) (Adamu *et al.*, 2015; Craggs *et al.*, 2016; Malacarne *et al.*, 2018; Stojanovic *et al.*, 2015) (Abuelmaatti & Ahmed, 2018; Joblot *et al.*) (Charlson & Oduoza, 2014; Lam *et al.*, 2015; Lam *et al.*, 2017) (Poirier *et al.*, 2015b, 2015c) (Muñoz & Arayici, 2015; Tah & Zhou, 2013) (Olatunji, 2011)	60.8%

Table 4: Theoretical lens

Technology Lens	**Knowledge Lens**	**Other Lens**
Innovation Diffusion Theory (Hochscheid & Halinb, 2018; Hong *et al.*, 2018; Hosseini *et al.*, 2016a)	Knowledge-based innovation (Kori *et al.*, 2019)	Competitive Dynamics Perspective (Hosseini *et al.*, 2018)
Technology Acceptance Model (Hochscheid *et al.*, 2016; Hong *et al.*, 2018; Hong *et al.*, 2016; Longwe *et al.*, 2015)	Project-Based Learning (Udomdech *et al.*, 2018)	Lazy Person Theory (Hochscheid *et al.*, 2016)
Digital Divide Concept (Dainty *et al.*, 2017)		Theory planned Behaviour (Hochscheid *et al.*, 2016)

Table 5: Status of BIM adoption in SMEs

SMEs	**Method/ (Size)**	**Result**	**Country**	**Source**
Contractors	Survey (80)	36.25% non-users	Australia	Hong *et al.* (2018)
All	Survey (206)	15% have used BIM	France	Tranchant *et al.* (2017)
Architects	Survey (34)	46% level of awareness	Indonesia	Furry *et al.* (2017)
All	Survey (40)	46.8% currently use BIM on project	Australia	Rodgers *et al.* (2015)
All	Survey (78)	42% engaged with BIM	Australia	Hosseini *et al.* (2016b)
All	Survey (135)	42.2 % adopters	Australia	Hosseini *et al.* (2016a)
All	Survey (41)	48.8% currently using BIM	Australia	Monozam *et al.* (2016)
All	Survey (22)	25-27% level of awareness	UK	Ghaffarianhoseini *et al.* (2016b)

Table 6: Challenges/Barriers of BIM in SMEs

ID	Barriers	Sources	Type	Description
C01	Shortage of skills and expertise	(Anuar & Abidin, 2015; Caroll & McAuley, 2017; Dainty *et al.*, 2017; Forsythe, 2014; Furry *et al.*, 2017; Ghaffarianhoseini *et al.*, 2016a; Ghaffarianhoseini *et al.*, 2016b; Gledson *et al.*, 2012; Hochscheid & Halinb, 2018; Hong *et al.*, 2018; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2018; Hosseini *et al.*, 2016b; Mahdzir & Khuzzan, 2016; Malacarne *et al.*, 2018; Muñoz & Arayici, 2015; Zhou *et al.*, 2012)	Process/People-related	BIM is not just a technology but also a process and it has been said to be 90% process (Munir & Jeffrey, 2013). Most of the challenges of BIM in SMEs stems from the process and people. There is shortage of expertise and often there is lack of support from the management and clients. Most of the available guides and regulations are always tailored to the large firms without due consideration of the SMEs. Thus, most SMEs resist change as they perceived it to be disruptive and may not be necessary.
C02	Lack of client's demand	(Bataw *et al.*, 2014; Caroll & McAuley, 2017; Dainty *et al.*, 2017; Furry *et al.*, 2017; Gledson *et al.*, 2012; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2018; Hosseini *et al.*, 2016b; Mellon & Kouider, 2016; Monozam *et al.*, 2016; Poirier *et al.*, 2015a)		
C03	Lack of implementation guide and strategies/standards	(Anuar & Abidin, 2015; Caroll & McAuley, 2017; Ghaffarianhoseini *et al.*, 2016a; Gledson *et al.*, 2012; Hochscheid & Halinb, 2018; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2016b; Joblot *et al.*; Lam *et al.*, 2015; Loveday *et al.*, 2016; Malacarne *et al.*, 2018; Mellon & Kouider, 2016; Monozam *et al.*, 2016; Zhou *et al.*, 2012)		
C04	Resistance to change/Satisfaction with status quo	(Anuar & Abidin, 2015; Caroll & McAuley, 2017; Furry *et al.*, 2017; Ghaffarianhoseini *et al.*, 2016b; Gledson *et al.*, 2012; Hochscheid & Halinb, 2018; Hochscheid *et al.*, 2016; Hong *et al.*, 2018; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2016b; Kouch *et al.*, 2018; Loveday *et al.*, 2016; Monozam *et al.*, 2016)		
C05	Risks	(Bataw *et al.*, 2014; Forsythe, 2014; Gledson *et al.*, 2012; Kouch *et al.*, 2018; Lam *et al.*, 2015; Lam *et al.*, 2017;		

		Monozam *et al.*, 2016; Poirier *et al.*, 2015b; Zhou *et al.*, 2012)		
C06	Lack of management support	(Caroll & McAuley, 2017; Gledson *et al.*, 2012; Kouch *et al.*, 2018)		
C07	Lack of understanding of supply chain and stakeholders	(Bataw *et al.*, 2014; Caroll & McAuley, 2017; Forsythe, 2014; Furry *et al.*, 2017; Ghaffarianhoseini *et al.*, 2016b; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2016b; Jaradat & Sexton, 2016; Mellon & Kouider, 2016; Poirier *et al.*, 2015a)		
C08	Lack of technical know-how of BIM adoption and implementation	(Anuar & Abidin, 2015; Caroll & McAuley, 2017; Dainty *et al.*, 2017; Forsythe, 2014; Furry *et al.*, 2017; Ghaffarianhoseini *et al.*, 2016a; Gledson *et al.*, 2012; Hochscheid & Halinb, 2018; Hong *et al.*, 2018; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2018; Hosseini *et al.*, 2016b; Mahdzir & Khuzzan, 2016; Malacarne *et al.*, 2018; Muñoz & Arayici, 2015; Zhou *et al.*, 2012)	Technology-related	These are challenges that are related to the BIM technology and a significant one is the cost; Olatunji (2011) posited that it could be as high as 55% of the total cost of implementation and it ranges thousands of dollars. Other challenges are related to the technical know-how, interoperability and legal issues.
C09	Communication issues with other project participants/ supply chain	(Caroll & McAuley, 2017; Furry *et al.*, 2017; Hochscheid *et al.*, 2016; Hong *et al.*, 2018; Mellon & Kouider, 2016; Monozam *et al.*, 2016)		
C10	High cost of software	(Anuar & Abidin, 2015; Bataw *et al.*, 2014; Caroll & McAuley, 2017; Dainty *et al.*, 2017; Forsythe, 2014; Furry *et al.*, 2017; Ghaffarianhoseini *et al.*, 2016a; Ghaffarianhoseini *et al.*, 2016b; Gledson *et al.*, 2012; Hochscheid & Halinb, 2018; Hong *et al.*, 2018; Hong *et al.*, 2016; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2018; Hosseini *et al.*, 2016b; Kouch *et al.*, 2018; Loveday *et al.*, 2016; Malacarne *et al.*, 2018; Mellon & Kouider, 2014; Monozam *et al.*, 2016; Muñoz & Arayici, 2015; Poirier *et al.*, 2015a; Stojanovic *et al.*, 2015; Tah & Zhou, 2013; Tranchant *et al.*, 2017)		
C11	Interoperability	(Hochscheid *et al.*, 2016; Joseph Garcia *et al.*, 2018; Malacarne *et al.*, 2018; Monozam *et al.*, 2016; Tah & Zhou, 2013)		

C12	Legal issues	(Bataw *et al.*, 2014; Forsythe, 2014; Gledson *et al.*, 2012; Kouch *et al.*, 2018; Lam *et al.*, 2015; Lam *et al.*, 2017; Monozam *et al.*, 2016; Poirier *et al.*, 2015b; Zhou *et al.*, 2012)		
C13	Lack of BIM benefits evaluation	(Bataw *et al.*, 2014; Ghaffarianhoseini *et al.*, 2016a; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2018; Hosseini *et al.*, 2016b; Mellon & Kouider, 2016; Poirier *et al.*, 2015a)	Economic-related	These are economic-related challenges facing BIM in SMEs. One of the widely reported challenges is the cost of implementation; this is considered a major bottle neck for SMEs because they don't have access to large finance, and they do not have slack resources to try out BIM without affecting efficiency. Also, most SMEs still believe that BIM is meant for large projects and this is coupled with the fact that there is lack of empirical evidence to support BIM benefits in SMEs. Thus, in the face of unclear BIM benefits, of what essence is the expensive BIM to the SMEs with limited funds? Does BIM investment breakeven early for the SMEs?
C14	High cost of implementation (staff training cost)	(Anuar & Abidin, 2015; Bataw *et al.*, 2014; Caroll & McAuley, 2017; Dainty *et al.*, 2017; Forsythe, 2014; Furry *et al.*, 2017; Ghaffarianhoseini *et al.*, 2016a; Ghaffarianhoseini *et al.*, 2016b; Gledson *et al.*, 2012; Hochscheid & Halinb, 2018; Hong *et al.*, 2018; Hong *et al.*, 2016; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2018; Hosseini *et al.*, 2016b; Kouch *et al.*, 2018; Loveday *et al.*, 2016; Malacarne *et al.*, 2018; Mellon & Kouider, 2014; Monozam *et al.*, 2016; Muñoz & Arayici, 2015; Poirier *et al.*, 2015a; Stojanovic *et al.*, 2015; Tah & Zhou, 2013; Tranchant *et al.*, 2017)		
C15	BIM not suitable for small and building projects	(Forsythe, 2014; Furry *et al.*, 2017; Hosseini *et al.*, 2016a; Hosseini *et al.*, 2018; Hosseini *et al.*, 2016b; Monozam *et al.*, 2016)		
C16	Effort/Time for staff training	(Furry *et al.*, 2017; Hochscheid & Halinb, 2018; Hosseini *et al.*, 2016a; Loveday *et al.*, 2016; Zhou *et al.*, 2012)		
C17	Reduced working efficiency temporarily	(Hochscheid & Halinb, 2018; Hong *et al.*, 2018; Poirier *et al.*, 2015a)		
C18	Lack of access to finance	(Caroll & McAuley, 2017)		

Table 7: Benefits of BIM in SMEs

ID	Benefits	Sources
B01	Improved project collaboration	(Anuar & Abidin, 2015; Arayici *et al.*, 2009; Bataw *et al.*, 2014; Furry *et al.*, 2017; Gledson *et al.*, 2012; Hong *et al.*, 2018; Loveday *et al.*, 2016; Mellon & Kouider, 2016; Rodgers *et al.*, 2015; Tranchant *et al.*, 2017; Zhou *et al.*, 2012)
B02	Improved project information management	(Arayici *et al.*, 2009; Caroll & McAuley, 2017; Furry *et al.*, 2017; Hochscheid *et al.*, 2016; Hong *et al.*, 2018; Joblot *et al.*; Loveday *et al.*, 2016; Poirier *et al.*, 2015a)
B03	Improved stakeholders' understanding	(Gledson *et al.*, 2012; Hochscheid *et al.*, 2016; Hong *et al.*, 2018; Joblot *et al.*; Rodgers *et al.*, 2015; Zhou *et al.*, 2012)
B04	Reduced project's overall cost	(Arayici *et al.*, 2009; Hong *et al.*, 2018; Joseph Garcia *et al.*, 2018; Poirier *et al.*, 2015b, 2015c) (Anuar & Abidin, 2015; Gledson *et al.*, 2012; Rodgers *et al.*, 2015)
B05	Time saving	(Anuar & Abidin, 2015; Furry *et al.*, 2017; Gledson *et al.*, 2012; Hochscheid *et al.*, 2016; Hong *et al.*, 2018; Joseph Garcia *et al.*, 2018; Poirier *et al.*, 2015c; Tranchant *et al.*, 2017; Zhou *et al.*, 2012)
B06	Enabling more design alternatives/improved buildability of project design	(Anuar & Abidin, 2015; Arayici *et al.*, 2009; Gledson *et al.*, 2012; Hochscheid *et al.*, 2016; Hong *et al.*, 2018; Joseph Garcia *et al.*, 2018; Loveday *et al.*, 2016; Rodgers *et al.*, 2015; Tranchant *et al.*, 2017)
B07	Reduced errors in design and construction	(Anuar & Abidin, 2015; Arayici *et al.*, 2009; Furry *et al.*, 2017; Gledson *et al.*, 2012; Hochscheid *et al.*, 2016; Joblot *et al.*; Malacarne *et al.*, 2018)
B08	Request for information (ROI)	(Bataw *et al.*, 2014; Kouch *et al.*, 2018; Poirier *et al.*, 2015a; Tranchant *et al.*, 2017)
B09	Productivity/ Efficiency enhancement	(Gledson *et al.*, 2012; Mellon & Kouider, 2016; Zhou *et al.*, 2012) (Anuar & Abidin, 2015; Poirier *et al.*, 2015c)
B10	3D visualization	(Caroll & McAuley, 2017; Hong *et al.*, 2018; Joblot *et al.*; Joseph

		Garcia *et al.*, 2018; Loveday *et al.*, 2016; Malacarne *et al.*, 2018; Poirier *et al.*, 2015c; Stojanovic *et al.*, 2015; Tranchant *et al.*, 2017; Zhou *et al.*, 2012)
B11	Environmental analysis/Sustainability/energy analysis	(Arayici *et al.*, 2009; Caroll & McAuley, 2017; Hong *et al.*, 2018; Loveday *et al.*, 2016; Rodgers *et al.*, 2015)
B12	Life cycle maintenance	(Hong *et al.*, 2018)
B13	Quantity take off	(Arayici *et al.*, 2009; Caroll & McAuley, 2017; Gledson *et al.*, 2012; Hong *et al.*, 2018; Joseph Garcia *et al.*, 2018; Loveday *et al.*, 2016; Malacarne *et al.*, 2018; Zhou *et al.*, 2012)
B14	Cost estimation and cost planning	(Anuar & Abidin, 2015; Gledson *et al.*, 2012; Hong *et al.*, 2018; Malacarne *et al.*, 2018; Rodgers *et al.*, 2015; Sebastian, 2011; Zhou *et al.*, 2012)
B15	Facility management	(Hong *et al.*, 2018)
B16	Clash detection	(Caroll & McAuley, 2017; Gledson *et al.*, 2012; Hong *et al.*, 2018; Poirier *et al.*, 2015c; Rodgers *et al.*, 2015; Sebastian, 2011)
B17	Procurement	(Hong *et al.*, 2018)
B18	Construction logistics/fabrication	(Arayici *et al.*, 2009; Forsythe, 2014; Gledson *et al.*, 2012; Hong *et al.*, 2018)
B19	Safety management	(Gledson *et al.*, 2012; Hong *et al.*, 2018)

Table 8: Drivers/Motivation of BIM in SMEs

ID	Drivers/Motivation	Description
D1	Market competitiveness	The need to remain competitive can motivate SMEs to adopt and Implement BIM (Hochscheid *et al.*, 2016; Hong *et al.*, 2018).
D2	Client's demand	Client's demand for BIM on their project would motivate and drive organisations (Caroll & McAuley, 2017; Hong *et al.*, 2018)
D3	Perceived benefits/perceived usefulness (Time savings, cost savings, profits, productivity etc.)	The perceived benefits of BIM such as time-saving, positive ROI, cost reduction among others can motivate or drive SMEs towards BIM adoption (Hochscheid & Halinb, 2018; Hong *et al.*, 2016; Longwe *et al.*, 2015; Mahdzir & Khuzzan, 2016; Poirier *et al.*, 2015a) .

D4	Ease of operation/maintenance	This is the perceived ease of use of the BIM and motivates the SMEs towards BIM (Hong *et al.*, 2016; Longwe *et al.*, 2015; Mahdzir & Khuzzan, 2016).
D5	Organisation Capability and Expertise	This is the ability of the organisation to adopt and implement BIM and its expertise (Anuar & Abidin, 2015; Ghaffarianhoseini *et al.*, 2016a; Hong *et al.*, 2016; Mahdzir & Khuzzan, 2016)
D6	Organisation readiness	This can be measured as the organization's intention to adopt BIM (Hong *et al.*, 2016).
D7	Organisation support	This is the support within the organisation with regards to BIM (Hong *et al.*, 2016; Longwe *et al.*, 2015; Mahdzir & Khuzzan, 2016).
D8	Contractual arrangement	Contractual arrangement can serve as a platform to push the parties to BIM adoption.
D9	Supply Chain	The supply chain within which the SME operates can motivate the SMEs.
D10	Inter-organizational network/Business/institutional network	This is the influence of the external environment to drive and motivate the SMEs.

Table 9: Adopted Theoretical Lenses

S/N	**Theory**	**Innovation Attributes**	**Internal Environment**	**External Environment**
a	Innovation Diffusion Theory	Relative advantage, Compatibility, Complexity, Trialability, and Observability	-	-
b	Technology-Organisation-Environment Framework (TOE):	BIM attributes	SMEs' internal environment characteristics	SMEs' external environment
c	Institutional Theory	-	-	Coercive pressure, Mimetic pressures and Normative pressures

Table 10: Synthetization of the constructs

Constructs	Theoretical lens	Related ID	Description
Internal Environment (SME characteristic and structure)	Organisation element of the TOE framework	(C02, C03, C04, C5, C06, C08, C14 – C18); (D1, D2, D5-D8); (IC2-IC5)	This is the SME internal environment and it influences the BIM innovation phases and it is also related to the BIM characteristics. The internal environment varies depending on the Influencing factor, e.g. organisation structure, level of implementation of BIM etc.
BIM attributes	Perceived innovation characteristics of Innovation diffusion theory and Technology element of the TOE framework	(B01-B17); (C01, C10, C11, C12, C13); (IC2-IC5)	This relates to the BIM characteristic and it is influenced by the internal environment of the SMEs and it also varies with the influencing context.
External environment	Environment element of the TOE framework and Isomorphic pressures of institutional theory	(D9, D10); (C07, C09); (IC1-IC5)	This is the external environment and its pressures, and it varies depending on the influencing context, e.g. external pressure in developed countries would be stronger than that of developing countries with low level of implementation; pressure in an area with government mandate would also differ from the area without a mandate.

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