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INVESTIGATING THE STRATEGIC PLANNING OF BIM ADOPTION ON CONSTRUCTION PROJECTS IN A DEVELOPING COUNTRY

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ABSTRACT: Strategic planning of BIM adoption has become increasingly important, owing to the need to minimise BIM adoption risks, maximise BIM benefits, and ensure successful BIM adoption. Our understanding of strategic planning of BIM adoption in a developing country is limited. Therefore, this study develops a framework for strategic BIM adoption on construction projects. The applicability of the framework was tested by using it to analyse the pattern of BIM adoption on construction projects in South Africa. Findings of the study demonstrate interrelationships between project milestones and deadlines, the extent of use of BIM software platforms used for the BIM-based construction projects (BBCPs), and the extent of collaboration on the BBCPs. The findings also confirm interrelationships between the regulatory system, the extent of use of BIM software platforms, the extent of collaboration, and the extent of integration on the BBCPs. This research has shown that the strategic planning of BIM adoption enables the proper management of BIM tools and processes. The research has also provided practical guidelines for strategic planning of BIM adoption in developing countries.

Keywords: BIM; BIM adoption; strategic planning; BIM adoption framework; BIM execution plan

1. INTRODUCTION

BIM adoption is an act undertaken by construction organisations or professionals, to take up or follow the provisions and guidelines of BIM in the planning, execution, management, and operation of construction projects (Olugboyega and Windapo, 2019). In the light of this definition, the terms 'BIM adoption' or 'BIM adoption on projects' refer to the application of BIM tools, principles, and processes on construction projects throughout the project lifecycles. Zhao et al., (2018), Chien et al., (2014), Okakpu et al., (2020), Sun et al., (2015), Qiang (2012), and Hammad et al., (2012) made it known that BIM adoption poses personnel, management, technical, legal, and financial risks to the project, project participants, project owners, and project objectives.

These risks cannot be eliminated, and if not properly managed, they may frustrate the success of BIM adoption and discourage its future adoption on construction projects (Khoshfetrat et al., 2020; Olugboyega and Windapo, 2019). A BIM execution plan (BEP) is useful for mitigating the risks that are associated with BIM adoption (Lin et al., 2016; Olugboyega and Windapo, 2019).

Hadzaman et al., (2016) describe a BEP as the BIM adoption plan for a particular project across the project phase, detailing the load of work and data input that users should comply with. Bloomberg et al., (2012) refer to the BEP as a BIM adoption plan that provides a framework tol enable project participants to use BIM technology, best practice, and most effective procedures for the execution, monitoring, and control of projects. Likewise, Ramírez-Sáenz et al., (2018) refer to a BEP as a procedural process that outlines the project's overall vision with implementation details for the project team to follow throughout the project. These definitions show that a BEP emphasises the importance of strategic planning in BIM adoption. They also show that the BEP provides a framework for planning BIM adoption. Several attempts have been made to develop frameworks for planning the adoption of technological innovations. For example, Pan et al., (2018) proposed a framework of indicators for assessing the sustainability performance of utilizing construction automation and robotics for building projects. The study claimed that the framework provides a robust and reliable assessment method that can be used in the industrial context; specifically, to assess the sustainability of building construction projects which consider using construction automation and robotics. Pena-Mora et al., (1999) proposed a strategic planning framework based on information technology (IT) diffusion to maximize the value of investments in large-scale projects. The essential steps in the strategic planning framework include an environmental scan, internal scrutiny, IT diffusion analysis, and IT investment modelling. Peansupap and Walker (2006) provide an information communication technology (ICT) innovation diffusion organisational level framework, which provides insights about how it may be applied to improve ICT adoption at different implementation stages for construction projects. The framework highlighted that ICT implementation planning should be strategic and consider issues of critical management support, technical support, supportive work environment, and ICT users' individual-characteristics. This is so that the framework processes can be effectively applied.

Shelbourn et al., (2007) developed a framework for planning effective collaborative working on projects. The proposed framework combines technological solutions, such as computer-aided-design, extranets, and knowledge management technologies with the people and business aspects of collaborative working, to provide an approach which allows stakeholders to benefit fully from having a collaborative working approach to their projects. Manley (2008) developed a theoretical framework that highlights methods by which small construction firms can overcome the disadvantages of their size, to implement innovation on construction projects. The framework emphasises working with advanced clients, prioritising relationship-building strategies, and using patents to protect intellectual property, as the key methods of innovation implementation by small firms on construction projects. Ahuja et al., (2010) developed protocols for strategic and enhanced adoption of information communication technology (ICT) for building project management by small and medium enterprises (SMEs).

These frameworks emphasise the place of strategic planning in adoption processes. However, the frameworks have concentrated on construction robotics, ICT, and collaborative working which make them inappropriate for planning BIM adoption.

A set of BIM adoption planning frameworks have been proposed to meet the shortcomings of the existing planning frameworks. These are described in detail in the Literature Review. They include guidelines for municipalities, (Bloomberg et al., 2012), execution planning of green building projects (Wu and Issa, 2015, Soetanto et al., 2014) and various models and planning prodecures for a range of construction projects.

The frameworks for planning BIM adoption as advanced by these studies have provided the understanding of the planning of BIM application on construction projects (that is, what to do with BIM technologies and processes on a construction project). However, the studies did not pay explicit attention to the strategy of BIM adoption on construction projects (that is, how not to use BIM technologies and processes). This seems to be a significant omission, because BIM adoption on construction projects requires the understanding of what to do and what not to do, to ensure an effective and efficient BIM adoption (Saluja, 2009; Olugboyega and Windapo, 2019). An effective and efficient BIM adoption will bring about the minimisation of BIM adoption risks, improve the derivation of BIM benefits and the successful adoption of BIM (Olugboyega and Windapo, 2019). Also, none of these studies has drawn attention to the frameworks in use in developing countries for planning BIM adoption. Thus, the question to be addressed in this study is '*What framework is being employed for strategic planning of BIM adoption on projects in developing countries*?

2. LITERATURE REVIEW

2.1 Theoretical background

A strategic plan describes a logical, proactive, and systematic plan that sets up a sense of direction, increases operational efficiency and reduces risks. The implication of this is that strategic planning of BIM adoption will reduce the risks of BIM adoption, increase its efficiency and effectiveness, and render the adoption of BIM technologies and processes on projects clear and methodical. Several attempts have been made to propose and develop frameworks for the strategic planning of BIM adoption on construction projects. These frameworks include a framework of a BIM execution plan for facility management (Lin et al., (2016), a BIM project execution planning guide (Messner et al., 2011; Saluja, 2009), requirements for a BIM execution plan (Ramírez-Sáenz et al., (2018), a BIM execution process for construction organisations (Gerçek, 2016), BIM guidelines for municipalities in New York City (Bloomberg et al., (2012), and BIM execution plan in the Czech Republic (Hrdina and Matejka, 2016). Others are a BIM execution planning guide for contractors, specialty contractors, and designers (Manenti et al., 2020; Lee et al., 2015), a BIM execution plan procedure for mega construction projects (Hadzaman et al., 2016), a BIM execution plan for BIM model management during the pre-operation phase (Lin et al., 2016; Pruskova and Kaiser, 2019), a BIM execution planning in green building projects (Wu and Issa, 2015; Soetanto et al., 2014), and framework for characterising BIM-based construction projects (Olugboyega and Windapo, 2019).

The frameworks for strategic planning of BIM adoption on construction projects proposed in the literature fall under three headings: country-based, organisational-based, and project-based.

2.1.1 Country-based frameworks

The BIM guidelines for municipalities in New York City (Bloomberg et al., 2012) and the BIM execution plan used in the Czech Republic (Hrdina and Matejka, 2016) are examples of country-based frameworks. Specifically, Bloomberg et al., (2012) developed BIM guidelines for the development and use of BIM across multiple building types for municipal agencies in New York City. The objective of the guide is to ensure uniformity in the use of BIM for public building projects in NYC. The provisions in the guide cover the end-use of the BIM for multiple client agencies and the system of tailoring municipal agencies' requirements and standards to BIM. The study concluded that the guide would be reviewed and updated with advancement as more insights emerged on the use of BIM. Hrdina and Matejka (2016) explained the main BEP chapters and the benefits of the BIM project in the Czech Republic.

Gerçek et al., (2017) provided guidance in BIM implementation for construction companies, in countries where BIM implementation has not been mandated, particularly during the construction phase of the building projects. The study further identified issues that need to be addressed by BIM implementation guides.

2.1.2 Organisational-based frameworks

Organisational implementation guidelines and standards have been published around the world either to encourage organisations to adopt BIM, or to present the minimum requirements to be followed for BIM implementation. These include a framework of a BIM execution plan for facility management (FM) (Lin et al., (2016) and a BIM execution process for construction organisations (Gerçek, 2016). Others are BIM execution planning guides for contractors, specialty contractors, and designers (Manenti et al., 2020; Lee et al., 2015). Lin et al., (2016) developed the framework of a BIM execution plan for BIM model management for FM during the operation phase. The study claimed that through the application of the proposed BIM-FM execution plan, BIM could be implemented effectively during the operation and maintenance phases. The study made suggestions for further development of the BIM-FM execution plan framework for BIM model management during the operation phase. Manenti et al., (2020) proposed guidelines for a BIM Execution Plan (PEB) development for contracts. The aim is to guide the relationship between process stakeholders – especially those from Santa Catarina (a state in the southern region of Brazil) – within the BIM model production process, to meet the needs of designers and contractors. The study claimed that the developed PEB is suitable for BIM implementation.

Pruskova and Kaiser (2019) contributed to the strategic adoption of BIM by proposing a specific process of implementing BIM technology for an effective design process. Their study explained that the implementation of BIM technology in the design process would lead to a better virtual reality projection of the building, and that its transformation into physical reality would result in better construction; also, that the technology would allow for greater cost savings, not only during the construction phase, but also in other phases of the building life cycle, especially during its use. Lee et al., (2015) developed the BIM project execution plan for reinforced concrete construction. Their plan outlined the "Construction BIM Use List for the RC Work", "BIM Application Master Process" and "BIM Application Detailed Process" for the construction process.

2.1.3 Project-based frameworks

A number of project-based frameworks have also been proposed. These include those mentioned previously by Messner et al., 2011; Saluja, 2009, Hadzaman et al., 2016 Lin et al., 2016; Pruskova and Kaiser, 2019, Wu and Issa, 2015; Soetanto et al., 2014, and that of Olugboyega and Windapo (2019).

Lin et al., (2016) developed a BIM execution plan for acility management during the pre-operation phase. The study demonstrated through a selected case study of a building project in Taiwan that the proposed BIM execution plan is an effective approach for operation and maintenance management. Further, it was claimed in the study that the advantage of the proposed BIM execution plan lies not only in improving the efficiency of maintenance management work when integrated with BIM technologies, but also in maximizing the value and benefits of BIM to support maintenance management. McArthur and Sun (2015) presented a framework to guide the development of a lifecycle BIM execution plan, applicable to public-private partnership projects. According to the study, the framework is widely adaptable and can be used for the full range of project delivery techniques.

The study by Hadzaman et al., (2016) investigated the processes of BEP, identified the information exchange among stakeholders, and established the strategies to implement BIM in Mega construction projects. Also, the study revealed that the important elements of BEP include BIM goals, BIM use, responsible parties, decision making, level of development, collaboration, and modelling requirements. Olugboyega and Windapo (2019) proposed a strategic and contingent BIM application model for construction projects. According to the study, the strategic part of the model entails the determination of BIM value and BIM effectiveness on a construction project by using appropriate BIM tools and processes for the project. The contingent part of the model involves the use of project complexity to determine the project expectations. The model matched the extent of BIM application to the level of project complexity. It was further claimed in the study that the model presents unique attributes for characterising BIM-based construction projects, provides a guide for case studies of BIM-based construction projects, and provides a guide for planning and managing BIM-based construction projects.

Saluja (2009) established a BIM Process Mapping Procedure (BIM-PMP) for planning BIM adoption on a project. The BIM-PMP provides an opportunity for the project team to map the implementation process for the various uses of BIM on a project. Saluja (2009) explained that by mapping the detailed process, key information exchanges can be identified, and a method for documenting and planning the information exchanges can be created. The BIM-PMP specifically maps which organisations will be using BIM on the project, what will they be performing with BIM applications, and how will they share information between the primary BIM Uses. The information elements to be shared include the information delivery schedule, responsible party, and information content for the BIM deliverables. Saluja (2009) claimed that the BIM-PMP can increase the level of planning for a project by familiarizing the team with the strategies and processes of their team members to achieve a more informed and effective transition of information between responsible parties. Wu and Issa (2015) proposed an integrated green BIM process map (IGBPM) for green building projects. The IGBPM addresses unique business processes of implementing BIM in energy and environmental design (LEED), using a green building rating system, and it facilitates systematic green BIM practices, based upon clearly defined business processes and execution planning. Soetanto et al., (2014) developed a BIM-enabled sustainable design process model that identifies critical decisions and their related actions in the design process, as well as the information and level of detail that facilitate an informed and timely decision.

The past studies have shown that BEP defines the appropriate uses for BIM on a project along with a detailed design and documentation of the process for executing BIM throughout a project's lifecycle. A BEP provides the plan for the project team to follow and monitor their progress against the plan, to help derive the maximum benefit from BIM implementation. BEP provides a structured procedure for identifying high-value BIM uses during project planning, design, construction, and operational phases; designing the BIM execution process by creating process maps; defining the BIM deliverables in the form of information exchanges; and developing the form of contracts, communication procedures, technology, and quality control to support BIM implementation (Messner et al., 2011).

The past studies have also shown the need to understand strategies involved in the planning of BIM adoption in developing countries. Understanding the pattern of strategic planning of BIM adoption in developing countries will unravel how BIM-based project participants in those countries are ensuring collaborative relationships, settling copyright issues, avoiding legal battles, and establishing BIM goals in terms of project expectations, BIM effectiveness requirements, BIM performance evaluation, and extent of BIM application.

Investigating the evidence for strategic and contingent planning of BIM adoption in the developing countries is supported by Saluja (2009) and Olugboyega and Windapo (2019), and Hadzaman et al., (2016). According to Olugboyega and Windapo, (2019) the project team must perform detailed and comprehensive planning for a successful implementation of BIM on a project. Hadzaman et al., (2016) observed that ambiguity, lack of strategy, lack of expertise, and poor knowledge in executing BIM have obstructed the performance of BIM on projects. This claim has not been proven to be the case in developing countries. Olugboyega and Windapo (2019) postulated that BIM application on construction projects is a potential risk that must be managed, because risk factors in construction projects increase with the extent of BIM application because of the inherent challenges associated with BIM application. This means that managing the risk of BIM application on projects and the realisation of BIM value depends on the appropriate use of BIM. Also, the view by Olugboyega and Windapo (2019) indicates that the frameworks or models for ensuring a balance between the BIM value, project characteristics, and BIM application must be investigated. Saluja (2009) concluded that BIM adoption on projects requires a strategy that considers process integration, along with information interoperability throughout the lifecycle of a project. This made it clear that BIM adoption on projects follows a pattern.

2.2 Research framework and hypothesis formulation

Figure 1 presents the conceptual framework for strategic planning of BIM adoption on construction projects. The Figure 1 illustrates the concept of interrelationships between the *BIM process, project complexity, project expectations,* and *BIM software platforms*. Further description of these relationships is shown in that the BIM process was conceptualized to consist of the *extent of collaboration* and the *extent of integration*. The *extent of collaboration* entails the *size of the BIM supply chain, the number of building information models, the choice of collaborative procurement,* and *the intensity of collaboration*. The *extent of integration* entails a *level of development, level of object clarity,* and *BIM capacity*.

The *extent of the use of BIM software platforms* is made up of *the type of BIM tools* and *the phase of BIM application*. *Project complexity* was conceptualized to consist of the *project size, project duration, project sensitivity, construction system for the project, project milestone and deadline, and project technologies* and *regulatory requirements*. *Project expectations* were classified into four groups, namely, *cooperation, coordination, partial integration,* and *full integration*. The concept of the interrelationships between these elements posits that the extent or degree of *project complexity* and *project expectations* determines the degree of *BIM process* and *BIM software platforms* that are adopted for the BBCPs.

The key piece of the conceptual framework involves the assurance of BIM worth and BIM viability on a construction project by utilizing suitable BIM software platforms and BIM processes for the undertaking. This key pieceof the conceptual framework includes the utilization of project complexity to decide the project expectations. The conceptual framework presents exceptional characteristics for describingg BBCPs, and this makes it simpler to distinguish non-BBCPs. The conceptual framework presumes that coordinating the degree of BIM adoption on construction projects with the degree of project complexity and expectations will guarantee high BIM viability in the delivery of construction projects. The conceptual framework also presumes that the performance of BIM on construction projects will be much easier to evaluate, with a strategic and contingent BIM application.

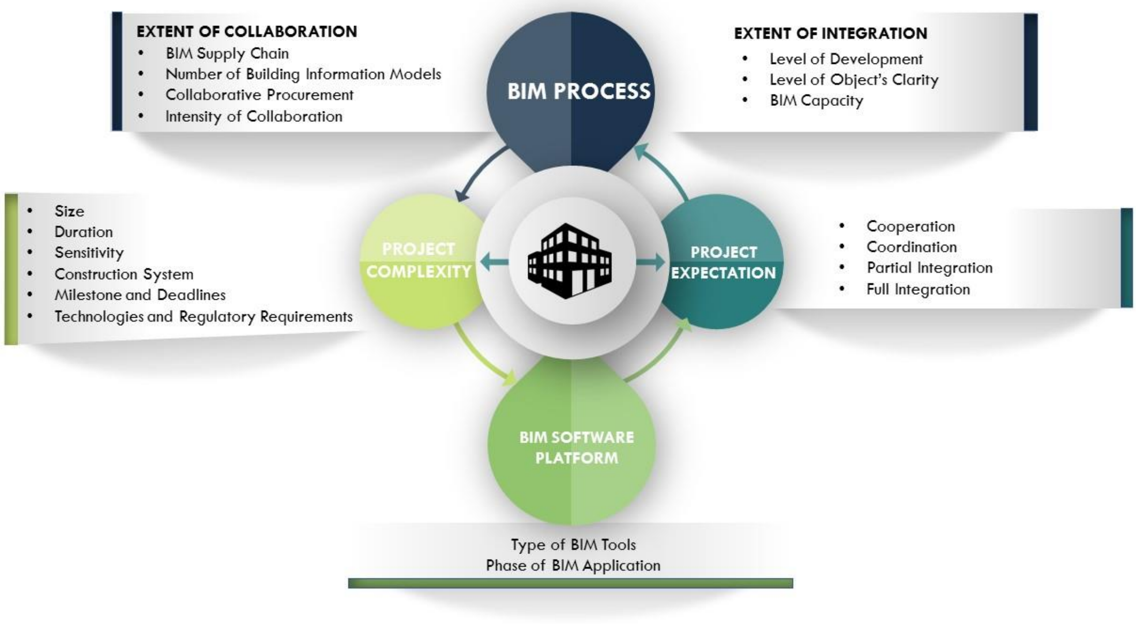

Figure 1: Conceptual framework for strategic BIM adoption on construction projects

The conceptual framework is valuable because it builds up a BIM application on construction projects as a strategy for deciding on the project contingency based on complexity. This is in line with the contention by Qazi et al. (2016) and Chatterjee et al. (2018) that project complexity is the primary characteristic of construction projects. Likewise, Wood and Ashton (2010) explain that project complexity is the main characteristic that decides the way to deal with project delivery, since it manages the degree of difficulty, insecurity, vulnerability, uniqueness, and dynamism of construction projects. Cao et al. (2015) and Lattifi et al. (2013) have established that the extent of BIM adoption on construction projects must be based on the extent of project complexity. Yang et al. (2011) argued that profoundly complex projects are innovatively and strategically demanding, and require multidisciplinary collaboration. Brockmann and Girmscheid (2007) concluded that megaprojects encapsulated high project complexity, due to their high capital expense and long lifespan.

The uniqueness of construction projects indicates that their expectations cannot be uniform. Project success depends upon detailing the uniqueness or expectations of the project in the BBCPs; and adopting BIM so that its benefits may be realised in carrying out the project. The success of the BBCPS thus must be assessed in order to show that the project performance is high. Studies, such as those by Zandieh et al. (2016) and Tulenheimo (2015), provide support for the relationships between the project expectations of the BBCPs and the extent of the effect of BIM adoption on BBCPs. Likewise, Liu et al. (2017) contend that BIM adoption on construction projects is a potential risk that must be overseen, because risk factors on construction projects increase with the degree of BIM adoption and the difficulties related to BIM adoption, such as capacity factors and experience. Porwal and Hewage (2013) observed that BIM adoption on construction projects should entail the articulation of project expectations. Baiden and Price (2011) agreed that project expectations must decide the degree of BIM adoption on a construction project.

Construction projects are unique in their characteristics, purposes, and requirements (Ryd, 2014). Therefore, this conceptual framework serves as a system of drawing comparisons between BBCPs and non-BBCPs (Harun et al., 2016; Chen and Luo, 2014; Olugboyega and Windapo, 2019). Based on the above, it is hypothesised that:

H1a: *The extent of use of BIM software platforms varies with the project complexity*.

H1b: *The extent of adoption of BIM processes for the BBCPs varies with the project complexity*.

H2a: *The extent of use of BIM software platforms varies with the project expectation*.

H2b: *The extent of adoption of BIM processes varies with the project expectation*.

3. RESEARCH METHODS

A total of 232 BBCPs were identified and used to determine the study population. The study population was determined in three stages: firstly, study population based on estimation, then study population based on the available e-mail contacts of the BBCPs direct participants, and lastly study population based on the number of BBCPs' direct participants who replied and consented to the invitation letter. The study population based on estimation was determined using the following equation as described by Bass et al., (2018):

$$Study\ population\ = A \times Bx_i^n$$

where
A = *number of reported or identified BIM-based construction projects,*
B = *sub-groups of direct participants in BIM-based construction projects,* and
n = *number of direct participants in BIM-based construction projects.*

The sampling process was achieved by identifying and dividing the study population into 14 sub-groups. The groups comprised of the fourteen major BIM supply chain members as identified by Succar (2009). Combining the identified BBCPs and the sub-groups of BBCPs' direct participants gave a total of 3,248 direct participants in BBCPs. Based on the available e-mail contacts, the number of direct participants reduced to 2,345. The number further reduced to 1,871 based on their willingness to participate in the research. Hence, a total of 1,871 was taken as the final study population for the research. According to Singh et al., (2014), a minimum of 5% of a large study population is adequate to determine the sample size. Therefore only 52% of the final study population was considered to obtain a representative sample. Hence, the sample size for the study was 975.
In the questionnaire, the respondents were asked to indicate the category of the BBCPs, clients for the BBCPs, and modalities for sharing the cost of BIM platforms and BIM-related services incurred for the BBCPs. Questions were asked about the stages at which BIM principles were adhered to on the BBCPs, and at which the BIM principles were adhered to on the BBCPs. Also, questions about the BIM processes employed for the BBCPs covered BIM capacity, size of the project consulting team, formation of a project team for the BBCPs level of object clarity, and the collaborative procurement process for the BBCPs. The selection of the research participants from among the study population was done using a random selection technique. The use of a random selection technique enables the selection of samples within each sub-group, so that sufficient representativeness is guaranteed for all the identified population sub-groups. Questionnaires were sent to the 975 research participants. The actual data collection was carried out over thirteen (13) months (August 2018 – August 2019). However, only 872 of the research participants completed the questionnaires without a substantial amount of missing and incomplete data. This gives a response rate of 89%.

The data collected was analysed using the frequency distribution and the Chi-square test. A Chi-square test was employed to investigate the relationship between the BIM process, project complexity, project expectation, and the BIM software platform. Table 1 summarises the demographic characteristics of the research participants for this research.

Table 1: Characteristics of the research participants

Answer Choices	**Response Percent**
Educational background of the research participants	
Certificate-Diploma with Grade 12	35.17%
Bachelor's Degree	22.49%
Higher Diploma [Technicon/University of Tech]	18.4%
N4-6/NTC4-6/Certificate-diploma with less than Grade 12	25.13%
Master's Degree	10.84%
PhD	1.02%
Designation of research participants	
Director Cadre	73.75%
Management Cadre	19.5%
Technical Officer	8.88%
Services provided	
Main Contractor	38.45%
Subcontractor	29.24%
Supplier	27.26%
Construction Manager	22.2%
Project Manager	17.87%
Consultants	17.33%
Developer/Client	5.6%
Specialist	5.6%
BIM Manager	2.71%
Area of Expertise	
Building and civil engineering construction	48.96%
Building construction	44.63%
Civil engineering	25.42%
Special construction/ special works	11.49%
Mechanical engineering works for infrastructure	7.72%
Electrical engineering works for building	7.16%
Mechanical engineering works for building	6.97%
Electrical engineering works for infrastructure	6.78%
Years of experience in the construction industry	
11 – 15 years	70.75%
16 – 20 years	19.88%
21 years and above	10.5%

4. RESULTS

4.1 BIM adoption plan for BBCPs

Figures 2 – 6 provide the analysis of the BIM adoption plan for the BBCPs, BIM processes employed for the BBCPs, project complexity of the BBCPs, and project expectations of the BBCPs. This analysis aims to validate the pattern of matching the extent of BIM adoption to the level of project complexity and expectations of the BBCPs.

The results revealed that BIM adoption plans are being developed with the skills and understanding of the conventional project management plan. For instance, BIM adoption plans for the projects were targeted at improving the time, cost, and quality performance of the projects as revealed by the intense use of visualization, budget simulation, and construction sequencing. Also, the BIM supply chain for the projects did not usually include the suppliers and subcontractors. As expected, BIM-friendly conventional procurement systems were favoured over integrated project delivery. This could be a result of familiarity with these conventional procurement systems. Likewise, Revit and ArchiCAD, which were the most popular BIM software technologies, were predominantly utilized for the BIM-based construction projects. It also emerged from the results that the CAD experience and competence of the BIM supply chain were much more pronounced in the BIM capacity that was employed for the BIM-based construction projects. This implies that CAD experience and competence are perceived as a basic and integral part of BIM adoption.

The BIM adoption plans for the BBCPs articulated the service requirements, design details, and specifications as revealed by the Level of Development employed for the projects. This indicates a proven strategy for regulating the quality and contents of building information models. It can be inferred that the BIM adoption plans incorporated project milestones and deadlines, construction technologies and systems, the political and cultural sensitivity of projects, and regulatory requirements for the projects, into the evaluation of project complexity for BIM adoption. In the same way, the plans address the integrated expectation of clients, projects, and participants during BIM adoption planning and execution.

PROFILE OF BIM-BASED CONSTRUCTION PROJECTS

CATEGORY OF THE BBCPs

Ports and Harbour	3.20%
Airports	3.65%
Railways and Tunnels	4.11%
Commercial Buildings	29.68%
Industrial Buildings	29.22%
Institutional Buildings	28.31%
Buildings for Domestic Use	52.97%
Bridge and Culvert	15.98%
Dams	9.59%
Roads	45.66%

MODALITIES FOR SHARING THE COST OF SOFTWARE TECHNOLOGIES HARDWARE, TECHNICAL SUPPORT, TRAINING, AND BIM -RELATED SERVICES INCURRED FOR THE PROJECTS

Client - 40%: Project Team - 60%	5.09%
Client - 30%: Project Team - 70%	9.26%
Client - 10%: Project Team - 90%	10.19%
Client - 20%: Project Team - 80%	12.50%
Client - 50%: Project Team - 50%	16.67%
Client - 0%: Project Team - 100%	58.33%

CLIENTS FOR THE BBCPs

Private Public Partnership	18.30%
Regional/District Department	23.66%
Metropolitan Department	17.41%
Provincial Department	47.77%
National Department	28.57%
Public Corporation	29.46%
Private Sector	56.25%

Figure 2: Profile of BIM-based construction projects (BBCPs).

BIM SOFTWARE PLATFORMS

BIM SOFTWARE TECHNOLOGIES USED FOR THE PROJECTS

Hyperwave	0.52%
Chatter	0.52%
Sharepoint	0.52%
Digital Project	0.52%
Archibus	0.52%
EcoDesigner	0.52%
Naviswork	4.17%

Asite	0.52%
BIMx	0.52%
Aconex	0.52%
TIBBR	0.52%
COSTX	0.52%
Zutec	0.52%
Allplan	4.17%

Bentley	0.52%
Solibri	1.04%
Project Libre	1.04%
RIBProject Center	1.04%
Autodesk Naviswork	1.04%
Robot	1.04%
Revit	16.15%
E-mail	37.50%

WINQS	2.08%
BuildCloud	2.08%
Collaborative Solutions	2.08%
Skype for Business	2.08%
QSCAD	2.08%
Dimensionx	2.60%
ArchiCAD	16.67%
AutoCAD Plant 3D and Structural Steel	1.04%

STAGES WHERE BIM PRINCIPLES WERE ADHERED TO ON THE PROJECT

De-construction/Demolition Stage	9.95%
Operation and Management Stage	18.10%
Completion and Commisioning Stage	23.53%
Conceptual Stage	34.39%
Feasibility Stage	43.44%
Design Stage	47.06%
Planning Stage	50.63%
Construction Stage	61.09%

BIM PRINCIPLES THAT WERE ADHERED TO ON THE PROJECT

Creation of Federated/Integrated Building information Models (design reviews, clash detection, data interoperation, the creation of the project database)	19.09%
Information Coordination and Manegement (BIM Protocols)	22.73%
Creation of Discipline - Specific Building Information Models	23.64%
Multidisciplinary Collaboration (trust and teamwork among the supply chain)	30.45%
Knowledge Sharing and Transfer among the Supply Chain	30.91%
Client Participation in Project Delivery	37.27%
Information Sharing and Exchange among the Supply Chain	41.82%
Supply Chain Integration (cooperation and communication among the project supply chain	55.45%

Figure 3: Extent of use of BIM software platforms for the BBCPs

BIM PROCESSES

BIM SUPPLY CHAIN FOR THE PROJECT

Curtain Wall Subcontractor	12.61%
Ductwork Subcontractor	15.22%
BIM Manager	16.52%
Precast Products Supplier	18.26%
Flooring Specialist	19.57%
Facilities Manager	20.00%
Town Planner	22.61%
Steelwork Subcontractor	29.13%
Mechanical Engineer	33.91%
Electrical Engineer	37.83%
Architect	49.57%
Project Manager	53.48%
Quantity Surveyor	53.91%
Structural/Civil Engineer	64.78%
Main Contractor	67.83%

COLLABORATIVE PROCUREMENT PROCESS FOR THE PROJECTS

Build-Operate-Lease and Transfer	3.14%
Build-Own-Operate and Transfer	3.59%
Build-Operate and Transfer	8.97%
Build-Own-Operate	11.66%
Design, Build, Finance and Operate	17.04%
Project Partnering	18.39%
Integrated Project Delivery	19.28%
Design and Build	25.11%
Management Contract	34.53%
Design-Bid-Build	42.15%

SIZE OF THE PROJECT CONSULTING TEAM

46 and above	11.40%
34-45 members	14.20%
24-34 members	16.60%
13-23 members	21.10%
2-12 members	36.70%

LEVEL OF OBJECT'S CLARITY

G3 - Rendered	18.13%
G2 - Defined	17.47%
G1 - Concept	11.18%
G0 - Schematic	11.05%

BIM CAPACITY

Competence in BIM Tools and Software Technologies	14.75%
Competence in 3D CAD Tools Software Technologies	15.14%
Information Integration Skills	13.23%
Information Exchange Skills	14.95%
Multi-Disciplinary Collaborative Skills	16.83%

LEVEL OF DEVELOPMENT OF THE INFORMATION MODEL FOR THE PROJECTS

LOD 350 - Information for Coordination and Interface Management	23.04%
LOD 500 - Detailed Information for Operation and Maintenance	24.88%
LOD 400 - Detailed Information for Assembly, Installation and Fabrication	28.11%
LOD 200 - Information for Design and Analysis	32.26%
LOD 100 - Approximate Information	42.86%
LOD 300 - Information for Measurement, Costing and Bidding	47.93%

FORMATION OF PROJECT TEAM FOR THE PROJECT

Integrated Supply Team (project team staffed with internal and external members)	20.18%
Collaborative Supply Team (project team staffed with internal and external members)	28.51%
Integrated Project Team (project team staffed with internal and external members)	39.04%
In-House Project Team (project team staffed with internal and external members)	48.68%

Figure 4: BIM processes employed for the BBCPs

PROJECT COMPLEXITY

CONSTRUCTION TECHNOLOGIES AND SYSTEMS USED FOR THE PROJECT

Unproven and New Technologies and Systems	8.04%
Innovative/Ground-Breaking Technologies and Systems	17.41%
Proven but New Technologies and Systems	25.45%
Conventional Technologies and Systems	67.73%

PROJECT SIZE / TENDER SUM

R6.5Million - R40Million	16.81%
Above R40Million	19.47%
R2Million - R6.5Million	30.97%
Below R2Million	42.92%

PROJECT MILESTONES AND DEADLINES

Over-ambitious Milestones and Deadline (Target dates that are fixed based on very high aspiration and are very difficult to achieve)	7.83%
Ambitious Milestone and Deadline (Target date that are fixed based on high aspirations and are difficult to achieve)	16.52%
Aggressive Milestone and Deadline (Target dates that are fixed and pursued in determined and forceful way)	35.65%
Flexible Milestone and Deadline (Target dates that are not fixed but created as the project proceeds)	50.00%

DURATION OF THE BBCPs

1 year and above	47.79%
6 months - 1 year	31.86%
3 - 6 months	23.45%
Less than 3 months	16.37%

REGULATORY REQUIREMENTS FOR THE PROJECT

Technologies that need new regulatory requirements	11.35%
Standard Regulations	91.70%

THE POLITICAL AND CULTURAL SENSITIVITY OF THE PROJECT

Very High Political and Cultural Implications	11.69%
High Political and Cultural Implications	24.24%
Little High Political and Cultural Implications	35.93%
No High Political and Cultural Implications	36.80%

Figure 5: Project complexity of the BBCPs

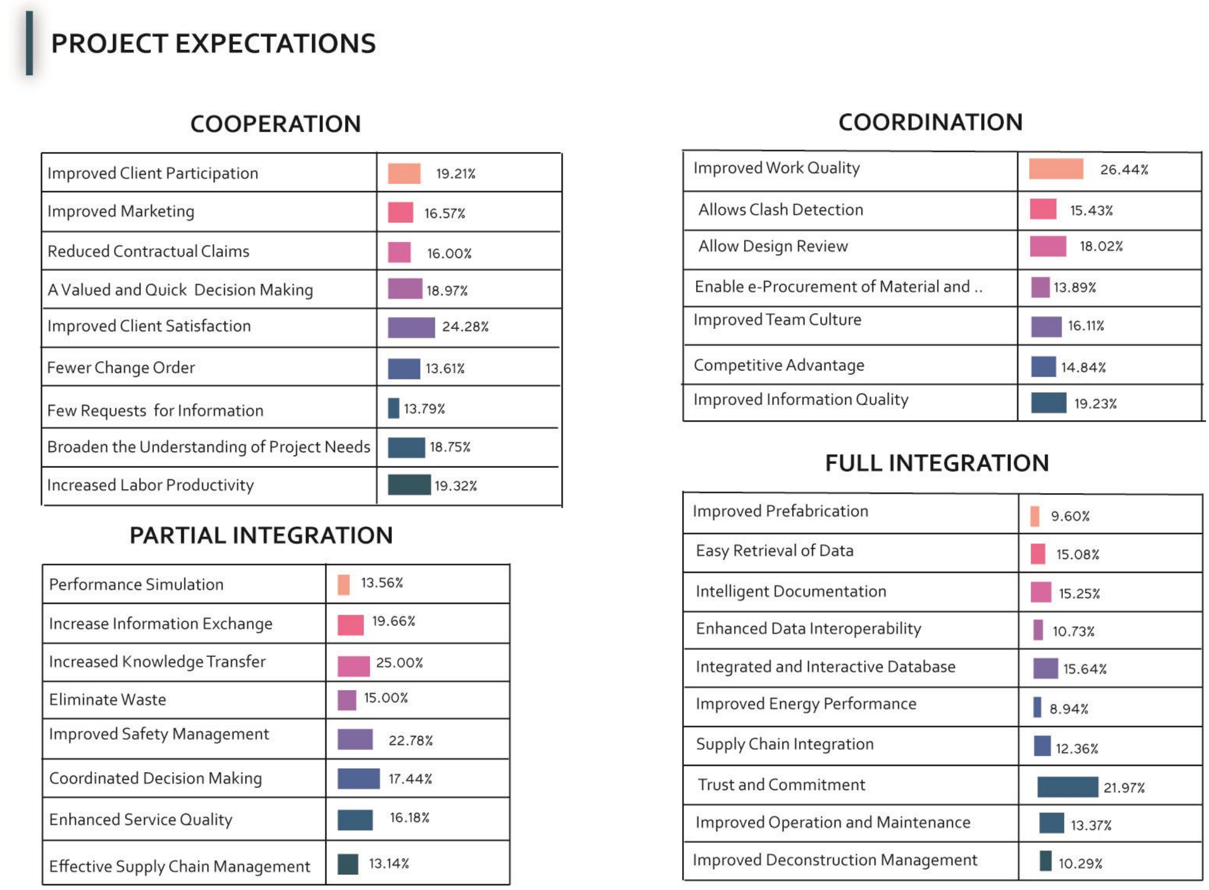

Figure 6: Project expectations of the BBCPs

4.2 Hypothesis testing

As shown in Table 2, the links between project size and extent of use of BIM software platforms ($\chi 2$ = 1.25, p = 0.26), project size and extent of collaboration ($\chi 2$ = 1.63, p = 0.20), and project size and extent of integration ($\chi 2$ = 0.93, p = 0.33) were not significant.

This means that the extent of use of BIM software platforms for the BBCPs did not differ by the project size. The result also means that the extent of collaboration and integration on the BBCPs did not differ by project size. The links between project duration and extent of use of BIM software platforms ($\chi 2$ = 6.19, p = 0.10), project duration and extent of collaboration ($\chi 2$ = 4.73, p = 0.31), and project duration and extent of integration ($\chi 2$ = 2.00, p = 0.73) were not significant. This suggests that the extent of use of BIM software platforms for the BBCPs and extent of collaboration and integration on the BBCPs did not vary with the project duration.

Table 2 also showed that the association between project sensitivity [extent of use of BIM software platforms ($\chi 2$ = 3.66, p = 0.45), extent of collaboration

($\chi2 = 3.66$, $p = 0.45$), extent of integration ($\chi2 = 2.00$, $p = 0.73$)], construction system [extent of use of BIM software platforms ($\chi2 = 5.43$, $p = 0.14$), extent of collaboration ($\chi2 = 2.73$, $p = 0.60$), extent of integration ($\chi2 = 1.05$, $p = 0.90$)], and construction technologies [extent of use of BIM software platforms ($\chi2 = 5.93$, $p = 0.11$), extent of collaboration ($\chi2 = 2.75$, $p = 0.60$), and extent of integration ($\chi2 = 0.85$, $p = 0.93$)] were not significant.

This suggests that the extent of use of BIM software platforms, extent of collaboration, and extent of integration on the BBCPs were not different. Significant connections were found between project milestones and deadlines and the extent of use of BIM software platforms ($\chi2 = 12.19$, $p = 0.00$), and project milestones and deadlines and extent of collaboration ($\chi2 = 12.20$, $p = 0.01$).

Project milestones and deadlines did not have a significant connection with the extent of integration ($\chi2 = 8.88$, $p = 0.06$). This implies that the extent of use of BIM software platforms used for the BBCPs and the extent of collaboration on the BBCPs differ, by the project milestones and deadlines.

Table 2: Significance of the link between project complexities, the extent of use of BIM software platforms, and adoption of BIM processes

Link between project complexities, extent of use of BIM software platforms, and adoption of BIM processes	Significance (Level of significance is @ $p< 0.05$)
Project size → Extent of use of BIM software platform	$\chi2 = 1.25$, $p = 0.26$
Project size → Extent of collaboration	$\chi2 = 1.63$, $p = 0.20$
Project size → Extent of integration	$\chi2 = 0.93$, $p = 0.33$
Project duration → Extent of use of BIM software platform	$\chi2 = 6.19$, $p = 0.10$
Project duration → Extent of collaboration	$\chi2 = 4.73$, $p = 0.31$
Project duration → Extent of integration	$\chi2 = 2.00$, $p = 0.73$
Project sensitivity → Extent of use of BIM software platform	$\chi2 = 5.93$, $p = 0.20$
Project sensitivity → Extent of collaboration	$\chi2 = 3.66$, $p = 0.45$
Project sensitivity → Extent of integration	$\chi2 = 2.00$, $p = 0.73$
Construction system → Extent of use of BIM software platform	$\chi2 = 5.43$, $p = 0.14$
Construction system → Extent of collaboration	$\chi2 = 2.73$, $p = 0.60$
Construction system → Extent of integration	$\chi2 = 1.05$, $p = 0.90$
Project milestone and deadline → Extent of use of BIM software platform	$\chi2 = 12.19$, $p = 0.00$

Project milestone and deadline → Extent of collaboration	$\chi2 = 12.20$, $p = 0.01$
Project milestone and deadline → Extent of integration	$\chi2 = 8.88$, $p = 0.06$
Construction technologies → Extent of use of BIM software platform	$\chi2 = 5.93$, $p = 0.11$
Construction technologies → Extent of collaboration	$\chi2 = 2.75$, $p = 0.60$
Construction technologies → Extent of integration	$\chi2 = 0.85$, $p = 0.93$
Regulatory requirements → Extent of use of BIM software platform	$\chi2 = 41.11$, $p = 0.00$
Regulatory requirements → Extent of collaboration	$\chi2 = 44.15$, $p = 0.00$
Regulatory requirements → Extent of integration	$\chi2 = 38.94$, $p = 0.00$

Table 2 reveals a significant link between regulatory requirements and extent of use of BIM software platforms ($\chi2 = 41.11$, $p = 0.00$), regulatory requirements and extent of collaboration ($\chi2 = 44.15$, $p = 0.00$), and regulatory requirements and extent of integration ($\chi2 = 38.94$, $p = 0.00$). These results suggest that different projects require different regulatory requirements. The extent of BIM software platforms used for the project, extent of collaboration on the BBCPs, and extent of integration on the BBCPs vary with the type of regulatory requirements required by the BBCPs. Construction regulations are statutory instruments that serve as the basis for issuing construction permits to various types of construction projects. It appears from this result that the use of an appropriate number of BIM tools, the extent of collaboration, and the extent of integration for a different type of BBCPs are being undertaken to secure construction permits for the BBCPs.

Table 3 shows the result of a Chi-square test conducted to establish whether there is a significant link between project expectations, the extent of BIM used for the BBCPs, the extent of collaboration on the BBCPs, and the extent of integration on BBCPs. Project expectations for BBCPs were conceptualised to consist of four levels of project expectations, namely *cooperation, coordination, partial integration,* and *full integration* (see Figure 1). As illustrated in Figure 1, the extent of project expectations for BBCPs must determine the extent of use of BIM software tools, the extent of collaboration, and the extent of integration. However, the results in Table 3 did not validate this proposition.

Table 3: Significance of the link between project expectations, the extent of use of BIM software platforms, and adoption of BIM processes

Link between project complexity, the extent of BIM software platforms, and adoption of BIM processes	**Significance (Level of significance is @ $p< 0.05$)**
Cooperation → Extent of use of BIM software platform	$\chi2 = 5.54, p = 1.35$
Cooperation → Extent of collaboration	$\chi2 = 3.26, p = 0.51$
Cooperation → Extent of integration	$\chi2 = 0.64, p = 0.95$
Coordination → Extent of use of BIM software platform	$\chi2 = 5.25, p = 0.15$
Coordination → Extent of collaboration	$\chi2 = 3.27, p = 0.51$
Coordination → Extent of integration	$\chi2 = 0.64, p = 0.95$
Partial integration → Extent of use of BIM software platform	$\chi2 = 5.39, p = 1.45$
Partial integration → Extent of collaboration	$\chi2 = 3.53, p = 0.47$
Partial integration → Extent of integration	$\chi2 = 0.88, p = 0.92$
Full integration → Extent of use of BIM software platform	$\chi2 = 5.29, p = 0.15$
Full integration → Extent of collaboration	$\chi2 = 3.17, p = 0.52$
Full integration → Extent of integration	$\chi2 = 0.55, p = 0.96$

Table 3 reveals that the links between cooperation [extent of use of BIM software platforms ($\chi2 = 5.54, p = 1.35$), extent of collaboration ($\chi2 = 3.26, p = 0.51$), extent of integration ($\chi2 = 0.64, p = 0.95$)], coordination [extent of use of BIM software platforms ($\chi2 = 5.25, p = 0.15$), extent of collaboration ($\chi2 = 5.25, p = 0.15$), extent of integration ($\chi2 = 0.64, p = 0.95$)], partial integration

[extent of use of BIM software platforms ($\chi2 = 5.39, p = 1.45$), extent of collaboration ($\chi2 = 3.53, p = 0.47$), extent of integration ($\chi2 = 0.88, p = 0.92$)], and full integration [extent of use of BIM software platforms ($\chi2 = 5.29, p = 0.15$), extent of collaboration ($\chi2 = 3.17, p = 0.52$), extent of integration ($\chi2 = 0.55, p = 0.96$)] were not significant.

5. DISCUSSION OF FINDINGS

The existing frameworks for planning BIM adoption did not fully consider the strategies for minimizing BIM adoption risks, maximizing BIM adoption benefits, and ensuring the successful adoption of BIM. Also, there is a dearth of frameworks for planning BIM adoption in developing countries. To fill this gap, this study developed a conceptual framework for strategic planning of BIM adoption on construction projects. The framework explained that to minimize the risks of BIM adoption and maximize the benefits of BIM adoption, the extent of use of BIM software platforms (type of BIM tools and the phase of BIM application), as well as the extent of integration and collaboration must be determined by the project complexity and expectations. The framework was built on the lapses observed in the existing frameworks. Also, the framework was conceptualized to capture the peculiarities and requirements of BIM adoption planning in developing countries.

Four hypotheses were formulated to test the framework. The first hypothesis (H1a) states that *the extent of use of BIM software platforms varies with the project complexity*. The second hypothesis (H1b) states that *the extent of adoption of BIM processes for the BBCPs varies with the project complexity*. The third hypothesis (H2a) states that *the extent of use of BIM software platforms varies with the project expectation*. The fourth hypothesis (H2b) states that *the extent of adoption of BIM processes varies with the project expectation*. The first and second hypotheses were partly supported by the findings of the study (see Tables 2 and 3). Among the six sub-constructs (project size, project duration, project sensitivity, construction system, project milestone and deadline, construction technologies, and regulatory requirements) that represent project complexity; only regulatory requirements varied with (H1b)the extent of collaboration, the extent of integration, and (H1a)the extent of use of BIM software platforms. It also emerged from the findings that the extent of collaboration and the extent of use of BIM software platforms varied with the project milestone and deadline. This suggests that different BBCPs require different milestones and regulatory requirements.

Project milestones signify a transition from one project stage to another. They also mark the completion of major project tasks. Therefore, the significant connection between project milestones and deadlines, the extent of use of BIM software platforms used for the BBCPs, and the extent of collaboration on the BBCPs may mean that the extent of collaboration decreases or increases with the change in project stages, and completion of different tasks. It may also mean that different types of BIM software platforms are required for different tasks and project stages. This explanation is in line with previous studies which have indicated different BIM adoption frameworks for different project stages, such as the project design stage (Hamieh et al., 2020; Minunno et al., 2020), project planning and scheduling stage (Elghaish and Abrishami, 2020; Rahman et al., 2020), construction stage (Muhammed et al., 2020; Ma et al., 2019), and operation and maintenance stage (Brunet et al., 2019).

In line with the strategies for BIM adoption on projects, as explained in Figure 1, the significant connection between project milestones and deadlines, the extent of use of BIM software platforms used for the BBCPs, and extent of collaboration on the BBCPs may serve as the validation for the interrelationships between project milestones and deadlines, the extent of use of BIM software platforms used for the BBCPs, and extent of collaboration on the BBCPs. This validation holds for the interrelationships between the regulatory system, the extent of use of BIM software platforms, the extent of collaboration, and the extent of integration on the BBCPs.

The findings of this study did not support the third and fourth hypotheses. Contrary to the conclusions by Ryd (2014), Tulenheimo (2015), and Zandieh et al. (2016), the results of this study suggest that regulating the extent of BIM adoption on BBCPs with the extent of project expectations, was not a valid strategy for minimising BIM adoption risks, and maximising BIM adoption benefits in South Africa.

6. CONCLUSION

This study investigated the frameworks employed for strategic planning of BIM adoption on projects in developing countries, using South Africa as the study area. To achieve the research objectives, hypotheses were formulated based on the conceptual frameworks for the research, as illustrated in Figure 1. The hypotheses were tested using a chi-square test of independence. The results of the Chi-square test partially validated H1a and H1b; while H2a and H2b were not validated. Information on the validity of the strategies for BIM adoption on the BBCPs showed that there is a significant association between the extent use of BIM software platforms, the extent of collaboration, the extent of integration, project milestones and deadlines, and regulatory requirements for the BBCPs. This research has provided practical guidelines for strategic planning of BIM adoption in developing countries. Owing to the scarcity of resources in developing countries, it is important to maximise the benefits of BIM adoption on construction projects. The framework developed in this research will be useful in this regard.

BIM adoption is slower in developing countries compared to the developed countries. This emphasises the need to encourage BIM adoption on construction projects in developing countries through the mitigation of the risks associated with BIM adoption. The strategies contained in the framework are useful for maximising the BIM adoption risks. Theoretically, this research has shown that the strategic planning of BIM adoption enables the proper management of BIM tools and processes. Also, the research has shown that the adoption of BIM on construction projects is as important as the process of the adoption and the adherence to best practice. Failure to link BIM adoption to project expectations and complexities will likely result in an unsuccessful BIM adoption.

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