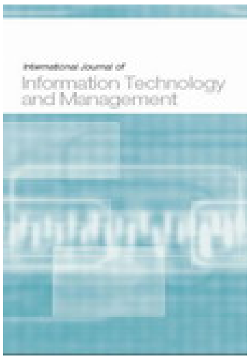

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If you cannot fly, then run: a model of BIM implementation taxonomies and thresholds

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If you cannot fly, then run: a model of BIM implementation taxonomies and thresholds

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Abstract: The barriers to BIM adoption are various and overpowering. These barriers should be continuously defeated through a recursive BIM implementation strategy and evaluation. The point of this paper is to recognise the key reduction indicators for tracking BIM adoption barriers and lay out whether the key reduction indicators will give a model of BIM implementation taxonomies and thresholds for assessing BIM implementation performance. Meta-analysis methodology was utilised to synthesise the diverse findings. These key reduction indicators were sorted into three BIM implementation thresholds: *BIM advanced industry*, *BIM emerging industry*, and *BIM frontier industry*. It was observed that BIM implementation taxonomies have various levels of the implementation plan, levels of market adequacy, and levels of goals. The study inferred that the proposed model would assist with smoothing out the necessities and instruct on the BIM implementation needs concerning different construction industries, most especially the developing construction industries.

Keywords: building information modelling; BIM; BIM implementation; BIM adoption; BIM adaptation; BIM application; BIM utilisation; BIM adoption barriers; BIM implementation taxonomies; BIM implementation thresholds.

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1 Introduction

Building information modelling (BIM) implementation and adoption involve national pride and efficiency (Migilinskas et al., 2013). As of now, the implementation and adoption of BIM are in the middle phase of examination and thought in practically all of the construction industries around the world (Kurul et al., 2013). Even though BIM implementation and BIM adoption are interrelated, both have different importance, scientific classification, and limits. While BIM implementation looks for BIM adoption through legislation and policies, BIM adoption, on the other hand, is concerned with BIM use or investigations through mastery and applications (Jin et al., 2015). BIM implementation is a progressive interaction since it looks to drive the reception of a cooperative approach to working in a fragmented industry and among experts or organisations that are stereotyped to work in isolation. These necessities and challenges make BIM implementation to be a multi-layered and complex process.

Similarly, the transformative idea of BIM adoption makes it not to be an immediate and frictionless subsidiary of BIM implementation. This is the case because BIM adoption is a progressive and ceaseless course of creating BIM capability and the process of applying BIM apparatuses and standards (Succar and Kassem, 2016). The ramifications of the connection between BIM implementation and BIM adoption is that BIM implementation in given construction industry should just be considered fruitful when BIM adoption is dynamic at the organisation level and the project level (Poirier et al., 2015). These clarifications feature fruitful BIM adoption as the objective of BIM implementation and furthermore cause to notice the way that BIM adoption barriers are the difficulties of BIM implementation (Miller et al., 2013; Silva et al., 2016). Consequently, it is laid out that the course of BIM implementation starts with the distinguishing proof of BIM adoption barriers (Proctor et al., 2013; Aarons et al., 2011; Arayici et al., 2011).

BIM adoption barriers are the deterrents or variables that disappoint the BIM implementation process (Arayici et al., 2011; Eadie et al., 2013). In other words, BIM adoption barriers allude to the shortfall of the highlights of BIM implementation in the specific construction industry. This infers that the accessibility of a portion of the highlights of BIM implementation in a construction industry means a decrease in BIM adoption barriers (that is, the progressive overcoming of BIM adoption barriers). In light of this comprehension, obviously, the advancement of the BIM implementation process relies generally upon how the limits or levels of decrease in BIM adoption barriers have been arranged. It likewise turns out to be certain that there should be a framework to follow whether the construction industry is conquering the hindrances to BIM adoption. Throughout this paper, the term key reduction indicator (KRI) will allude to the quantifiable factors for tracking the degree of decrease in BIM adoption barriers. The utilisation of KRI, as per McAuley et al. (2017), will give a benchmark to BIM implementation since they cause to notice the BIM adoption barriers that are essential over all others in giving experiences on BIM implementation process and how it very well may be sought after.

One more fundamental point on the side of the utilisation of KRI for BIM implementation is the distinction in market size and production capacity of construction industries (Ofori, 2001; Ruddock, 2002). This connotes that construction industries that are little in market size and production capacity cannot be anticipated to attempt the BIM implementation process at a similar level and rate as those with huge market size and production capacity. Along these lines, the thresholds of reduction (KRI) in BIM adoption barriers should perceive the distinctions in the market size and production capacity of various construction industries. In any case, an appropriate issue is a way to build BIM implementation thresholds involving the pace of decrease in BIM adoption barriers and making arrangements for market size and production capacity of various construction industries.

A few endeavours have been made to build BIM implementation thresholds (Kassem et al., 2013; Succar and Kassem, 2016; Edirisinghe and London, 2015; Abdullahi and Chan, 2019; Olawumi and Chan, 2019). These examinations have in general zeroed in on BIM capacity thresholds among the organisations and on construction projects. Though, the attention should be on BIM implementation thresholds through the decreased pace of BIM adoption barriers (Navendren et al., 2014). Moreover, the limits proposed in these investigations cannot educate strategy creators on the plan regarding suitable arrangements for BIM implementation. For instance, Kassem et al. (2013) proposed the accessibility of important publications, BIM knowledge content of the publications, and significance of the publications, as BIM adoption thresholds. While these thresholds have suggestions for the definition of BIM research goals, it gives no data detailing BIM implementation policies. Consequently, there are no obvious thresholds to order the BIM implementation-centred endeavours in the construction industry.

This paper seeks to remedy this issue by recognising the key decrease pointers for following BIM adoption barriers, and laying out whether the KRIs will give a model of BIM implementation taxonomies and thresholds for assessing BIM implementation endeavours. The general construction of this paper appears in five segments, including this introductory section. Section 2 starts by spreading out the theoretical background of the study and also presents the conceptual model for the study, while Section 3 presents the research methodology. Investigations of the outcomes and approval of the conceptual model are discussed in Section 4 and Section 5. Finally, Section 6 concludes the paper.

2 Research framework and background

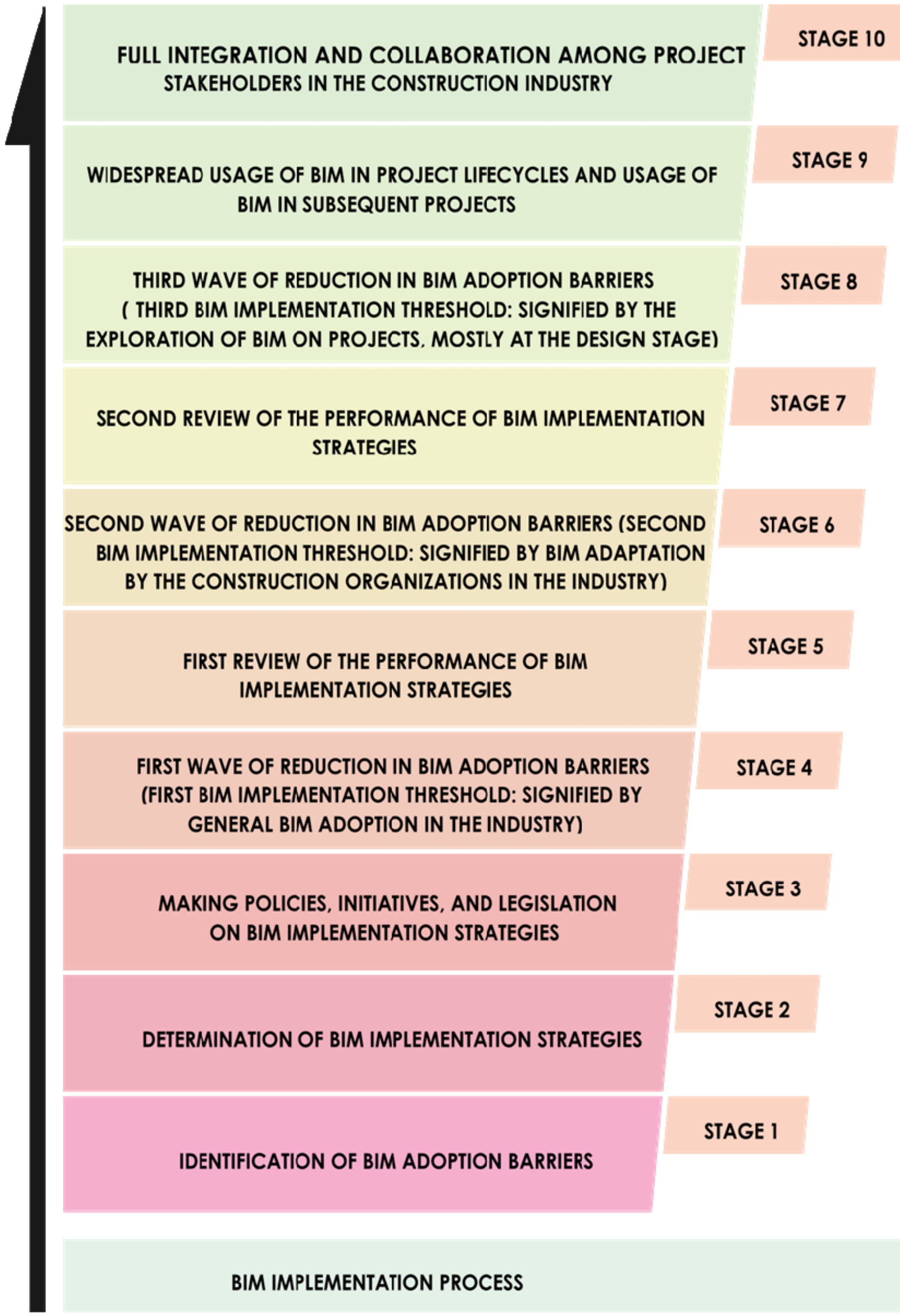
2.1 Theoretical framework

Studies on the identification of BIM adoption barriers and BIM implementation have been generally educated by the diffusion of innovation theory (DOI) or technology acceptance model attributable to the conceptualisation of BIM as technological innovation (Eadie et al., 2013; Stanley and Thurnell, 2014; Kekana and Aigbavboa, 2015). This has impacted the viability of BIM implementation and the dependability of the BIM adoption barriers (Gerges et al., 2017; Lyytinen and Damsgaard, 2001). Studies on BIM adoption like Succar and Kassem (2016) have affirmed that a solitary theoretical perspective is lacking for recognising huge BIM adoption barriers, substantially more driving the BIM implementation process. This implies that BIM implementation and BIM adoption barriers should be managed from the perspectives of various theories like institution theory (IT), DOI, and implementation process theory (IPT) (Dowsett and Harty, 2013; Migilinskas et al., 2013; Smith, 2014; Lindblad and Vass, 2015; Shou et al., 2015; Cheng and Lu, 2015; Gerges et al., 2017; Ho and Rajabifard, 2016; McAuley et al., 2017; Andrés et al., 2017; Attewell, 1992; Miller et al., 2013; Lyytinen and Damsgaard, 2001).

IPT proposes the course of starting and supporting the adoption of a system or innovation in an environment (Yetton et al., 1999; Leonard-Barton and Deschamps, 1988). The theory explains that no matter what the idea of the system or innovation to be carried out, there are hindrances in the primer phases of the implementation process and barriers that will forestall the supportability of the choice to take on the system or innovation (Al-Mashari and Zairi, 1999; Yetton et al., 1999). The identification of barriers to preliminary adoption of a system or innovation and implementation of specific approaches might start the adoption decision. Be that as it may, the progress of the implementation process or sustainability of the adoption decision is exceptionally subject to the elimination of implementation process blockages like change opposition, association pressures, assets requirements, and jobs clashes (Mumford, 1995; Bashein et al., 1994; Al-Mashari and Zairi, 1999; Towers, 1994; Bruss and Roos, 1993; Talwar, 1993). These implementation process blockages will be effectively gotten through the promotion of collaborative teamwork culture and management of change, opposition, capability, hierarchical design, and assets (Jackson, 1997; Hammer and Stanton, 1995; Hagel, 1993; Stow, 1993; Kettinger et al., 1997).

Drawing from IPT, this study contends that BIM implementation is a cycle. Along these lines, given the intricacy of BIM implementation as an idea, the theoretical take-off point for this study has been based on a blend of IPT, IT and DOI Theories. Accordingly, a point by point BIM implementation process is introduced in Figure 1.

Figure 1 Theoretical framework of the BIM implementation process (see online version for colours)



2.2 Theoretical model

This study gives a portrayal of BIM implementation taxonomies and thresholds through the comprehension of BIM implementation key terms and distinguishing proof of KRI. In the first place, the study proposes a theoretical model (model of BIM implementation taxonomies) that explains the distinctions and connections between BIM implementation and BIM adoption. The model of BIM implementation taxonomies depends on the accompanying four foundations through which the distinctions and connections between BIM implementation and BIM adoption are featured: BIM implementation process, level of the execution plan, level of market proficiency, and level of targets. The main foundation (BIM implementation process) summed up the stages expected to accomplish BIM implementation in the construction industry (as speculated in Figure 1) into the BIM implementation stage, BIM adaptation stage, and BIM utilisation stage. The subsequent foundation (level of implementation plan) portrays the proper execution plan for every one of the stages in the execution cycle. The third foundation (level of market proficiency) accentuated the level in the construction industry where the implementation plan will be compelling.

The last foundation (level of goals) in the model made sense of the targets that every one of the implementation stages and implementation plans is supposed to meet. The target at the implementation stage is to drive BIM adoption by diminishing the BIM adoption barriers. Nonetheless, the BIM implementation process as outlined in Figures 1 and 2 show that BIM implementation is in stages. These stages can additionally be summed up as primer BIM adoption and sustained BIM adoption (Kim et al., 2005; Proctor et al., 2013; Fixsen et al., 2005; Aarons et al., 2011; May, 2013; Linton, 2002). In light of Figure 2, a fundamental BIM adoption takes place when regulations and approaches are made on the use of BIM implementation in the construction industry. This might create energy in the construction industry, consequently prompting an investigation of BIM on construction projects, for the most part at the design stage (Enegbuma et al., 2014; May, 2013; Proctor et al., 2013).

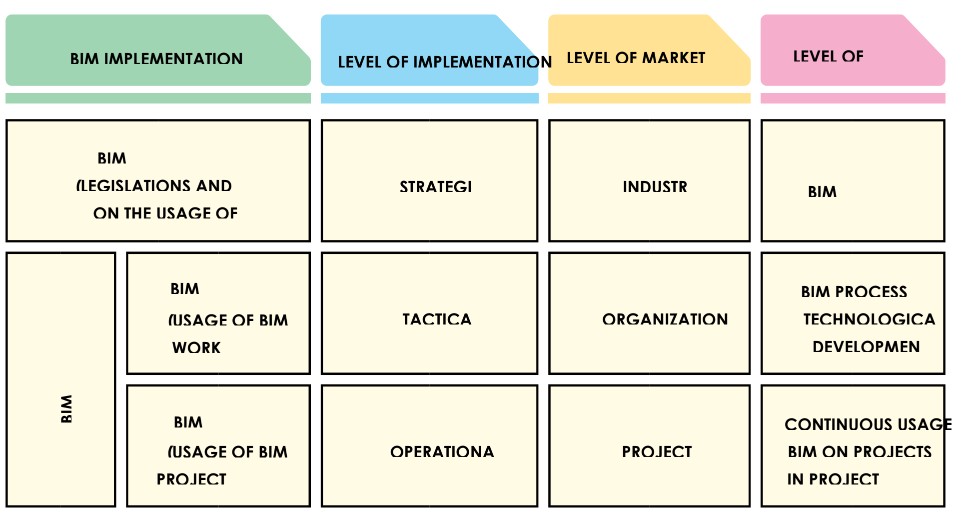
Sustained BIM adoption happens when BIM transformation happens in the construction organisations and when BIM is being utilised on construction projects (in all project lifecycles and on continuous projects) (Grover et al., 1995; Al-Mashari and Zairi, 1999; Towers, 1994; Kim et al., 2005). Basically, a fundamental BIM adoption is just effective at the industry level because of a decrease in BIM adoption barriers related to the industry. On the other hand, for sustained BIM adoption, the goals of the BIM transformation stage and BIM use stage are to drive BIM adoption by diminishing the BIM adoption barriers related to the construction organisations (development of BIM process and technologies) and BIM adoption barriers associated related with the construction projects (the nonstop utilisation of BIM on projects and in project lifecycles).

To a great extent, BIM adoption can comprehensively be sorted into boundaries to preliminary BIM adoption and barriers to sustained BIM adoption. A critical constraint of the past examinations on BIM adoption barriers is the emphasis on the obstructions to fundamental BIM adoption (Proctor et al., 2013; Aarons et al., 2011; Arayici et al., 2011; Eadie et al., 2013). As introduced in Figure 3, this study recognised the obstructions to sustained BIM adoption by utilising experiences from IPT. The study likewise coordinated the barriers to preliminary BIM adoption with the obstructions to sustained BIM adoption to foster a model of BIM implementation thresholds.

To develop the model of BIM implementation thresholds, the study utilised a three-venture process: BIM-frontiers, BIM-emerging, and BIM-advanced. The coordinated BIM adoption barriers (barriers to preliminary BIM adoption and barriers to sustained BIM adoption) were utilised as the reason for recognising the threshold for the BIM implementation process. Altogether, 33 integrated BIM adoption barriers were recognised as the critical rules (KRI) for a compelling BIM implementation in the construction industry. The model outlines the BIM implementation thresholds to classify construction industries as indicated by the pace of decrease in BIM adoption barriers as per their market size and production capacity. The thresholds indicated that construction industries can be delegated as BIM advanced industry, BIM-emerging industry, and BIM-frontier industry, contingent upon their degree of BIM implementation endeavours.

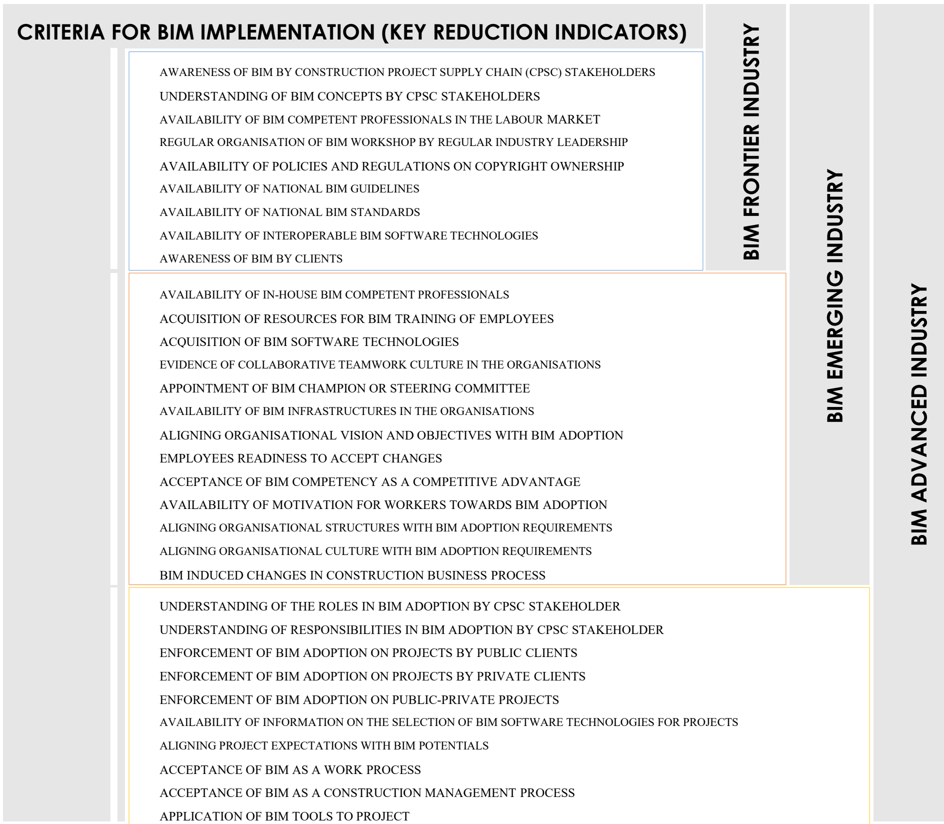
In the model, a BIM-frontier industry gives an image of the construction industry that is showing a degree of interest in BIM implementation. A BIM emerging industry portrays the construction industry that is gradually and consistently executing BIM; while a BIM-advanced construction industry depicts the construction industry that had implemented BIM, that is consummating the reception cycle in construction organisations, and that is propelling the use of BIM interaction and advances on construction projects. The criteria in every one of the thresholds are reliant and they portray the needs and arrangements that are expected to advance within the threshold. This intends that for the construction industry to climb the thresholds, the set of criteria (KPI) in the previous thresholds is more likely than not to be met. All construction industries that do not fall into any of the thresholds recognised in the model, might be considered non-BIM-implementing construction industries.

Figure 2 Model of BIM implementation taxonomies (see online version for colours)



The model helps assess the similar limit of various construction industries for BIM implementation. The model will likewise give inspiration to BIM implementation and give feasible thresholds for BIM implementation.

Figure 3 Model of BIM implementation thresholds (see online version for colours)



2.3 *Theoretical background*

2.3.1 *BIM implementation taxonomies*

A BIM implementation taxonomy depicts the phrasings and characterisation frameworks for the related ideas of BIM implementation. The current grouping frameworks for BIM implementation such as the Bew-Richards BIM maturity map (Barlish and Sullivan, 2012) have not obviously expressed the distinctions between BIM implementation and BIM adoption. These classification systems have given data fair and square of BIM appropriations in organisations and on construction projects, yet they have neglected to give data on the level of BIM implementation according to the BIM implementation prerequisites for lessening BIM adoption barriers. There is a wide gap between BIM implementation and BIM adoption. BIM adoption manages the potential and elements of BIM that users can adopt in their organisations or on their projects (Becerik-Gerber and Rice, 2010). BIM implementation, on the other hand, connects with the strategies, guidelines, and drives setup for driving BIM adoption (Jin et al., 2015). According to Gerges et al. (2017), BIM implementation could be in an advanced stage; while BIM adoption would stay in its beginning phase in the same construction industry.

An unequivocal system of BIM implementation taxonomy should be laid out on an unmistakable comprehension of the meaning of BIM implementation and BIM adoption (Matarneh and Hamed, 2017; Gerges et al., 2017). The definitions of BIM implementation and BIM adoption in the literature are scant and a couple of those accessible come up short on lucidity expected to comprehend and separate between the two terms. Authors, for example, Arayici et al. (2011) and Eadie et al. (2013) have utilised the two terms reciprocally. This is befuddling on the grounds that the adoption of BIM and its implementation is particularly unique. The contrast between adoption and implementation is indisputable in the implementation theory literature. For example, implementation is portrayed as an intentionally started process in which specialists plan to take on organised approaches or practices by the principal. In another word, implementation is the transition period of the adoption decision (May, 2013). Similarly, Linton (2002) and Klein and Sorra (1996) depict implementation as including all activities from initial adoption decision to sustained adoption decision.

To summarise the definitions, implementation in this way alludes to the most common way of systematising approaches by the principal and the process of executing policies by the agents. Implying that both the principal and the agents are engaged with the implementation process. Then again, adoption is portrayed as the choice to utilise an innovation or as the goal to follow systematised practices or strategies (May, 2013). Complimentary to this definition is the contention by Proctor et al. (2013), Fixsen et al. (2005), Aarons et al. (2011) and Klein and Sorra (1996) that adoption is a result or the target of implementation. It very well may be found from these definitions that organisations play parts to play in the implementation process, however, adoption is altogether their choice. In any case, the adoption decisions involve preliminary and sustained adoption decisions. While the preliminary adoption decision is simpler to make, the sustained adoption decision requires responsibility and consistency to accomplish (Proctor et al., 2013; Fixsen et al., 2005; Aarons et al., 2011; May, 2013).

On account of BIM implementation and adoption, the government and the industry leaders are the principal making policies for the construction industry, while the organisations and professionals operating in the construction industry are the agents. Besides, the prerequisites for BIM implementation at the industry and organisational levels are not something similar. There are three unmistakable levels in the construction industry, to be specific: macro, meso and micro levels. The macro-level addresses the industry level, the meso-level addresses the organisational level, and the project level is addressed by the micro-level (Poirier et al., 2015; Papadonikolaki, 2017). Poirier et al. (2015) noticed that BIM implementation ought to be dynamic at the three levels. Albeit, the terms BIM implementation means BIM adoption at the three levels; this shows that the extent of BIM implementation is more extensive than that of BIM adoption and it ought to be utilised to indicate the approach driving BIM adoption at the macro or industry level and the commitment to and consistency of BIM adoption on projects by the organisations operating in the industry.

To expound on the distinctions between BIM adoption and implementation. BIM implementation drive is a public and industry issue, hence, it portrays formal acknowledgement of BIM by the industry leaders and policymakers to be all around the world significant and cutthroat. BIM adoption portrays drives the degree of organisations or projects in light of the assumptions for the organisations or the clients and within the provisions of the BIM implementation initiative. This shows that BIM implementation is a result of political will or regulation and it requires systems, plans, choices, guidelines, and rules to bring it into impact; while BIM adoption is a result of necessities by clients, hierarchical vision and top administration responsibility and backing. Without BIM implementation, BIM adoption is not lawfully restricting on organisations or construction projects, aside from what was requested by clients. Indeed, even with BIM implementation, BIM adoption is as yet not lawfully restricting on organisations if the clients (public or private) do not command it. This shows that the outcome of BIM implementation relies upon approaches by the public authority, yet is just the responsibility of organisations' top management.

Likewise, BIM has turned into a worldwide prerequisite that each nation is committed to executing, however, its execution depends on the necessities of the nation, along these lines prompting the formation of new and particular necessities for the country which construction industry players in the country could embrace to their projects and work processes (Jung and Joo, 2011; Miller et al., 2013; Silva et al., 2016). This explanation depicts BIM implementation as the method involved in ordering or making BIM a formal or satisfactory working framework in the construction industry. While BIM adoption is a demonstration done by organisations working in a specific construction industry, either to take up or adhere to the arrangements and rules of BIM as given in a BIM implementation requirement. BIM adoption likewise alludes to the conventional acknowledgement of BIM by organisations in the construction industry.

2.3.2 BIM Implementation thresholds

BIM Implementation Thresholds portray the degree of decrease in BIM reception not entirely settled by the event of the elements or facilitators of BIM implementation in the construction industry (Navendren et al., 2014). The highlights of BIM implementation become accessible in the construction industry when the huge BIM reception obstructions are tended to through BIM implementation strategies (Succar and Kassem, 2016). Various examinations have been led to distinguish BIM adoption barriers. A few of these investigations have endeavoured to recognise BIM adoption impediments utilising theoretical perspectives (Khosrowshahi and Arayici, 2012; Eadie et al., 2013; Panuwatwanich and Peansupap, 2013; Stanley and Thurnell, 2014; Chan, 2014); while others resolved the issue in light of BIM adoption barriers identified from literature review (Tse et al., 2005; Kekana and Aigbavboa, 2015; Ezeokoli et al., 2016; Yusuf et al., 2016; Gerges et al., 2017). For example, Tse et al. (2005) recognised the hindrances to the reception of BIM by architects in Hong Kong.

The study recognised eight significant barriers, specifically, absence of interest for BIM by the client, absence of interest by other project team members, insufficient BIM highlights, failure of BIM to diminish drafting time, absence of BIM skilled experts, cost of BIM use, adequacy of existing computer-aided-design, and absence of the need to deliver BIM. Yan and Demian (2008) zeroed in on BIM adoption barriers in the USA and the UK utilising a literature review as an aide for the study. The study detailed the expense of copyright and preparation, the inadmissibility of BIM, waste of time and human resources, and fulfilment with computer-aided design as obstacles to BIM reception in the UK and USA. The theoretical approach was embraced by Khosrowshahi and Arayici (2012) to recognise BIM adoption barriers in the UK and this achieved a more far-reaching identification of BIM adoption barriers. The study detailed seven hindrances some of which are altogether unique in relation to the previous ones revealed by Yan and Demian (2008). These incorporate absence of knowledge of BIM application, the absence of top administration backing and responsibility, the absence of a business case, the absence of funding to put resources into BIM, speculation risk, protection from culture change, and absence of interest in BIM. The discoveries of studies that depended on theoretical perspectives, for example, Eadie et al. (2013), Panuwatwanich and Peansupap (2013), Stanley and Thurnell (2014) and Chan (2014) support prior research by Khosrowshahi and Arayici (2012) even though they were done in various nations.

Then again, studies that embraced no theoretical perspective to direct the recognisable proof of BIM reception hindrances give clashing outcomes. Albeit the hindrances should not be any different for various nations, they should connect with the implementation process (Kim et al., 2005; Proctor et al., 2013). The investigations that embraced theoretical perspectives to distinguish BIM reception hindrances did not by and large group the obstructions as one or the other preliminary or sustained BIM adoption barriers; while it is harder to separate between the barriers to preliminary and sustained adoption in examinations that did not adopt any theoretical perspective directs the recognisable proof of BIM adoption barriers. Indeed, even investigations that embraced theoretical perspectives to recognise BIM adoption barriers are not any doubt dependable because the obstacles utilised in the examinations were drawn from a solitary theoretical perspective (technology acceptance or DOI).

As indicated by the theories on the implementation process (Kim et al., 2005; Proctor et al., 2013; Migilinskas et al., 2013; Miettinen and Paavola, 2014; Bui et al., 2016; Kassem and Succar, 2017), numerous theoretical perspectives are required for solid recognisable proof of reception obstructions and advancement of powerful implementation strategies. One more remarkable impediment of this approach in the treatment of top management backing and responsibility as a variable and not as a construct. The help and responsibility of top management for BIM adoption is key to the sustainability of the adoption choice and different factors decide the help and responsibility of top management for an adoption decision (Kim et al., 2005). Instances of such factors are appropriate to change management processes (Grover et al., 1995; Al-Mashari and Zairi, 1999), settling the irreconcilable situation between the organisational vision and adoption of an innovation (Kim et al., 2005), and developing new reward and incentive systems (Towers, 1994).

Drawing from IPT, this study contends that BIM implementation is a cycle which suggests that critical BIM adoption barriers should be tended to in a continuous and orderly manner. Also, the utilisation of BIM implementation strategies towards disposing of critical BIM adoption barriers in a construction industry is not set in stone by the market size and production capacity of the construction industry. These necessitated the need for BIM implementation thresholds (KRI for BIM adoption barriers) to direct the BIM implementation process in the construction industry of different market sizes and production capacities.

3 Research method

3.1 Database

The study conducted a four-stage search of potential sources of data to populate the database for the meta-analysis. In the principal stage, search keywords (BIM adoption facilitators, BIM implementation barriers, BIM adoption barriers, BIM uptake factors, BIM adoption challenges, critical success factors for BIM adoption/implementation, IPT, impediments to BIM implementation/adoption) were placed into the electronic datasets (Scopus, Engineering Village, Ebesco, Google Scholar, and Web of Science). The rejection rules for the search include non-peer-reviewed journal articles, articles not published in the English Language, and articles published before 1990. The principal stage yielded 2,600 pertinent articles. The second phase of the searching process depended on the meaningful significance of the journal articles. BIM, barriers/impediments, and implementation process were utilised as the essential search keywords for the titles and abstracts of the journal articles. Through this process, duplicate articles and articles with anonymous authors were eliminated. A total of 504 articles remained at the end of this stage.

The third stage involves the selection of journal articles that have empirical contents. The searching was done utilising keywords such as test, findings, survey, evidence, data, and analysis. The subsequent journal articles were considered pertinent to the study. Toward the end of this stage, 97 significant journal articles remained. The last phase of the searching process starts with the point by point perusing the 97 significant journal articles from stage three. The substantive and empirical significance of these examinations was confirmed by utilising the quality of data to be extracted from these journal articles. Eleven comparable and important articles with factual data, for example, mean score, correlation coefficient, sample size, standard deviation, and detailed method of analysis were recognised and included in the database for the meta-analysis procedure. The condition in this last stage depended on Hom et al. (1992) who indicated that the dataset for meta-analysis should contain only studies that encompass the variables in the theoretical model and provide information that could be utilised for the meta-analysis.

3.2 Meta-analysis procedure

Meta-analysis is a powerful method for assessing connections between factors by consolidating factual data from independent but similar studies (LePine et al., 2002). The meta-analytic methodology utilised in this study was a fixed-effects analysis as illustrated by Hunter and Schmidt (2004). Based on the steps outlined in Hunter and Schmidt (2004), the following parameters were estimated: population variance, the population mean, population standard deviation, sample weighted mean, standard error of the mean, standard mean difference (effect size), true score correlation, credibility interval, variance, and confidence interval. These parameters were estimated utilising statistical information extracted from the database. An effect size of 0.2 and above was considered a strong effect in this study. Variables with an effect size of 0.2 were considered valid in the theoretical model. Values above zero are taken as the acceptable confidence interval for the variables in this study (Judge et al., 2002).

4 Results

4.1 Reliability of the dataset

The outcomes in Table 1 show that the highest number of publications was in the years 2014 and 2015. This recommends a developing interest in BIM implementation and BIM adoption in late 2014 and mid-2015. The Table additionally shows that every one of the publications in the database has factors that connect with the standards for BIM implementation (KRI) that are being proposed in this study. Most of the publications adopted mean score as a method of analysis and questionnaire survey as the method of data collection. This affirms that the publications actually measured BIM adoption barriers/facilitators/indicators. These discoveries propose that the publications considered for the dataset contain valuable data for the computation of the correlation coefficient and that the publications have a significant study population and variables for the research. It likewise shows that the publications are comprehensive and that the result of the investigation will be a genuine gauge of the interrelationship between the standards recognised in the theoretical model.

Table 1 Descriptive analysis of the database

Publications	*Number of related variables*	*Sample size*	*Method of analysis*	*Methodology*
Eadie e al. (2013)	10	30	Mean score and relative importance index	Questionnaire survey
Hosseini et al. (2015)	13	50	Mean score and exploratory factor analysis	Questionnaire survey
Olugboyega and Aina (2016)	19	282	Mean score and relative importance index	Questionnaire survey
Zahrizan et al. (2013)	15	48	Mean score and relative importance index	Questionnaire survey
Jin et al. (2015)	13	81	Mean score and relative importance index	Questionnaire survey
Nicholas (2016)	7	29	Mean score	Questionnaire survey
Matarneh and Hamed (2017)	8	180	Mean score	Questionnaire survey
Kiani et al. (2015)	16	32	Mean score	Questionnaire survey
Rogers et al. (2015)	14	41	ANOVA and Kruskal Wallis test	Questionnaire survey
Chan (2014)	12	52	Mean score	Questionnaire survey
Won and Lee (2010)	19	61	Mean score	Questionnaire survey

4.2 Validation of the criteria for BIM implementation (KRI)

Table 2 presents the results of the meta-analyses conducted in this study. The meta-analysis examined the validity of 33 variables as criteria for BIM implementation. The meta-analysis showed that the variables are valid criteria for driving BIM implementation in the construction industry. Every one of the variables has a strong positive correlation, which means their effects on BIM implementation in the construction industry. The results show that every one of the variables has a positive and strong effect on BIM implementation in the construction industry. *Acceptance of BIM as a work process and acceptance of BIM as a construction management process* have the minimum effect size (d = 0.239); while the *acquisition of resources for BIM training of employees* has the maximum effect size (d = 2.060). All of the confidence intervals and credibility intervals exclude zero and overlap.

Table 2 Meta-analysis estimate for the criteria for BIM implementation (KRI)

Criteria for BIM implementation (KRI)	*K*	*r*	*d*	*Zr*	*95% confidence interval*		*95% credibility interval*		*V*
					Lower	*Upper*	*Lower*	*Upper*	
Awareness of BIM by construction project supply chain (CPSC) stakeholders	51	0.14	1.01	0.15	–0.04	0.32	–0.04	0.33	0.01
Understanding of BIM concepts by CPSC stakeholders	40	0.15	0.97	0.15	–0.04	0.33	–0.04	0.34	0.01
Availability of BIM competent professionals in the labour market	39	0.04	0.27	0.04	–0.15	0.23	–0.15	0.24	0.01
Regular organisation of BIM workshop by regular industry leadership	44	0.08	0.49	0.08	–0.26	0.11	–0.27	0.11	0.01
Availability of policies and regulations on copyright ownership	44	.08	0.49	0.31	–0.16	0.12	–0.28	0.10	0.01
Availability of national BIM guidelines	38	0.29	1.86	0.03	0.11	.047	0.11	0.51	0.01
Availability of national BIM standards	490	0.21	0.22	0.21	–0.21	0.15	–.21	0.15	0.01
Availability of interoperable BIM software technologies	39	0.08	1.26	0.08	0.02	0.39	0.02	0.41	0.01
Awareness of BIM by clients	61	0.10	0.59	0.11	–0.26	0.09	–0.26	0.09	0.01
Availability of in-house BIM competent professionals	64	0.23	0.78	0.24	–0.07	0.28	–0.07	0.28	0.01
Acquisition of resources for BIM training of employees	57	0.33	1.55	0.34	–0.39	0.05	–0.42	0.05	0.01
Acquisition of BIM software technologies	38	0.21	2.06	0.21	0.14	0.50	0.14	0.54	0.01
Evidence of collaborative teamwork culture in the organisations	47	0.24	1.26	0.25	–0.38	0.02	–0.40	0.02	0.01
Appointment of BIM champion or steering committee	43	0.19	1.42	0.19	–0.42	0.06	–0.44	0.06	0.01

Note: K = average sample size; r = correlation coefficient; d = effect size; Zr = Fister's Zr.

Table 2 Meta-analysis estimate for the criteria for BIM implementation (KRI) (continued)

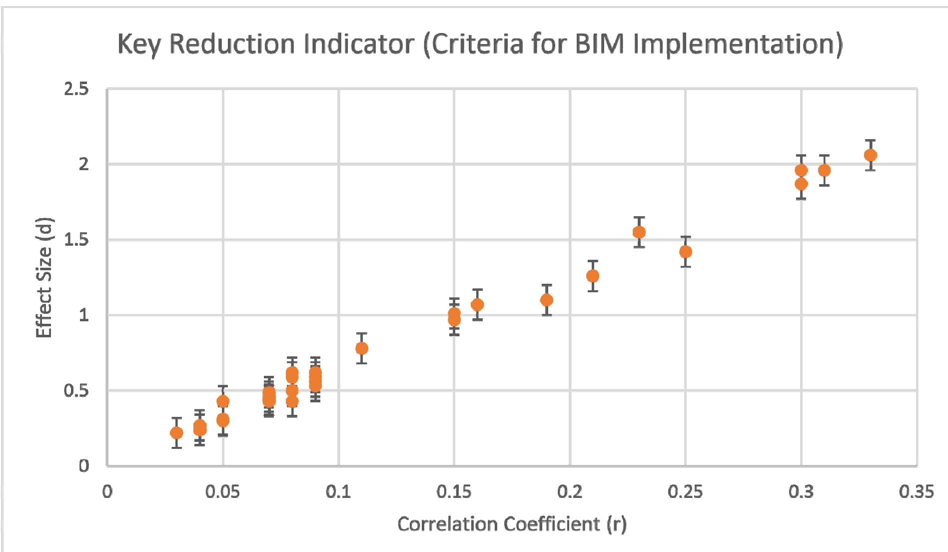
Criteria for BIM implementation (KRI)	*K*	*r*	*d*	*Zr*	*95% confidence interval*		*95% credibility interval*		*V*
					Lower	*Upper*	*Lower*	*Upper*	
Availability of BIM infrastructures in the organisations	36	0.09	1.10	0.09	–0.37	0.01	–0.39	0.01	0.01
Aligning organisational vision and objectives with BIM adoption	37	0.07	0.56	0.09	–0.28	0.10	–0.29	0.10	0.01
Employees' readiness to accept changes	51	0.09	0.46	0.07	–0.25	0.11	–0.26	0.11	0.01
Acceptance of BIM competency as a competitive advantage	61	0.15	0.62	0.09	–0.27	0.08	–0.27	0.08	0.01
Availability of motivation for workers towards BIM adoption	64	0.30	1.07	0.16	–0.32	0.02	–0.33	0.02	0.01
Aligning organisational structures with BIM adoption requirements	54	0.29	1.96	0.32	–0.13	0.47	–0.13	0.51	0.01
Aligning organisational culture with BIM adoption requirements	52	0.07	1.96	0.30	–0.12	0.45	–0.12	0.49	0.01
BIM-induced changes in construction business process	50	0.07	0.43	0.08	–0.26	0.11	–0.26	0.10	0.01
Understanding of roles in BIM adoption by CPSC stakeholder	60	0.09	0.49	0.07	–0.25	0.10	–0.25	0.10	0.01
Understanding of responsibilities in BIM adoption by CPSC stakeholder	32	0.08	0.59	0.09	–0.29	0.09	–0.29	0.11	0.01
Enforcement of BIM adoption on projects by public clients	60	0.05	0.62	0.08	–0.25	0.12	–0.26	0.09	0.01
Enforcement of BIM adoption on projects by private clients	60	0.04	0.43	0.05	–0.23	0.13	–0.23	0.12	0.01
Enforcement of BIM adoption on public-private projects	61	0.07	0.30	0.05	–0.22	0.25	–0.23	0.13	0.01
Availability of information on the selection of BIM software technologies for projects	52	0.08	0.44	0.07	–0.11	0.11	–0.11	0.26	0.01
Aligning project expectations with BIM potentials	41	0.05	0.53	0.09	–0.27	0.14	–0.28	0.11	0.01
Acceptance of BIM as a work process	48	0.03	0.30	0.05	–0.23	0.16	–0.23	0.14	0.01
Acceptance of BIM as a construction management process	39	.04	0.23	0.04	–0.23	0.15	–0.23	0.16	0.01
Application of BIM tools to projects	40	.04	0.23	0.04	–0.23	0.13	–0.27	0.15	0.01
Awareness of BIM by Construction Project Supply Chain (CPSC) stakeholders	30	0.07	0.43	0.07	–0.27	0.13	–0.24	0.15	0.01

Note: K = average sample size; r = correlation coefficient; d = effect size; Zr = Fister's Zr.

4.3 Relationship patterns among the criteria for BIM implementation (KRI)

Figure 4 shows a scatterplot for the correlation coefficient and effect size data listed in Table 2. A scatterplot was done to determine the relationship patterns among the criteria (KRI). The results in the figure show an uphill pattern. This is an indication of a strong positive relationship among the criteria. This affirms the interrelationships among the criteria in every one of the thresholds as theorised in the proposed model (Figure 3). The positive linear relationship that shows up in the scatterplot among the correlation coefficient and effect size of the criteria implies that the interrelationships among the criteria are liable for the strong positive effects of the criteria on the effectiveness of BIM implementation. There are no outliers among the data points in the scatterplot. This is an indication of a strong correlation among the criteria.

Figure 4 Scatterplot for the correlation coefficient and effect size of the criteria for BIM implementation (KRI) (see online version for colours)



5 Discussion, implications and limitations

The advancement of the BIM implementation process relies generally upon how the thresholds or levels of reduction in BIM adoption barriers have been arranged. In any case, explicit BIM implementation terms should be perceived, while the thresholds of reduction (KRI) in BIM adoption barriers should perceive the distinctions in the market size and production capacity of different construction industries. Thus, it becomes basic to build BIM implementation thresholds involving the pace of decrease in BIM adoption barriers and making provisions for market size and production capacity of various construction industries. This study was intended to distinguish the key decrease markers for tracking BIM adoption barriers, and to lay out whether the key decrease pointers will give a model of BIM implementation taxonomies and thresholds for evaluating BIM implementation endeavours. In doing as such, the study integrated knowledge from IPT to determine irregularities in BIM implementation-specific terms and distinguish thresholds for the BIM implementation process.

The proposed model was explained utilising Figures 1, 2 and 3 (Figure 2 expands on Figure 1 and Figure 3 expands on Figure 2) and it introduced 31 measures for BIM implementation (KRI). Accompanying four significant BIM implementation explicit terms were recognised and characterised in Figure 2: BIM implementation, BIM adoption, BIM adaptation, and BIM utilisation (application). As per the model, BIM implementation alludes to the proper acknowledgement of BIM by the industry leaders and policymakers in the construction industry through the formulation of initiatives to drive BIM reception across the industry, organizations, and projects. The term BIM adoption was utilised to depict BIM adaptation in construction organisations and BIM application or utilisation on construction projects.

BIM adaptation was portrayed as the BIM-incited change process by which construction organisations become BIM-complaint and BIM-competent given the necessities of BIM implementation. BIM utilisation or application, on the other hand, alludes to the utilisation of BIM tools, technologies, and processes in the project design stage or every one of the phases of construction, and on ensuing construction projects. These depictions did not match those provided in earlier studies by Succar and Kassem (2016) and Succar and Kumar (2015). Be that as it may, there are likenesses between the definitions provided in this study and the assessment communicated by Jin et al. (2015) about BIM application similar to an investigation of the elements of BIM as an apparatus, interaction, and project management system.

The results of the meta-analysis approve the pertinence of the 33 criteria for BIM implementation in the construction industry, thus approving the model proposed by this study. As made sense in Figure 2, these criteria address the BIM implementation thresholds (BIM frontiers, BIM emerging industry, and BIM advanced industry). A basic investigation of the thresholds in Figure 3 utilising insights from Figure 1 and Figure 2 shows that the criteria for the construction industry to be named as a BIM frontier industry connect with general BIM implementation at the industry level (that is, the proper acknowledgement of BIM by the industry leaders and policymakers in the construction industry through the formulation of initiatives).

The model introduced in this study portrays general BIM implementation at the industry level as the accessibility of BIM technologies, enactment of BIM-friendly regulations and strategies, mindfulness and comprehension of BIM ideas by professionals and clients, and accessibility of BIM competent professionals. These criteria are fundamental to BIM implementation in any construction industry, as they address the foundation on which the BIM implementation endeavours are assembled. Studies, for example, by Enegbuma et al. (2014) have affirmed that BIM implementation fixates on individuals, cycle, and innovation. A potential clarification for this is that the smooth progression of the BIM process is exceptionally subject to policies, guidelines, legislation, and standards that provide support for BIM. Similarly, without individuals (BIM skilled experts) and innovation (BIM advancements and apparatuses), the course of BIM implementation cannot begin in any construction industry.

Further, the model explains that BIM implementation can be supposed to be arising in a construction industry when in that construction industry there are general BIM implementation endeavours at the industry level and BIM adaptation endeavours at the organisation level. This threshold of BIM implementation shows that along with the criteria for BIM implementation at the industry level, the industry has additionally met the criteria for BIM adaptation at the organisation level, for example, advancement of collaborative teamwork culture, procurement of BIM infrastructure and technology, formulation of BIM adoption-based organisational vision, BIM adoption-based organisation structures and culture. At this threshold, BIM implementation is still about individuals, cycle, and innovation. The main contrast is that individuals, interaction, and innovation expected for BIM adaptation in the organisation should right off the bat be accessible in the industry in which the organisations operate before they are customised in the organisations. This theory corroborates the findings of a great deal of the previous studies on BIM adoption in organisations (Lee et al., 2013; Won et al., 2013; Son et al., 2015; Arayici et al., 2011).

Studies on BIM utilisation or application in construction projects are not quite so various as the ones on BIM adoption in the construction industry (Olatunji, 2011; Cao et al., 2014; Manning and Messner, 2008; Olofsson et al., 2008; Cao et al., 2015; Kerosuo et al., 2015). This is an indication that the applications of the capacities and possibilities of BIM are as yet advancing, and they will keep on developing. A definitive reception of BIM will take a long cycle (Jin et al., 2015), that is, there is a large gap between BIM exploration at the project design stage and BIM application in all project lifecycles and consequent projects. A lot of innovations and inquisitions should be placed into the innovative work of BIM innovation, devices and cycle.

In the industry where these innovations and inquisitions will find true success and unquestionable significance must have accomplished BIM implementation at the industry level and organisation level, and regularly utilise BIM on construction projects. This category of the industry is qualified to be named a BIM advanced industry in that it is authorising BIM adoption on a wide range of projects and by a wide range of clients, creating discipline-explicit roles and obligations in BIM adoption, practising BIM as a work process and project delivery system, and adjusting project assumptions to BIM possibilities. In a BIM advanced construction industry, it is still individuals, interaction, and innovation. Be that as it may, individuals, cycles, and innovation are not simply being made accessible at the organisation levels, yet they are additionally being vivaciously and ceaselessly utilised on construction projects.

The significance of the proposed model and the findings in this study is that it clarifies the BIM implementation process as comprising of BIM implementation, BIM adaptation, and BIM utilisation (application). In addition, it clarifies that BIM implementation is like and not quite the same as BIM adoption and that BIM adoption manifest as either BIM implementation or BIM adaptation or BIM utilisation (application) contingent upon the market levels. This intends that in the BIM implementation process, BIM adoption appears as BIM implementation at the industry level. At the organisation level, BIM adoption alludes to BIM adaptation, and at the project level, BIM adoption appears as BIM application or utilisation. It is empowering to contrast this theory with the conclusion by Miller et al. (2013), Silva et al. (2016) and Jin et al. (2015) which indicated that BIM implementation is not altogether equivalent to BIM adoption and that BIM implementation has levels one of which is BIM application. Equally important is the theory in this study which advances that the construction industry of different market sizes and production capacities should not be supposed to implement BIM at a similar level. The utilisation of BIM implementation thresholds as postulated in this study will provide guidance and classification systems for the construction industry that are enthusiastic about BIM implementation. This postulation is per the position of Abdullahi and Chan (2019) that BIM implementation themes and trends are different across the construction industry.

6 Conclusions

The present study was intended to recognise the criteria for BIM implementation (KRIs) for tracking BIM adoption barriers. The study additionally established whether the BIM implementation (KRIs) will give a model of BIM implementation taxonomies and thresholds for evaluating BIM implementation endeavours in the construction industry. Meta-analysis affirmed the validation of the criteria for BIM implementation. These criteria were utilised to propose BIM implementation taxonomies and thresholds. The proposed BIM implementation taxonomies explain that the BIM implementation process is a collection of steps, initiatives, and activities that are expected for driving BIM adoption. BIM adoption was likewise demonstrated to be an ever-evolving process of BIM legislation and policymaking, BIM capability and technology development, and BIM application on construction projects.

In this manner, apparently, BIM implementation is a time-bound transformation in the construction industry; while BIM adoption is an endless headway and utilisation of BIM technologies, tools, and processes. This conclusion arose because of the distinguishing proof of the connection between BIM adoption, BIM implementation, BIM adaptation, and BIM utilisation. The distinctions between these BIM implementation explicit terms were given by their definitions as examined in this study. A significant finding that arose out of this study is that a fruitful BIM implementation should be compelling at the three levels of the construction market (industry, organisation, and project). At the industry level, BIM implementation will find lasting success when the activities and orientations of the industry stakeholders are fixated on the reception of the BIM process and technology. At the organisation level, BIM implementation will become a success when the construction organisations are coordinating their visions, cultures, capacities, and investments towards the transformation of BIM process and technology in their organisational work processes.

The viable utilisation of the BIM process and technologies on construction projects (at all times and every stage) will mean the outcome of BIM implementation at the project level. This proposition expands the knowledge of the BIM implementation process by proposing thresholds for BIM implementation given the comprehension of BIM implementation taxonomies. The BIM frontier industry represents the entry-level for the threshold and it means fruitful BIM implementation at the industry level. A fruitful BIM implementation at both the industry and organisation level connotes the second BIM implementation threshold (BIM emerging industry). The last threshold (BIM advanced industry) is characterised by the effective implementation of BIM at all three market levels.

6.1 Theoretical implications of the study

This study has made noteworthy contributions to the theories on BIM implementation and adoption. In the first place, the study has given a blueprint of BIM implementation in explicit terms. Second, the model introduced in this study will help the different construction industries to successfully dissect the remarkable BIM adoption barriers in their respective industry towards the detailing of the implementation plan (strategic, tactical, or operational). Third, the BIM implementation thresholds will provide a BIM implementation classification system for construction industries given the degree of decrease in BIM adoption barriers, along these lines giving a decent improvement to the construction industry in the developing countries. Fourth, the model will facilitate cross-country and inter-temporal comparisons for BIM implementation, which will permit the grouping of construction industries into relatively homogeneous classes. Finally, the model will improve on the difficulties of BIM implementation through the enablement of simple recognisable proof of KRI for BIM adoption barriers and informed allocation of limited resources for BIM implementation. This is no question that will yield a most extreme BIM implementation performance.

6.2 Practical implications of the study

The practical implications of the findings in this study are the need to reconsider the current BIM implementation strategies to integrate the intricacy and procedural nature of BIM implementation, and the need to perceive the difference in BIM implementation capability and statuses of countries. The other viable implications are the need to regard BIM implementation as a cycle and not as an announcement or oddball action as most nations are presently doing, and the requirement for an organised BIM implementation plan in the developing and under-developed countries.

6.3 Limitations of the study

An arguable shortcoming of this study is the utilisation of meta-analysis for validating the KRI or criteria for BIM implementation thresholds. Meta-analysis cannot deliver a powerful quantitative discovery. It is prescribed that further exploration be embraced to approve the rules and affirm the connections among the criteria in the thresholds.

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