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BIM implementation: an empirical validation for a four-wheel model

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Abstract

Purpose – Because BIM adoption is still afflicted by various types of hurdles, a complete BIM implementation model is required to provide the necessary methods for driving BIM adoption. As a result, this study looked into the parts of the BIM implementation model that had the most impact on increasing the percentage of BIM adoption in South Africa.

Design/methodology/approach – This study developed a four-wheel model of BIM implementation based on implementation process theory, which includes BIM inspiration, BIM capacity development, BIM use and BIM commitment. To assess BIM capacity development, two sub-constructs (BIM learning process and BIM learning methodologies) were used. Two sub-constructs were used to assess BIM utilisation (efficient BIM application and effective BIM application). The sub-constructs employed to quantify BIM motivation were organisational competitiveness, societal conformity and contractual obligations. Incentives, investments and obligations were used to assess BIM commitment. The model was validated using four assumptions and maximum likelihood estimation – structural equation modelling (MLE-SEM).

Findings – The MLE-SEM results demonstrated unequivocally that all of the constructions are critical components of the BIM deployment paradigm in the South African construction industry. BIM motivation, as characterised by organisational competitiveness and social compliance, has the greatest impact. The findings on BIM motivation also revealed that the desire for technological sophistication, competitiveness and social acceptance by clients are encouraging construction organisations and professionals to embrace BIM adoption.

Research limitations/implications – This study's findings have contributed to the increasing body of literature on BIM deployment. The study has significant implications for achieving BIM implementation in underdeveloped nations where BIM deployment is either non-existent or in its early stages. The theoretical component of the study serves as the foundation for further analysis of BIM deployment.

Practical implications – This research is important for identifying BIM goals, developing a BIM implementation framework, allocating resources for BIM implementation and defining key performance indicators for BIM implementation. The BIM implementation aspects outlined in this study will be effective in lowering BIM adoption hurdles.

Originality/value – This study makes a unique contribution to BIM research by providing theoretical and empirical analysis into the elements of the BIM implementation model in a developing country. The study offers an excellent opportunity to further our understanding of BIM application in underdeveloped nations.

Keywords BIM, BIM implementation, BIM implementation Model, BIM adoption, South Africa

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1. Introduction

BIM implementation refers to the process of guaranteeing BIM utilisation or adoption in the construction industry (Lindblad and Guerrero, 2020). Olugboyega and Windapo (2019) described BIM implementation as the process of securing BIM adoption in the construction industry by mandating or making BIM a formal or acceptable working system in the construction industry. However, as Cao *et al.* (2018) observed, the process of BIM adoption in the construction industry sets considerable demands on the technical capabilities of organisations and people. This is changing as BIM deployment becomes more important to the competitiveness of construction organisations, professionals and projects.

The necessity to research relevant and appropriate BIM deployment models has become critical for a variety of reasons. First, BIM adoption is still afflicted by many types of hurdles that must be removed before consistent and realistic BIM adoption can occur (Saka and Chan, 2020). Second, an all-encompassing BIM implementation model is required to provide the essential support, policies, strategies, legitimacy, incentives, resources and standards to drive BIM adoption (Olugboyega and Windapo, 2019). Third, the proper BIM implementation model must address the growth of the construction industry, economic performance of construction organisations and capacity development of construction organisations (Olugboyega and Windapo, 2019). Fourth, the consequences of BIM adoption on activities, attributes, relationships and management requirements must be minimised.

Many research works have recently sought to establish and study the BIM implementation model that will be effective and suitable for pushing BIM adoption. These studies span the BIM implementation model for various forms of BIM adoption (Dakhil *et al.*, 2019; Koseoglu and Nurtan-Gunes, 2018); different countries (Lindblad and Guerrero, 2020; Junior *et al.*, 2020; Sanchís Pedregosa *et al.*, 2020); and different continents (Lindblad and Guerrero, 2020; Junior *et al.*, 2020) Sanchus-Pedregos (Olugboyega and Windapo, 2019; Panteli *et al.*, 2020). BIM implementation models for various forms of BIM adoption have been studied, with an emphasis on BIM competencies (Pillay *et al.*, 2018), construction site activities (Koseoglu and Nurtan-Gunes, 2018) and facilities management task efficiency (Edirisinghe *et al.*, 2016).

Appropriate BIM implementation methods for nations such as Sweden (Lindblad and Guerrero, 2020), China (Herr and Fischer, 2019), Singapore (Liao and Ai Lin Teo, 2018), the Netherlands (Papadonikolaki, 2018), Taiwan (Yang and Chou, 2018), Brazil (Junior *et al.*, 2020) and Peru (Sanchís Pedregosa *et al.*, 2020) have been proposed or examined. According to research on BIM implementation, what developing countries lack is a clear knowledge of the prevailing elements of a comprehensive BIM implementation model (Saka and Chan, 2020; Olanrewaju *et al.*, 2021). Understanding of the parts of the BIM implementation model with the most significant utilisation in the BIM adoption process and environment is also inadequate (Liao and Ai Lin Teo, 2018).

According to Khanzadi *et al.* (2020), a thorough grasp of the fundamental parts of the BIM implementation model will result in balanced and active BIM adoption in the construction sector, as well as be valuable in assessing the efficacy of the BIM implementation model already in use as well as the necessary improvements. As a result, the following questions were investigated in this study: (a) *what are the predominant aspects of South Africa's BIM implementation model?* (b) *Which of the prevalent BIM implementation model aspects has the most impact on increasing the proportion of BIM adoption in South Africa?*

As a result, the goal of this research is to look at the parts of the BIM implementation model that have the most impact on increasing the proportion of BIM adoption in South Africa. BIM is defined in this study as the use of collaborative processes, principles, platforms and technologies that promote or enable integration amongst participants, integration of information and cooperation on project information generation for the delivery of construction projects. In addition, the BIM implementation model will be formally defined as a collection of efforts or strategies for increasing BIM adoption. The major body of this work is organised into five pieces, including this introduction. Section 2 examines the degrees of BIM implementation in developing nations, as well as the conceptualisation of the four-wheel model of BIM implementation. Section 3 explains the research methods and Section 4 discusses the findings of the study. Finally, Section 5 concludes the paper by discussing the study's practical implications and limits.

2. Literature review

2.1 BIM implementation level in developing countries

In undeveloped countries, BIM implementation is low (Saka and Chan, 2020, 2021; Ismail *et al.*, 2017; Belay *et al.*, 2021). This reality has encouraged scholars to conceptualise and benchmark BIM implementation models in poor countries (Olawumi and Chan, 2019; Olugboyega and Windapo, 2019), investigate BIM implementation uptake and hurdles (Ismail *et al.*, 2017; Babatunde *et al.*, 2020; Adekunle *et al.*, 2020; Olanrewaju *et al.*, 2020; Saka and Chan, 2021; Olugboyega and Windapo, 2021b) and look at BIM implementation activities and projects in emerging nations (Hamma-adama and Kouider, 2019). Furthermore, researchers have looked into measures and strategies for improving BIM implementation (Belay *et al.*, 2021), markers for gauging a decrease in BIM implementation barriers (Olugboyega and Windapo, 2021a), determining factors for BIM implementation (Al-Mohammad *et al.*, 2022), scientific proof for project-level BIM adoption (Olugboyega *et al.*, 2022) and strategic planning of BIM acceptance and integration in projects (Olugboyega and Windapo, 2021c).

Apart from proving that BIM implementation is poor in developing nations, these research works have also revealed that BIM acceptance is uneven amongst large and small enterprises, as well as inconsistent across both extremely and modestly complex projects. These studies' BIM implementation methodologies did not contain constrained rationalities and did not address the economic consequences of BIM adoption by construction professionals and organisations. If the economic consequences of BIM adoption are not addressed, the "BIM-gap" between large and small enterprises or between international and indigenous construction firms, would expand. This suggests that in order to solve the lower degree of BIM implementation in developing nations, it is necessary to focus on the overall condition of BIM implementation in developing countries. This would result in a more realistic picture of BIM adoption by identifying the main parts of the BIM implementation model capable of removing BIM adoption obstacles and challenges.

2.2 Conceptualising the four-wheel model of BIM implementation

Based on implementation process theory (IPT), this study conceptualised a four-wheel model of BIM implementation (see Figure S1), which includes BIM motivation (which defines the motivation required by construction organisations to adopt BIM tools, technologies, processes and platforms on construction projects), BIM capacity developments (which describes the training and re-training of personnel to use BIM tools and technologies on construction projects), BIM utilisation (describes the policies and plans for strategic adoption of BIM on construction projects) and BIM commitment (which describes the obligations and support of top management of construction organisations for BIM adoption and to motivate construction professionals). Figure S2 depicts the proposed model for the four-wheel model of BIM implementation.

Motivation can emerge as innate forces (desires or pleasure), personal challenge, dynamic circumstances (regulations), sense of mastery, desire for value, pursuit of perfection, achievement or competence, emotional push to a move by the opponent and desire for a positive outcome (Shiroma, 2014). The above manifestations of the concept of motivation show that there are a variety of techniques that can be used to generate internal and external drive, reinvigoration and enthusiasm, eagerness and orientation, requirements and expectations, feeling of satisfaction and enticement and incentives for BIM adoption. This combination of strategies is referred to as BIM motivation by Olugboyega and Windapo (2019).

Furthermore, Olugboyega and Windapo (2019) proposed that BIM motivation refers to initiatives that produce normative, imitative and coercive factors in order to generate reasons and incentive schemes for BIM adoption. Coercive forces, as defined by Olugboyega and Windapo (2019), will compel individuals, groups and organisations to perform in accordance with the expectations outlined in guidelines and regulations. This means that normative factors will drive industrial actors to seek identity, survival and legitimacy. Imitative tendencies will cause small construction companies to emulate large construction companies. Normative force, imitative force and coercive force are all examples of motivational forces (Cao *et al.*, 2017; Lee *et al.*, 2019). Based on the foregoing, this study hypothesises that *BIM motivation is important for increasing the proportion of BIM adoption (Hypothesis 1).*

BIM utilisation as a component of the BIM implementation model refers to the efficiency and effectiveness of BIM application on construction projects (Olugboyega and Windapo, 2019). This means that strategic methods and systems are required for a practical BIM application or usage on construction projects (that is, to maximise the performance and benefits of BIM adoption). Due to the resources and time required for BIM adoption, it also indicates that construction organisations and experts must work more effectively when adopting BIM. Furthermore, BIM utilisation denotes the peak level of BIM performance that produces the greatest level of BIM advantages while utilising the fewest resources.

This emphasises the significance of preserving resources for BIM applications while maintaining an adequate degree of BIM advantages. In practise, however, harmonising the effectiveness and efficiency of BIM applications can be problematic. According to Olugboyega and Windapo (2019), strategic and contingent BIM adoption will allow for the balance of the efficacy and efficiency of BIM applications. As per the study (ibid), BIM utilisation is a crucial component in a BIM implementation model for realising the success, sustainability, and performance efficiency of BIM adoption. As a result, this study recommends that *BIM utilisation is important for increasing the proportion of BIM adoption* (Hypothesis 2).

Commitment is the feeling of being psychologically or cognitively bound to a particular path of action (Naotunna and Arachchige, 2016). Commitment as a notion can take many forms, including job commitment, employee commitment, organisational commitment and top management commitment. Top management makes commitments in anticipation of future rewards or a shift (Colwell and Joshi, 2013). Change is unavoidable, and the predictability of change has an impact on an organisation's survival and competitiveness (Lines, 2004). Organisations' chances of survival and competitiveness are determined by top management's willingness to change.

This means that top management commitment can be defined as an organisation's leadership's readiness to persist and sustain a course of action or a responsibility. In the context of top management commitment, the aspects of commitment will thus comprise the extent of investments, the degree of obligations, a sense of vow, a sense of duty and a desire to preserve an obligation. The concept of BIM commitment can be deduced from this line of reasoning. BIM commitment refers to the attitudes, interventions, investments, commitments, vow, duty and tenacity required by the top management of construction organisations to launch and sustain BIM adoption.

In this scenario, BIM adoption is the need or course of action. Since construction organisations and construction employees are critical to the BIM implementation process, the management of construction organisations must commit to the BIM adoption path. This suggests that BIM commitment is critical for managing transition, resistance, competence, organization structures, organisational culture and organisational resources during the BIM adoption process.

More precise characteristics of BIM commitment have been uncovered by Olugboyega and Windapo (2019), which define BIM commitment as the whole dedication of construction organisations' top management to BIM adaption, adoption, application and execution. Investigations such as Munir *et al.* (2020) and Sinoh *et al.* (2020) have highlighted top management commitment as a significant driving force for BIM adoption, lending support to the argument for BIM commitment as an essential component of a BIM implementation strategy. Based on this context, this study develops a hypothesis stating that *BIM commitment is important for increasing the proportion of BIM adoption (Hypothesis 3).*

Capacity development has really been discussed in terms of procedures and techniques. Capacity development, according to Lavergne and Saxby (2001), is the process of gaining, strengthening and retaining the ability to acquire appropriate skills and information. Alaerts and Kaspersma (2009) used capacity building as an approach to empower individuals, leaders and organisations. The idea of capacity development as a methodology emphasises the use of capacity development as a strategy for improving an individual's or a group's existing capabilities.

Given the preceding criteria, the parts of capacity development can be recognised as skill development, knowledge development and competency acquisition. This means that BIM capacity development refers to a BIM implementation process or strategy that uses training, skills, knowledge, competencies, and literacy forces to drive BIM adoption. "BIM capability" arose from this description as a word that describes the talents, skills, knowledge, understanding and behaviours required to perform in a BIM context.

Thinking of BIM capacity development as a process implies that it is the process through which BIM capability is instilled in a person or group of people. It will also demonstrate that BIM capacity development is a continual skill and competency improvement process aimed at creating a sufficient number of human resources for BIM adoption and deployment. BIM capacity development will be used as a mechanism to build BIM skills, knowledge and competences in construction professionals (current or prospective) or employees by providing a link to BIM training and education.

Accepting these arguments implies that BIM capacity development is the process and methodology for getting an organisation to the needed level of BIM maturity in terms of BIM skills, BIM knowledge, BIM leadership and BIM competencies. Several arguments have been advanced in favour of BIM capacity development as an essential component of a comprehensive BIM implementation model by Shahruddin *et al.* (2020) and Olugoyega and Windapo (2019). According to this study, increasing *BIM capabilities is important for increasing the proportion of BIM adoption (Hypothesis 4).*

3. Research methods

3.1 Sample and data collection

The research participants were chosen from the BIM supply chain participants listed by Succar *et al.* (2012). The research participants are a diverse set of professionals that have created building information models, engaged in BIM review meetings, held BIM knowledge and collaborated using BIM. The demographic features of the research participants are summarised in Table S1. Questions were distributed by e-mail invites and web links. The survey was divided into five components. The first portion addressed generic questions about the characteristics of the participants. The questionnaire's sections 2–5 focussed on BIM motives, commitments, capacity development and utilisation. The questionnaire was piloted with comments from five BIM managers prior to data collection. The feedback from BIM managers indicates that the questionnaire is valid and reliable.

The e-mail request and web-link for data collection were sent via the Construction Business and Management Research Group's SurveyMonkey™ subscription at the University of Cape Town's Department of Construction Economics and Management. The questionnaire was distributed to 975 (the sample size) research participants from a total population of 1,871 (as extracted from details of individuals who participate in BIM-based construction projects (BBCPs) from the cidb websites for project databases, submissions of BIM experts on Linked-In™ and postings of members of the South African BIM Club). The sample size was calculated methodically depending on the known e-mail contacts and the commitment to participate in the study. Only 872 of the 872 research participants returned the survey without missing or incomplete data. This results in an 89% response rate. According to the recommendations of Holtom *et al.* (2022). The response rate is adequate. The actual data gathering took place over a period of 13 months.

3.2 Constructs and sub-constructs measurement

To assess *BIM capacity development* (Y_1), two sub-constructs (*BIM learning process* – Y_{11} *and BIM learning techniques* – Y_{12}) were used. *BIM utilisation* (Y_2) was quantified using two sub-constructs (*efficient BIM application* – Y_{21} *and effective BIM application* – Y_{22}). The sub-constructs employed to measure *BIM motivation* (Y_3) were *organisational competitiveness* (Y_{31}), *social conformity* (Y_{32}) *and contractual obligations* (Y_{33}). *BIM commitment* (Y_4) was assessed through *incentives* (Y_{41}), *investments* (Y_{42}) *and obligations* (Y_{43}). Table S2 lists the variables for each sub-construct. All the variables were assessed on a 5-point Likert scale (strongly agree = 5, agree = 4, neutral = 3, disagree = 2 and strongly disagree = 1).

3.3 Method of data analysis

The data analysis was divided into two components. The first section dealt with the study of measurement models, while the second section dealt with the analysis of structural models. As indicated by Bandalos and Finney (2018), the measurement models were assessed for convergent and discriminant validity (confirmatory factor analysis and average variance explained), significance (mean item score), internal consistency and structure (factor loading) and reliability (Cronbach's alpha). The structural models were examined by estimating model parameters and assessing the models' goodness of fit.

Structural equation modelling-maximum likelihood estimation (SEM-MLE) employs multiple fit indexes, including the Chi-square goodness of fit test (the value of the chi-square test must be insignificant), the standardised root mean square residual (SRMR) index (at a cut-off value of 0.10), the comparative fit index (CFI) (at a cut-off value of 0.97), the root mean square error of approximation (RMSEA) index (at a cut-off value of 0.08 (at a cut-off value of 0.97). SEM-MLE was used as the analytical approach since it is an unbiased model estimation method that works well with high sample sizes (Kyriazos, 2018). Furthermore, the likelihood functions created by SEM-MLE can be used to assess model hypotheses. If $z = 1.96$ and $r = 0.05$, the tested hypotheses are accepted (Kyriazos, 2018).

4. Results

4.1 Measurement models

4.1.1 Validity and internal consistency of the variables. Table 1 shows the consistency, reliability, and validity tests for the construct's measured variables. Based on their factor loadings, Cronbach's alpha coefficients, correlation coefficients, eigenvalue, percentage of variance explained, KMO value and Bartlett's test results, all of the measured variables are consistent, reliable and valid. Using the cut-off values provided in section 3.3, all of the measured variables are within the Bandalos and Finney (2018) recommendations.

Main constructs	Sub-constructs	Number of significant variables	Factor loading	Cronbach's alpha	Average variance extracted
Y1	*Y11*	7	0.96	0.99	0.94
	Y12	7	0.93		
Y2	*Y21*	9	0.97	0.95	0.95
	Y22	5	0.95		
Y3	*Y31*	12	0.94	0.99	0.93
	Y32	9	0.89		
	Y33	12	0.93		
Y4	*Y41*	10	0.87	0.97	0.93
	Y42	10	0.92		
	Y43	16	0.94		

Table 1. Internal consistency of the constructs

The measured variables adequately explained the constructs Y3, and the sphericity test by Bartlett is significant. The results reveal that all of the variables are reliable and valid for SEM.

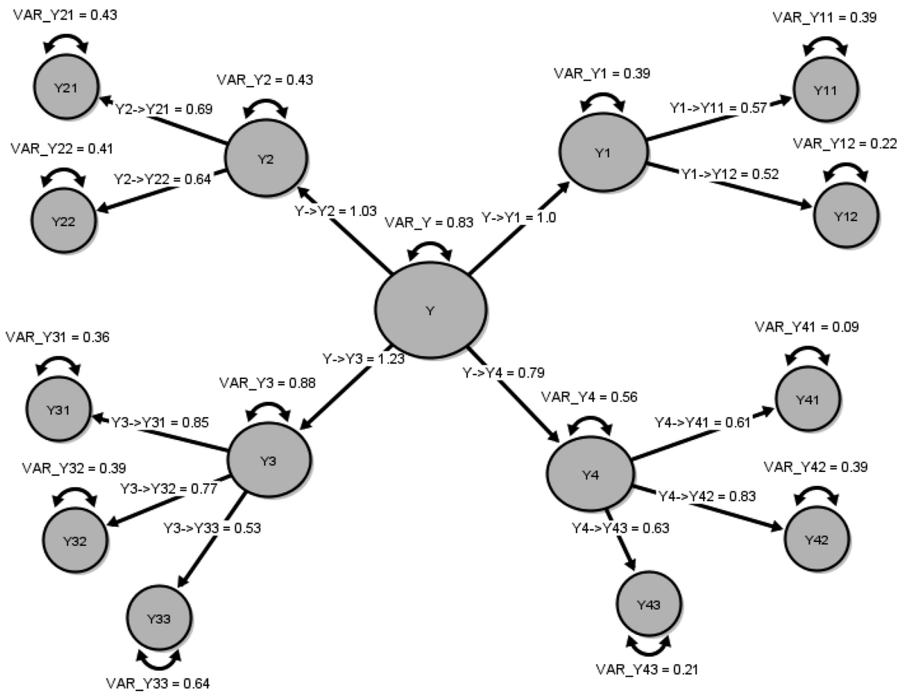
4.1.2 Significance of the variables. The study attempted to determine the prevailing aspects of the BIM implementation model in South Africa, as well as the prevailing elements of the BIM implementation model with the greatest influence on increasing the proportion of BIM adoption in South Africa. Table S3 displays the results of the mean score analysis, which identified the most relevant factors for the prevalent aspects of the BIM implementation model in South Africa. Variables having a mean item score of 3.61 or higher were deemed highly significant by Joshi *et al.* (2015).

Table S3 shows that all variables are very significant, with the 'need to increase organisational performance and efficiency in the long term (mean score = 3.82) and short term (mean score = 3.79)' having the highest mean values. The lowest mean scores were recorded for employees on-the-job BIM training (mean score = 3.61), self-initiated BIM training (mean score = 3.61), BIM seminars (mean score = 3.61), determining the appropriate BIM maturity levels for projects (mean score = 3.61), and assessing the performance of BIM adoption on the project (mean score = 3.61).

The findings shed light on the dominating features of the BIM implementation model, indicating that organisational competitiveness and social conformity were the primary determinants driving BIM deployment amongst South African construction firms. The findings also highlighted that the senior management of South African construction organisations is dedicated to the coordination of the BIM process within the organisation as well as the education of personnel on the potential of BIM. The findings revealed a strong desire for BIM implementation amongst South African construction organisations through participation in BIM workshops, the development of BIM adoption plans, the establishment of a collaborative teamwork culture in the organisations and staff participation in work process redesign.

4.2 Structural models

The purpose of this research was to identify the prevailing aspects of the BIM implementation model in South Africa, with the intention of discovering the prevailing features of the BIM implementation model having the greatest influence on increasing the percentage of BIM adoption in South Africa. Using SEM, four hypotheses were developed and tested. A SEM (see Figure 1) was created for SEM based on the hypothesised model in Figure S2. The SEM parameter estimation findings verified the hypotheses (see Table 2). The model was validated by the explanatory power of the parameter estimations. The SEM results clearly demonstrated that all of the constructs (Y_1, Y_2, Y_3 and Y_4) are important components of the BIM implementation model in the South African construction industry.



Note(s): Chi-Square: 1868.163; RMSEA: 0.069; SRMR: 0.021; CFI: 0.975; TLI: 0.983

Figure 1.
Path diagram for the structural equation model of prevailing elements of BIM implementation model in South Africa

Table 2.
Parameter estimation for the structural equation model of prevailing elements of BIM implementation model

Relationship	Estimate	Standard error	*Z*-value
Y → *Y1*	1.0029704725933677	1.20883631	0.8296991675117357
Y → *Y2*	1.0275424689673278	2.64802809	0.3880406256957445
Y → *Y3*	1.2268812190151934	2.25052052	0.5451544263012577
Y → *Y4*	0.7927561429518314	1.58202887	0.5011009330580443
Y4 → *Y43*	0.6344003361723509	1.96265072	0.32323649072645033
Y2 → *Y21*	0.6852159787915977	2.00643955	0.34150672474937654
Y3 → *Y31*	0.859139817119544	3.48071546	0.24682851246744478
Y3 → *Y32*	0.7709555338852675	2.16691111	0.355785436049084
Y3 → *Y33*	0.5379459893617098	1.24222805	0.4330492256006963
Y2 → *Y22*	0.6433907623436081	1.09546848	0.5877920139575263
Y4 → *Y42*	0.834516267486699	2.10863272	0.3957617976419761
Y1 → *Y11*	0.5783883828858485	1.72595992	0.3511113905240278
Y4 → *Y41*	0.6075609128469304	1.70320985	0.3567152468355716
Y1 → *Y12*	0.5241735354142927	0.59718699	0.8777376958900739

BIM motivation, as typified by organisational competitiveness and social compliance, has the greatest impact. Table S4 summarises the hypotheses that were supported by the structural equation model results.

5. Discussion of findings

The study topic sought to investigate the prevalent features of the BIM implementation model in South Africa and find the factor with the highest influence on raising the percentage of BIM adoption in the country. The conceptual model proposed via IPT that BIM capacity development, BIM use, BIM motivation and BIM commitment are the dominant parts of the BIM implementation model in the South African construction industry. The findings of the SEM verified the conceptual model and related hypotheses. The element with the greatest impact was discovered to be BIM motivation. Organisational competitiveness and social conformity were discovered to be the most important elements of BIM motivation in South African construction organisations.

According to the explanation for social compliance as a component of the BIM implementation model in South Africa, there is a natural desire in any organisation or professional to blend in with the trend in their work field and to have a long-term and pleasant relationship with their clients. These societal forces may be motivating construction companies and professionals to overcome barriers to BIM adoption. Competitiveness separates one building company or group of specialists from its competitors. It aids in avoiding complacency and competing for clients and credibility in the construction industry.

The pursuit of competitiveness by construction organisations and professionals through BIM implementation may be their approach for eradicating complacency and achieving supremacy over competing enterprises, or for fighting for viability in their areas of expertise. Previous research works in developed nations have shown that BIM deployment improves the worldwide competitiveness of indigenous construction organisations, according to the findings (Lindblad and Guerrero, 2020). According to Liao and Ai Lin Teo (2018), BIM deployment will transform the work and project delivery processes. According to Juan and Hsing (2017), BIM motivation will greatly motivate construction organisations to deploy BIM. According to Yang and Chou (2018) and Haron *et al.* (2015), BIM education and training are components of the BIM implementation model.

In comparison to previous South African studies, the findings of this study corroborate the findings of Kekana *et al.* (2015), who discovered that there is a level of BIM adoption amongst South African construction organisations (particularly multinational firms) because they want to be regarded as technically mature or advanced. According to the findings of Kekana *et al.* (2015), there are no country-specific BIM regulations and standards for BIM implementation in South Africa, and BIM adoption on construction projects in South Africa is pushed by clients who are clued up about BIM, private clients and project management organisations that consult for clients.

The current study found no evidence of mandated usage of BIM by the public client as a component of the BIM implementation model in South Africa. This contrasts with past research in China by Herr and Fischer (2019) and Zhou *et al.* (2019), which revealed that the required use of BIM by the public client was the primary BIM driver. The present research findings on BIM motivation demonstrate that the desires for technological sophistication, competitiveness and the want to be socially acceptable to clients are encouraging construction organisations and professionals to explore BIM adoption. This means that construction companies and experts are concerned with, and aware of, the excellence of their credentials and performance.

This encourages them to embrace BIM adoption as a means of acquiring and displaying cutting-edge construction technologies. Furthermore, the findings demonstrate that top management in construction organisations are embedding BIM adoption into their organisations' vision and have identified BIM competency as a new value for their employees. Lack of BIM-induced impact on organisational culture is a significant obstacle to BIM adoption since organisational culture affects the values and behaviours that characterise an organisation's work process and relationships. It appears that top management is strategizing to overcome BIM adoption challenges in their organisations by identifying BIM adoption as a present and future organisational goal.

This underscores why BIM competency has been considered as a value-add for their employees. It would be difficult to realise these organisations' current and future BIM visions without BIM-competent staff members. Top organisational management frequently employs the usage of organisational vision and values for organisational development. It seems that the top management of South African construction organisations is planning to implement this BIM strategy. According to the data, the most common BIM capacity building initiatives are self-initiated BIM training and on-the-job BIM training. Self-initiated training is a form of adult learning that enables people to learn with a special dedication.

It is also beneficial for the acquisition of new skills and knowledge, as well as the attainment of digital literacy. This suggests that construction professionals are relying on the benefit of self-initiated training in their desire to gain BIM knowledge and abilities. As a BIM capacity development strategy, on-the-job BIM training would enable construction organisations to satisfy BIM-specific needs. It is a hands-on approach of imparting BIM skills, knowledge and competencies, and its popularity amongst construction companies may be due to its fit for organisational growth and development. According to the findings, a BIM adoption plan (BIM execution plan) and a BIM performance appraisal are two of the most important aspects of BIM usage in South African construction organisations.

A BIM adoption plan, also known as a BIM execution plan, is a strategy for making informed decisions about the usage of BIM tools, technologies, concepts and procedures. It provides a method for an organisation's BIM goals to be met while meeting project requirements. A BIM adoption plan helps to ensure that resources are not squandered on BIM adoption and increases the likelihood of effective BIM adoption (Liu *et al.*, 2017). Construction organisations' usage of a BIM performance evaluation as a BIM utilisation strategy demonstrates that they realise the value of adding performance appraisal into BIM adoption.

It also demonstrates that these firms are interested in finding areas for development in BIM utilisation, receiving helpful review from BIM adoption, and evaluating project compliance. Another critical part of BIM implementation is determining the right level of development (LOD) for building information models for projects undertaken by South African construction firms. Determining the proper LOD for building information models for the project is a valuable BIM use strategy since it aids in specifying the content and dependability of building information models at various stages of the project. This method is used by construction organisations and professionals who are preoccupied with design details and specifications.

According to the findings of this study, construction companies in South Africa are aiming to instil a collaborative cooperation culture within their organisations. This is understandable given that BIM flourishes in a collaborative atmosphere. Construction companies and specialists are also obliged to try to impress their clientele. As a result, as shown in this study, the use of BIM competence by construction organisations to attract high-value clients is anticipated of any organisation or professional that is interested in attracting clients.

The findings also revealed that the top management of construction organisations is orchestrating BIM adoption processes in their organisations and experimenting with BIM on trial projects, and that building materials producers are establishing digital object identifiers for their products. This implies that upper management is particularly interested in BIM and that there is widespread appreciation for the automatic quantity take-off that BIM delivers. Automatic quantity take-off in the BIM process provides precise and fast cost modelling, as well as easy identification and assessment of construction materials. The establishment of digital item identifiers for building materials meets the BIM process's demand for automatic quantification.

6. Conclusion

It can be deduced that the prevailing features of the BIM implementation model in South Africa are *BIM capacity development, BIM utilisation, BIM motivation and BIM commitment*. According to the findings of this study, the BIM implementation model in South African construction organisations is characterised primarily by BIM motivation via organisational competency and social compliance. Furthermore, evidence from this study indicates that contractual requirements for BIM, incentives and investments from top management, techniques and practices of learning, as well as efficient and effective BIM application, are important for increasing the proportion of BIM implementation in South Africa.

As a result, this study indicates that the required BIM deployment model for the South African construction industry should be built on a mixed approach (that is, government-driven and private-driven). In a developing country like South Africa, such a BIM implementation model is required for the development of a BIM-friendly organisational structure and culture, the provision of in-house BIM training, the development of a BIM management process, the adoption of BIM as a marketing strategy, BIM education and training, BIM adoption support funds, the advancement of guidelines on BIM roles and responsibilities and strategic planning of BIM application on projects.

This study's findings are significant because they provide invaluable insight into the model used for BIM adoption in South Africa. The findings can help policymakers, industry leaders, organisational leaders, and all players in the South African construction industry determine which parts of BIM implementation to use to drive BIM adoption. Furthermore, the outcomes of this study have significant significance for achieving BIM implementation in poor nations where BIM adoption is either non-existent or in its early stages. The conclusions of this study will be relevant to these countries in creating BIM goals, designing a BIM implementation framework, distributing resources for BIM implementation and identifying key performance metrics for BIM implementation.

This study has identified the elements required for BIM implementation in underdeveloped nations. Nevertheless, it would be interesting to see how quickly these aspects eliminate BIM adoption hurdles and raise BIM adoption levels on building projects in underdeveloped nations.

6.1 Practical implications of the findings

The usefulness of the BIM implementation model developed and validated in this study for identifying BIM adoption goals, determining priorities, and developing a definitive and efficacious BIM adoption plan, overcoming BIM adoption barriers, and staying on track with BIM adoption is one of its implications. The model can be used to evaluate a practical and efficient BIM use by considering the degree of BIM investment (such as resources, time, and money) and the magnitude of BIM benefits to be obtained. According to the model, if the BIM benefits equal or surpass the BIM investment, the level of BIM application gets practicable and the cost of BIM adoption becomes affordable. BIM adoption's success, sustainability and performance efficiency may not be realised.

In practise, the model shows that a highly complicated project demands a greater degree of BIM application than a low-complexity project, such as a low-budget residential construction. The model has additionally advised us that creating an enabling BIM environment and assisting staff in migrating to the BIM process are realistic strategies for construction organisations' top management to boost BIM adoption in their organisations. The model likewise highlighted that the necessary human resources for BIM adoption will be realised via BIM capacity development by adapting human resources for diverse roles in BIM adoption, both now and in the future.

6.2 Study limitations and areas for future research

Because the data were acquired in South Africa, the study conclusions should be regarded with caution. The study also inherited quantitative research's shortcomings. To improve the generalisability of the research findings, future investigations should use a more robust research design. Future study should also look into other methods for expediting BIM deployment, comparative analysis of the extent of BIM implementation in countries with and without BIM guidelines and the effect of required BIM usage by the public client on the conviction to use BIM by the private client.

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Supplementary material

The supplementary material for this article can be found online.

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