A Contextualist Perspective to Drivers of BIM in the Architecture, Engineering and Construction (AEC) Industry

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There are disparities in the adoption of BIM between firms of different sizes and diverse locations. Although extant studies have explored drivers to BIM, there is a dearth of contextualist perspectives. How does the context of size (SME or large firm) and location (developed or developing economy) affects the perception of firms on drivers to BIM? Questions relating to these contexts are still underexplored in extant literature. Thus, this study aims to evaluate and analyse the divide of BIM drivers in these contexts via a comparative study. Data was collected through an international survey from 228 professionals in firms of diverse sizes and locations. The responses were analysed using mean score ranking, rank agreement factor, Mann-Whitney U test and principal components analysis. A comparative analyse was conducted which revealed that the SMEs and large firms differ in their perceptions of desire for innovation, availability of resources and collaboration as drivers to BIM. Similarly, it was highlighted that there is a deep divide between developed and developing countries which would underscore the transferability of best practices and global BIM solutions. The study provided empirical evidence of the BIM divide and would be of importance in bridging the traditionally fragmented construction industry.

Keywords: BIM drivers; developed countries; developing countries; SMEs; large firms

Introduction

Albeit many studies have been carried out on drivers of BIM in the architecture, engineering and construction (AEC) industry, and these studies have been important in understanding BIM. However, there is underrepresentation of contexts in extant studies. This contradicts the notion that BIM is highly contextual which is evidenced by disparities in adoption across practice and countries (Gu & London, 2010). Papadonikolaki (2017) emphasized the need to contextualize BIM studies as factors such as institutional logics vary across contexts. The point of departure of this present study from extant studies lies in its aim to contextualize BIM drivers with size and firms' location. It is premised on the basis that there exists a digital divide between developed and developing countries and between large firms and small and medium-sized enterprises (SMEs) (Dainty *et al.*, 2017; Saka *et al.*, 2022).

This study is significant as it aims to contribute to extant studies on the contextualist perspective of BIM drivers (Whetten, 1989). Although extant studies have been conducted on BIM drivers in SMEs, large firms, developed and developing countries separately. Nevertheless, there is a dearth of studies of BIM drivers perception between SMEs and large firms and between developed countries and developing countries. Answers to these questions would be beneficial in highlighting the nuanced differences between these contexts which would influence policies and practices in the AEC industry. Consequently, the objectives of the study are the following: a) to identify drivers of BIM in the AEC industry b) to identify the drivers of BIM in SMEs and large firms c) to compare BIM drivers in SMEs and large firms d) to identify the drivers of BIM in developing and developed countries e) to contrast the drivers of BIM in developing and developed countries.

Literature Review

Extant studies have highlighted the drivers, motivational factors, and critical success factors of BIM implementation in the AEC industry. In developed countries, Eadie *et al.* (2013) evaluated the drivers of BIM adoption in the UK construction industry and identified BIM benefits, government pressure and competitive pressure as the most important drivers. However, the study was conducted before the 2016 BIM mandate deadline by the government. Ahmed *et al.* (2017) categorized the BIM drivers into external and internal environment characteristics and BIM characteristics. The study found coercive pressure, compatibility, relative advantage, organisation readiness, top management and organisation size as significant drivers in the decision to adopt BIM in the UK architectural firms. However, the study was conducted in architectural firms alone. Boktor *et al.* (2014) identified the availability of BIM protocols and training modules as important strategies to improve BIM implementation in mechanical contracting firms in the US.

In developing countries, Ahmed and Suliman (2019) revealed that environment-related drivers and people-related drivers are responsible for driving BIM in the Bahrain construction industry. However, Ahuja *et al.* (2016) did not find environment-related drivers influential on BIM in the Indian construction industry, rather, trialability, BIM expertise and top management support were found to be significant (Ahuja *et al.*, 2018). Ding *et al.* (2015) found motivation, technical defects and BIM expertise to be significant, however, top management support was not considered as a key determinant of BIM adoption by the architects in the Chinese context. Similarly, Ma *et al.* (2020) reported well-defined objectives, financial support, capabilities and skills as the top drivers from the perspective of Chinese practitioners. Also, Chan *et al.* (2019a) identified client acceptance, organisation support and government support as the top critical success factors for BIM in contrary to Won *et al.* (2013).

In other developing economies, Ozorhon and Karahan (2017) highlighted BIM expertise, top management support and Information and Communication Technology (ICT) capability of the organisation as the top critical success factors in the Turkish context. Liao and Teo (2018) identified leadership support, collaborative design, training and change of workflow as the top drivers in the Singapore AEC industry. Abubakar *et al.* (2014) reported BIM expertise, clients' demand, organisation readiness, top management support, and financial resources are the drivers of BIM in the Nigerian context. Although there are often juxtapositions between studies from developing countries and findings from developed countries, there are few or no studies that have explicitly collected data from different contexts in the same research study. Thus, there is no uniform basis for comparison in those extant studies as each study is unique.

On studies relating to the size of firms, Saka *et al.* (2020) explored the drivers of BIM from the perspective of SMEs but there was no comparison with large firms. In addition, Gledson *et al.* (2012) asserted that there is a significant difference between BIM implementation barriers in SMEs and large firms in the UK construction industry. Similarly, Jaradat and Sexton (2016) found the size of firms to be significant in the perception of BIM in architectural firms in the UK. Other extant studies (Loveday *et al.*, 2016; Hong *et al.*, 2019) also corroborated the influence of firm size in the BIM adoption process, however, much is not known about the differences and similarities in BIM drivers perception with varying firm size.

In summary, the drivers of BIM stems from the internal environment, external environment, BIM characteristics and benefits. The internal environment drivers are drivers that are related to the organisation capabilities, stakeholders' behaviour and culture towards BIM adoption. Examples are desire for innovation, availability of trained personnel, organisation culture, top management support, and organisation financial capability. The external environment drivers of BIM often serve as a push from the stakeholders that firms depend on or have relationships with (direct and indirect). Examples are government mandate and support, pressures from clients and competitors, support from software vendors and availability of standards (Ahmed & Kassem, 2018; Chan *et al.*, 2019b). On the other hand, characteristics and BIM benefits encompass drivers that are inherent in BIM usage, the outcome of BIM usage, and the integration of BIM with other technologies. These are well reported in extant studies such as interoperability, visualization, positive return on investment, reduced construction cost and time, integration with GIS, IoT, BIM usage in FM and infrastructure (Elshafey *et al.*, 2020; Ozturk, 2020; Dahanayake & Sumanarathna, 2021).

Lastly, there is no doubt that there are many previous studies on BIM drivers, however, these studies are built on one another. Drivers identified in previous studies are often used in other studies, although in different contexts. Thus, this study focuses on identifying BIM drivers in extant studies and subsumed them into major drivers for evaluation. The significant contribution of this study lies in its contextualization of BIM; presentation of the perspective of underrepresented SMEs in BIM studies; evaluation of BIM drivers based on locations and firm size.

Research Methodology

This study adopted a quantitative research approach via an international questionnaire survey to solicit responses from professionals in architectural, engineering, and construction (AEC) firms across the globe. It is adopted in this current study for it is grounded in a positivist methodological perspective (Hair *et al.*, 2010), employed in assessing experts opinion and its offer of generalization (Yevu *et al.*, 2021). Also, the study aims to evaluate BIM drivers between large firms and SMEs and between developing and developed countries, thus a questionnaire survey would provide a wider reach for the study. Consequently, the targeted respondents are professionals in firms from developing and developed countries. The study was conducted in sequential steps which are retrieving and reviewing articles; developing of questionnaire and pilot survey; questionnaire modification and main survey administration as shown in Figure 1.

Insert Figure 1: Overall Research Approach for the Study

Scopus database was searched using the '*BIM driver*' within article title, abstract and keywords. A total of 81 documents were identified after refining the search results. The identified documents were reviewed, and 29 BIM drivers that were consistently reported in the extant studies (at least two) were identified. A questionnaire form which consist of two sections was developed to collect data about the respondents and to evaluate the BIM drivers using Likert Scale. The questionnaire was face validated by 5 experts (2 senior construction management researchers and 3 construction professionals) in the construction industry and a pilot survey was carried out with 25 respondents from the industry and academia. Sequel to the validation and pilot survey, the following suggestions were given to improve the quality of the survey: a) Merging drivers with similar meaning to have 20 major drivers b) Using employee size to measure firms' size for simplicity and uniformity c) location of firms should be country-based for categorization. The modified drivers before administering the main survey are as shown in Figure 2 and Appendix A.

The survey was hosted online, and a fillable PDF form was developed to reach a wider audience. The questionnaire was sent to AECO firms and professionals across the 6 continents of the globe through social media platforms, professional groups (LinkedIn groups) and emails. Snowballing technique was also adopted which is using respondents to contact other respondents (Streeton *et al.*, 2004) to reach a wider audience.

Insert Figure 2: Drivers of BIM adoption

Per Central Limit Theorem, a sample size of 30 is often deemed sufficient (Sproull, 1995; Ott & Longnecker, 2015) in a survey. Similar international survey studies have 51 responses (Adabre & Chan, 2019), 77 responses (Osei-Kyei & Chan, 2017), 99 (Kassem & Succar, 2017) and 104 (Darko *et al.*, 2017). However, Rummel (1988) suggested an item to response ratio of 1:4, Schwab (1980) suggested 1:10. Consequently, the survey was administered far and wide to reach respondents from diverse backgrounds in the AEC industry. A total response of 357 was recorded, however, only 228 responses gleaned from 26 countries are complete and meet the stated criteria of the survey. This is deemed sufficient as the responses are from diverse professions, firms' sizes, locations and higher than responses from similar studies. Also, the Kaiser-Meyer-Olkin (KMO) sampling adequacy test was conducted and the values are above the minimum threshold which signifies that the sample are adequate for structure dectection (Kaiser, 1974; Dunteman, 1989).

Data analysis techniques

Although this study adopted a comparative analysis approach, cronbach's alpha reliability test (for the relianility of data collection instrument), mean score (to rank and compare the drivers), rank agreement factor (to evaluate the agreement in ranking between the contexts and computed using equation 1 to 5) , Man-Whitney U test (to test if there is a statistically significant difference between the median value of the same driver between two groups), and factor analysis (for grouping and easy comaparative analysis) were employed in analysing the data for easy comparison.

$$R_i = \sum_{i=1}^{N}(R_{ij}) \quad (1)$$

$$R_{j2} = \frac{1}{N}\sum_{i=1}^{N}(R_{ij}) \quad (2)$$

$$RAF = \frac{\sum_{i=1}^{N} |R_{i1} - R_{i2}|}{N} \quad (3)$$

$$RAF_{max} = \frac{\sum_{i=1}^{N} |R_{i1} - R_{j2}|}{N} \quad (4)$$

$$PD = \frac{\sum_{i=1}^{N} |R_{i1} - R_{j2}|}{\sum_{i=1}^{N} |R_{i1} - R_{j2}|} X\ 100 \quad (5)$$

Data analysis

This section presents the data analysis for the collected responses from the surveyed firms.

Demographic Distribution

Table 1 shows the information about the firms and these firms were from diverse practices. About 14% of the respondents are project managers, approximately 14% are architects and quantity surveyors. Also, 13% are BIM managers in their respective firms. More than 70% of the firms have been in existence for more than 10 years, there is about equal representation from the SMEs and large firms. Furthermore, the organisation practices vary from contracting (36%), to consultancy (33%) and includes clients' firms, subcontractors and suppliers. These firms have diverse locations for their main practice across the six continents of the globe. The respondents' locations are grouped into developed and developing countries per United Nations (2020).

Insert Table 1: Demographic information about survey participants.

Figure 3 shows the status of BIM adoption in the surveyed firms and more than 50% of the firms are using BIM, and 2% have used BIM, whilst 40% are planning to adopt BIM in their firms.

Insert Figure 3: Status of BIM adoption of participating firms.

About 32% of the firms have been using BIM for more than 6 years, and 21% have been using BIM for less than 6 years, whilst only 4% and 2% have been using it for more than 11 years and 15 years respectively (Figure 4).

Insert Figure 4: Years of BIM usage of participating firms.

Figure 5 also shows the usage of BIM on the firm's projects. 58% of the firms are currently implementing BIM on their projects. About 12% have attained implementation on all projects, about 20% are using it on the minority of their projects, whilst about 27%

are using it on the majority of their projects. Evidently, these firms have experience in BIM implementation to give an opinion on the subject matter of the survey.

Insert Figure 5: Level of BIM usage on construction projects.

Cronbach's Alpha Reliability test

The alpha value for the SMEs category, large firms, developed countries and developing countries are 0.97, 0.95, 0.96 and 0.96 respectively.

Rank Agreement Factor (RAF)

The ranking of the BIM drivers using the mean score and SD for the SMEs and large firms are shown in Table 2. Also, the RAF is presented in the last column of the table using equations 1 to 5.

Thus, $\boldsymbol{PD} = \frac{\mathbf{68}}{\mathbf{172}} \times \mathbf{100} = \mathbf{39.53}\%$

Insert Table 2: Drivers ranking results between the SMEs and large firms.

Similarly, Table 3 presents the case of developing and developed countries. The percentage of disagreement between the two contexts is computed as:

$$\boldsymbol{PD} = \frac{\mathbf{108}}{\mathbf{152}} \times \mathbf{100} = \mathbf{71.05}\%$$

Insert Table 3: Drivers ranking results between firms from developed countries and developing countries.

Mann-Whitney U Test

Table 4 shows the Mann-Whitney U test for large firms and SMEs. There are no significant differences between the median values of the drivers between the SMEs and large firms except for 'Desire for innovation in the organisation' (D3), 'Availability of well-trained staff in the organisation' (D5), 'Awareness on BIM by project stakeholders' (D7), and 'Effective collaboration and coordination among project participants' (D18)

Insert Table 4: Results of the Mann-Whitney U Test between the SMEs and large firms

Similarly, the Mann-Whitney test was conducted for developed and developing countries. However, there exists a significant difference between the median value of the drivers between the two groups except in 'Client's demand for BIM on projects' (D4). The mean rank indicates the direction of difference when the result is statistically significant (Pallant, 2011). Thus, the group with a higher mean rank perceives the driver to be more important than the other group.

Factor analysis

SMEs and large firms

The KMO value is 0.925 (SMEs) and 0.915 (large firms) which is above the minimum threshold of 0.50 (Dunteman, 1989). The BTS is 1646.428 (SMEs) and 1175.719 (large firms) at a significance value of 0.000 and df of 190 which implies that the data is suitable for factor analysis as the correlation matrix is not an identity matrix (Chan & Choi, 2015). Varimax rotation method was used and a total of 2 clusters and 3 clusters were extracted for the SMEs and large firms respectively. Table 5 shows the clusters for the SMEs which account for 71.15% of the total variance and are well above the minimum threshold of 60% (Malhotra & Dash, 2016)

Insert Table 5: Factor clustering of BIM drivers in SMEs.

Similarly, 3 clusters representing 65.51% of the total variance were extracted from large firms' datasets. Items with factor loading less than 0.50 are dropped from the clustering and the closer the factor loadings of the items to 1 the more influential it is in the cluster. They are categorized into 'technical related drivers', 'contractual & economic-related drivers,' and 'external & internal pressure'.

Developed countries and developing countries.

The KMO value is 0.911 (developed countries) and 0.93 (developing countries) while the BTS is 1306.483 (developed countries) and 1339.432 (developing countries) at a significance value of 0.000 (df = 190). 2 clusters representing 62.66% of the total variance were extracted from the developed countries data set as shown in Table 6. The clusters are *'technical & economical related drivers'* and '*internal & external -related drivers'*.

Insert Table 6: Factor clustering of BIM drivers in developing countries and developed countries.

Similarly, 2 clusters representing 66.00% of the total variance were extracted from the developing countries dataset. The clusters are *'technical & economical related drivers'* and '*external & internal-related drivers'*.

Discussion of Survey Findings

Comparative analysis of BIM adoption drivers between SMEs and large firms

Drivers of BIM implementation in the AEC were evaluated by the identified firms across the globe and these firms have sufficient experience as most of the firms have implemented BIM on their projects or are planning to adopt BIM. The SMEs ranked '*Availability of well-trained staff in the organisation*' (D5), '*Clear BIM benefits'* (D8) and '*Awareness on BIM by project stakeholders'* (D7) top drivers of BIM while the large firms '*Supportive organizational culture and top management support*' (D6), '*Government support and mandate'* (D1) and '*Availability of well-trained staff in the organisation*' (D5) as the top drivers of BIM. The perception of the SME reflects that they perceived the availability of well-trained staff in the organisation as very important because they have limited access to resources to train their staff which is in tandem with the findings of Awwad *et al.* (2020). These SMEs also perceived clear BIM benefits and awareness of BIM by project stakeholders to be important which relates to the observability of BIM benefits and BIM knowledge respectively. This corroborates the findings of Saka and Chan (2020) that lack of BIM benefits and awareness are major barriers and the need for clear BIM benefits and awareness are major drivers.

Implementation of BIM for these SMEs is risky and capital intensive, thus adequate knowledge and clear information about what they would benefit from its implementation would encourage these firms. On the other hand, the large firms perceived top management support, government mandate and availability of trained staff to be the top drivers of BIM which are in tandem with Chan *et al.* (2019a). However, the large firms considered the government support and mandate to be more important than the SMEs, this reflects the perception of the SMEs that the government mandate has little or no impact on their use of BIM because they often do not operate on projects with BIM mandate as submitted by (Lam *et al.*, 2017)

The RAF indicated of difference between the ranking by the SMEs and the large firms, however, the result does not present the differences in the ranking. Thus, Mann Whitney U was employed to evaluate the differences between the two groups. The test revealed that they differ as regards '*Desire for innovation in the organisation'* (D3), '*Availability of well-trained staff in the organisation*' (D5), '*Awareness on BIM by project* *stakeholders'* (D7), and '*Effective collaboration and coordination among project participants*' (D18). This is an interesting new finding that sheds light on the differences varying firms' size. Albeit the SMEs and the large firms considered these drivers to be of importance, however, there are differences in their perceptions. For instance, there is a difference in the level of awareness of BIM in the SMEs and the SMEs are often lagging (Saka & Chan, 2021), thus it is not surprising to see differences in their perceptions as regards desire for innovation, availability of trained staff and awareness. Similarly, the projects on which these firms operate and implement BIM often differs and this could explain the differences in their perception of collaboration and coordination (Lam *et al.*, 2017).

In addition, factor analysis was employed to reduce the drivers into groups with common themes for SMEs and large firms. The drivers were grouped into 2 clusters representing 71.5% of the total variance for the SMEs and into 3 clusters representing 65.5% of the total variance for the large firms. The SMEs clusters are '*internal and external drivers',* and '*Technical & economic-related drivers*' while the large firms' clusters are '*Technical-related drivers'*, '*Contractual & economic-related drivers*' and '*External and internal pressure'.* A major point of departure is the emphasis placed on the technical related drivers by both the large firms and SMEs. The large firms considered the technical related drivers to be more important and this could be as a result of the complexity of projects that they are involved in compared to the SMEs. This is in agreement with the findings of Jaradat and Sexton (2016) that large firms have practice-based perception with a focus on technology and related practices. Also, the major driver-category which is the internal and external drivers cluster in the SMEs has the 'desire for innovation' and 'top management support' to be the top factors which reinforces Shelton *et al.* (2016), Thorpe *et al.* (2009) and Babatunde *et al.* (2018) that intrinsic benefits and desire are major drivers of innovations in the SMEs. Thus, the SMEs need to focus on their internal, and external environment to adopt BIM successfully per Manley (2008) findings in the SMEs. This also broadly agree with the studies of Sexton *et al.* (2006), and Sexton and Barrett (2010) that SMEs can adopt technology successfully with the right blend of the technology with the internal and external environment of the firms. On the other hand, these categories are considered the least significant out of the driver clusters by the large firms. Also, another point of difference is the contractual related cluster in the large firms which highlighted the importance placed on it by the large firms as the project they are involved in are often more complicated compared to the SMEs and a clear framework such as legal-related framework is needed. This is in agreement with Gledson *et al.* (2012) that SMEs and large firms perceive legal constraints differently.

Comparative analysis of BIM drivers between developing countries and developed countries.

Firms in developing countries ranked '*Clear BIM benefits'* (D8), '*Awareness on BIM by project stakeholders*' (D7), and '*Availability of well-trained staff in the organisation*' (D5) as the top drivers of BIM in the AEC while the firms in developed countries ranked '*Client's demand for BIM on projects*' (D4), '*Supportive organizational culture and top management support'* (D6) and '*Availability of well-trained staff in the organisation'* (D5) as the top drivers. Ranking the clear BIM benefits reflects the perception that there is a need for observability of BIM benefits in developing countries which are BIM infants and in tandem with the findings of Saka and Chan (2019b) that there is a need for more empirical studies on BIM benefits from developing countries to show the tangibility of BIM benefits. Also, the firms from developing countries prioritize awareness as the level of awareness in such countries are low compared to developed countries, however, they both prioritized the need for BIM expertise in firms that agrees with the findings in extant studies from developing (Ozorhon & Karahan, 2017) and developed countries (Hong *et al.*, 2018) that knowledge and education is a major BIM driver. On the other hand, the firms in developed countries ranked clients' demand and top management support as top drivers which are related to the government mandate and support for BIM on projects which would encourage management and clients (including government parastatals) to embrace BIM adoption which is in contrast to developing countries where government support and mandate are often lacking (Makabate *et al.*, 2021).

The RAF analysis revealed that there is a wide difference between the perception of the developed and developing countries which could be related to the widening digital divide between the two contexts as established in extant studies (Jung & Lee, 2015; Olawumi & Chan, 2019; Saka & Chan, 2019a). The Mann Whitney U test, on the other hand, revealed that there are significant statistical differences between the two groups in the ranking of all the drivers except for '*Client's demand for BIM on projects'* (D4) where there seems to be similarity in the ranking. It is worthy of note that the differences revealed by the Mann witney U do not connote that one of the group does not consider the drivers to be important, rather it shed light to the fact there are fundamental differences in the way they considered the importance of these drivers (Pallant, 2011). This is very germane as it revealed that the AEC industry in these two contexts are wide apart and have a different perspective regarding BIM adoption and implementation.

Similarly, factor analysis was employed to reduce the drivers of BIM in each context. 2 clusters accounting for 63% of the total variance and 2 clusters accounting for 66% of the total variance were extracted from the developing and developed countries responses respectively. The clusters in the developing countries are '*Technical and economic related'* and '*Internal & external-related drivers*', while the developed countries clusters are also '*Technical and economic related'* and '*external & Internal -related drivers*'.

Albeit these two contexts have similar clusters, however, there are differences in the ranking and composition of these clusters. The top factors in the '*Technical and economic related'* cluster of the developing countries are '*Technical support from software vendors'* (D16), '*Availability of BIM standards'* (D10) and '*Ease of use of BIM tools'* (D13) while on the other hand in developed countries, the top factors are '*Ease of use of BIM tools*' (D13), '*Availability and affordability of BIM tools'*(D14) and '*Organisation ICT capability'* (D12). Also in the second cluster in developing countries composed of '*Desire for innovation in the organisation'* (D3), '*Government mandate*' (D1) and '*Competitive pressure (Adoption by competitors)*' (D2) while the cluster in developed countries composed of '*Government support and mandate*' (D1), '*Development of appropriate legal framework for BIM use and deployment in projects'* (D17) and '*Competitive pressure (Adoption by competitors)*' (D2). These highlighted the similarities and subtle differences between the firms in developing countries and developed countries. For instance, there is more emphasis on technical support in the developing countries than the developed countries, and more emphasis on the legal framework in the developed countries than in the developing countries. The lack of emphasis on the legal framework in developing countries could be related to the low level of BIM implementation in most of those countries compared to developed countries where there is a high level of implementation and the need for a clear legal framework (Arensman & Ozbek, 2012; Abd Jamil & Fathi, 2018, 2020). Also, regardless of the contexts, government support and knowledge are considered important drivers of BIM in the AEC.

Conclusions

The study contributes to the extant studies by introducing context at a global level. It highlighted the differences and similarities between the perceptions of these contexts. It was revealed that albeit the SMEs and large firms are in the same AEC industry, there still exist some notable differences in their perceptions of BIM drivers. The SMEs considered the availability of resources and the benefits derived from BIM as the major drivers of BIM in contrast to large firms perception of organizational culture and top management support. Similarly, the study revealed that the perception of these firms is different when it comes to the desire for innovation, trained personnel, BIM awareness and the need for effective collaboration. These revelations are key to understanding the varying perception of these firms and how to strategize to drive BIM successfully. On the other hand, the study shows that there is a significant difference between the developed and developing countries which could be related to the deepening digital divide between the two contexts. The developing countries ranked benefits, awareness and available resources as the top drivers in contrast with client demand and organizational culture in developed countries.

Taken together, this study sheds light on the disparities in the effectiveness of BIM strategies in relation to the contexts . Also, strategies that worked in developed countries may not be effective in developing countries. There is a pressing need to determine the level of applicability of best practices which would be determined by the features and forces operating in the contexts. Another implication of the finding is the need to examine the effect of BIM mandate in developed countries and draw lessons for developing countries. However, attention should be given to improving infrastructure and education in developing countries.

Research Data

All data, models or codes that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix A: Drivers of BIM adoption as identified by literature review

Drivers	**References**
D1	1,2,3,4
D2	2,3,4,5
D3	1,2,4,10
D4	6,7,8,2,3,4,9,10
D5	11,12,9,13,14,15
D6	1,11,3,12,13,14,5,15
D7	7,16,17,18,19
D8	8,16,4,20
D9	21,22,19
D10	6,22,24,23
D11	18, 10
D12	17,21,25,19

D13	8,13,14,25,22,27
D14	16,4,18,25,22,27
D15	20,14,28,22,27
D16	2,28,21,24
D17	23,29,30,35,31,28,32,22
D18	35,31,13,28,22,19,27
D19	2,35,20,9,34,13,28,25,22,19,27
D20	29,20,13,28,25,32,22,27

1:Ahmed & Kassem, 2018; **2**:Cao et al., 2014;**3**: Chen et al., 2019;**4**: Eadie et al., 2013b;**5**: Saka et al., 2020;**6**: Abubakar et al., 2014 ;**7**: Ahuja et al., 2018 ;**8**: Aibinu & Venkatesh, 2014 ;**9**: Hong et al., 2018 ;**10**:Saka & Chan, 2020a;**11**:Ahuja et al., 2016; **12**:Ding et al., 2015;**13**: Juan et al., 2016; **14**:Lee et al., 2015 ; **15**:Son et al., 2015;**16**: Babatunde et al., 2018 ;**17**:Bosch et al., 2015 ;**18**:Hosseini et al., 2016 ;**19**: Ozorhon & Karahan, 2017;**20**:Hong et al., 2019;**21**:Chan et al., 2019a ;**22**:Olawumi & Chan, 2019a;**23**: Amuda-Yusuf, 2018 ;**24**: Saka et al., 2019a ;**25**: Mom et al., 2014 ;**26**: Oladapo, 2007;**27**: Won et al., 2013 ;**28**:Mahamadu et al., 2014 ;**29**:Arensman & Ozbek, 2012;**30**:Bui et al., 2016; **31**:Hadzaman et al., 2015;**32**:Olatunji, 2011; **33**:Liao & Teo, 2018; **34**: Hope & Alwan, 2012; **35**:Chan, 2014

Table 1: Demographic information about survey participants

Characteristics	Percentage (%)
Main Practice	
Project Manager	14.04
Architect	13.6
Quantity Surveyor	13.6
BIM Manager	13.16
Developer	10.96
Structural/Civil Engineer	9.65
Builder	8.77
Facility Manager/Estate Surveyor	8.77
Mechanical/Electrical Engineer	7.46
Years of organisation establishment	
Less than 6 years	8.77
6 to 10 years	17.54
11 to 15 years	8.33
16 to 20 years	28.95
More than 20 years	36.4
Firm Size	
Small and Medium-Sized Enterprises (SMEs)	50.7
Large firms	49.3
Organization Type	
Contracting	35.53
Consultancy	32.89
Client	14.47
Subcontractor	10.09
Supplier	7.02
Continent of practice	
Asia	41.23
Africa	19.3
Europe	16.23
Australia	8.33
South America	7.89
North America	7.02
Location	
Developed countries	48.67
Developing countries	51.32

Table 2: Drivers ranking results between the SMEs and large firms

No	Large Firms			SMEs			Rank Agreement Analysis		
Drivers	**Mean**	**SD**	**Rank**	**Mean**	**SD**	**Rank**	R_i	$(R_{i1} - R_{i2})$	$\lvert R_{i1} - R_{j2} \rvert$
D1	3.99	1.08	2	3.94	1.27	18	20	16	1

D2	3.76	1.06	19	3.98	1.09	16	35	3	14
D3	3.82	0.96	13	4.16	1.05	5	18	8	3
D4	3.94	1.19	6	4.13	1.27	7	13	1	8
D5	3.99	1.05	3	4.22	1.13	1	4	2	17
D6	4.10	0.98	1	4.18	1.06	4	5	3	16
D7	3.92	0.95	7	4.20	1.01	3	10	4	11
D8	3.99	1.06	4	4.21	1.06	2	6	2	15
D9	3.65	1.17	20	3.94	1.17	19	39	1	18
D10	3.80	1.12	15	4.04	1.06	13	28	2	7
D11	3.87	1.13	10	4.09	1.19	10	20	0	1
D12	3.81	1.07	14	3.95	1.23	17	31	3	10
D13	3.80	1.15	16	4.00	1.15	14	30	2	9
D14	3.87	1.07	11	4.10	1.12	9	20	2	1
D15	3.86	1.03	12	4.11	1.09	8	20	4	1
D16	3.77	1.05	17	3.99	1.17	15	32	2	11
D17	3.88	1.05	9	4.05	1.05	12	21	3	0
D18	3.92	0.93	8	4.15	1.06	6	14	2	7
D19	3.98	0.90	5	4.07	1.05	11	16	6	5
D20	3.77	1.02	18	3.83	1.04	20	38	2	17
								$\sum_{i=1}^{n}(R_{i1} - R_{i2}) = 68$	$\sum_{i=1}^{n}\lvert R_{i1} - R_{j2}\rvert = 172$

Table 3: Drivers ranking results between firms from developed countries and developing countries.

No	**Developed Countries**			**Developing Countries**			**Rank Agreement Analysis**		
Drivers	**Mean**	**SD**	**Rank**	**Mean**	**SD**	**Rank**	$\boldsymbol{R_i}$	$\boldsymbol{(R_{i1} - R_{i2})}$	$\boldsymbol{\lvert R_{i1} - R_{j2}\rvert}$
D1	3.83	1.18	4	4.12	1.16	16	20	12	1
D2	3.73	1.09	12	4.03	1.04	19	31	7	10
D3	3.74	1.02	11	4.27	0.94	8	19	3	2
D4	4.03	1.13	1	4.04	1.34	18	19	17	2
D5	3.86	1.03	3	4.37	1.11	3	6	0	15
D6	3.99	1.00	2	4.31	1.01	6	8	4	13
D7	3.76	1.01	10	4.38	0.86	2	12	8	9
D8	3.81	1.09	5	4.42	0.93	1	6	4	15
D9	3.61	1.17	18	4.00	1.15	20	38	2	17
D10	3.67	1.07	14	4.19	1.06	11	25	3	4
D11	3.80	1.15	7	4.18	1.15	13	20	6	1
D12	3.56	1.11	20	4.24	1.08	9	29	11	8
D13	3.66	1.11	16	4.17	1.14	15	31	1	10
D14	3.67	1.01	15	4.33	1.09	4	19	11	2
D15	3.81	0.96	6	4.18	1.15	12	18	6	3
D16	3.63	1.10	17	4.17	1.06	14	31	3	10
D17	3.72	1.07	13	4.24	0.96	10	23	3	2
D18	3.77	0.93	8	4.32	1.00	5	13	3	8
D19	3.77	1.03	9	4.31	0.84	7	16	2	5
D20	3.58	1.05	19	4.05	0.95	17	36	2	15
								$\sum_{i=1}^{n}(R_{i1} - R_{i2}) = 108$	$\sum_{i=1}^{n}\lvert R_{i1} - R_{j2}\rvert = 152$

Table 4: Results of Mann-Whitney U Test between the SMEs and large firms

Drivers	Large Firms	SMEs	Mann-Whitney U	Z-value	p-value	Conclusion to H_0
	Mean Rank					
D1	82.70	84.32	3377.000	-0.229	0.819	Accept
D2	77.84	89.30	2968.500	-1.638	0.101	Accept
D3	73.84	93.40	2632.500	-2.774	0.006	**Reject**
D4	78.30	88.82	3007.500	-1.521	0.128	Accept
D5	76.41	90.76	2848.500	-2.067	0.039	**Reject**
D6	80.08	87.01	3156.500	-0.998	0.318	Accept
D7	75.59	91.60	2779.500	-2.278	0.023	**Reject**
D8	77.82	89.32	2966.500	-1.652	0.099	Accept
D9	77.21	89.95	2915.500	-1.779	0.975	Accept
D10	78.09	89.04	2989.500	-1.543	0.123	Accept
D11	77.95	89.18	2978.000	-1.595	0.111	Accept
D12	78.74	88.37	3044.500	-1.352	0.176	Accept
D13	78.81	88.30	3050.000	-1.336	0.182	Accept
D14	77.00	89.07	2905.000	-1.715	0.086	Accept
D15	76.77	90.40	2878.500	-1.927	0.054	**Reject**
D16	77.50	89.65	2940.00	-1.704	0.088	Accept
D17	79.41	87.69	3100.500	-1.168	0.243	Accept
D18	76.34	90.84	2842.500	-2.059	0.040	**Reject**
D19	79.59	87.51	3115.500	-1.126	0.260	Accept
D20	81.92	85.12	3311.000	-0.452	0.651	Accept

Table 5: Factor clustering of BIM drivers in SMEs

Code	Group	Factor loading	Eigenvalues	% of variance explained	Cumulative % of variance explained
Factor Cluster 1: Internal and external drivers			**12.867**	**64.336**	**64.336**
D3		0.797			
D6		0.783			
D17		0.776			
D2		0.743			
D7		0.743			
D4		0.729			
D5		0.727			
D19		0.726			
D18		0.721			
D1		0.702			
D12		0.628			
Factor Cluster 2: Technical and economic related drivers			**1.364**	**6.819**	**71.154**
D10		0.828			
D9		0.815			

D16	0.797
D14	0.796
D8	0.791
D13	0.739
D20	0.645
D11	0.584
D15	0.562

Table 6: Factor clustering of BIM drivers in developing countries.

Code	Group	Factor loading	Eigenvalues	% of variance explained	Cumulative % of variance explained
Factor Cluster 1: Technical and economic related drivers			**11.084**	**55.42**	**55.42**
	D16	0.841			
	D10	0.775			
	D13	0.773			
	D14	0.761			
	D8	0.751			
	D20	0.718			
	D9	0.701			
	D11	0.565			
	D12	0.549			
	D15	0.545			
Factor Cluster 2: Internal and external related drivers			**1.448**	**7.241**	**62.66**
	D3	0.781			
	D1	0.763			
	D2	0.722			
	D7	0.682			
	D5	0.678			
	D6	0.677			
	D4	0.674			
	D17	0.633			
	D19	0.600			
	D18	0.562			