

Capability factors influencing the adoption of Building Information Modelling (BIM) by South African AEC organizations

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Abstract:

Building Information Modelling (BIM) has been identified as a possible moderating solution to the construction industry's challenges, such as delayed projects, high costs of construction, and compromised quality of products. However, the adoption of BIM processes has been slow within South African AEC organizations. This research identifies the capability factors influencing BIM adoption from organizations that have successfully adopted BIM. A qualitative analysis was conducted using a case study research design that incorporated semi-structured, personal interviews of AECs in South Africa and site observations. The interview questions were designed to figure out the level of BIM adoption, the capability factors that enable the adoption of BIM, and the main capability factor influencing BIM adoption within South African AEC firms. The three case studies revealed that the level of BIM adoption is still developing. The capability factors identified from the three case studies were grouped into three main categories - human resources, process and technology. The main capability factor discovered was the cost which falls under the process category. The findings presented in this paper aim to provide an insight into the needs and concerns of AEC firms regarding BIM adoption.

Keywords: AEC, BIM adoption, capability factors, competency

1 Introduction

The building's life cycle processes are managed with tools such as Building Information Modelling, which will administer the crucial building design and project data in a digital format for an easy flow of information. Aouad et al. (2006) and Succar (2009) note that the success of construction projects depends on the ability of the stakeholders, contractors, clients and other project teams to consider and communicate multi-disciplinary issues, constraints, goals and perspectives holistically. The construction industry recognizes Building Information Modelling as having significant potential to impact project delivery and performance positively. The BIM tools and processes have been developed to improve productivity in the construction industry. BIM allows the project team to aim towards improved construction site practices across the supply chain as it enables more accurate data, greater precision and reliable construction processes, and ease of operations and maintenance (Azhar, 2011; Khosrowshahi et al., 2012; Wortmann, 2016).

The construction industry plays a crucial role in the South African economy as it contributes to the country's economic growth. Success on projects is measured in terms of performance in time, quality and cost. However, success in these three main aspects is

rarely achieved due to constraints such as delays that affect cost and quality. Events such as delayed finances and payment of work stemming from the client, improper planning and general mistakes from the contractor, preparation and long waiting times for approval of documentation from consultants are some of the causes (Akintola et al. 2017; Babu and Suresh, 1996; (Odeh and Battaineh, 2002). These constraints are difficult to eradicate, and BIM is acknowledged as a possible solution. However, most AECs in South Africa have not successfully implemented and adopted BIM (Kiprotich 2014).

The point of interest in this research was to determine the capability factors influencing BIM adoption in the South African AEC industry to determine the extent organizations need to go to acquire these enablers of BIM adoption. BIM mainly operates on three characteristics: processes, technology, and human resources, with the latter, is usually the main challenge facing many organizations in successful adoption (Rogers et al., 2015). Other factors are significant as well, and while BIM capability factors are inexhaustible, a few are worth mentioning, mainly focusing on these three overarching aspects.

Arayici (2011) suggests the following as leading influencers of adoption: people's understanding of the value of BIM over traditional models, the training of workers to use BIM as well as finding a work team that understands its functionality, the adaptation to the high-quality hardware resources and networking facilities to run BIM applications and tools efficiently, and knowledge of the role of different stakeholders in the new process by construction lawyers and insurers. A survey done by Shakantu et al. (2014) aimed to assess the level of BIM awareness and adoption in South Africa. This survey showed that the innovation adoption by South African architects is 53% and for BIM awareness is 79%, whilst South African contractors had an awareness of 27% and adoption of 12%. These statistics have also been motivated by the South African government showing no interest in driving BIM practices as there are no government BIM standards or specifications required in practice (Wortmann et al., 2016).

The research focused on the capability factors of AEC organizations in adopting BIM in their workspace. An evaluation from organizations that have successfully adopted BIM was done. Capability is the power or ability to perform a task but, in this regard, the question being asked is what capabilities an organization needs in order to be BIM capable. Firstly, these capabilities include technical/physical resources such as adopting the necessary hardware, software availability, and network infrastructure availability. Secondly, administrative and strategic capacity such as IT Budget, BIM research and maturity, BIM research and development and clear BIM vision. Thirdly, BIM modelling capacity such as BIM standards and internal information management (Mahamadu et al., 2017). South African AEC Organizations have been adopting BIM at a languid pace compared to other countries globally. It is being used in an isolated environment mainly by architects instead of using a collaborative tool for the entire project team (Kiprotich 2014; and Shakantu & Froise, 2014). The objectives to be achieved in this research are to identify the level of BIM adoption within South African construction firms, identify the capability factors that influence its adoption, establish the key capability factors and determine the capability factor with the most significant influence on BIM adoption.

2 Literature Review

This chapter starts by giving an overview of the challenges faced in the Architectural, Engineering and Construction Industry to draw some attention to why BIM adoption is an

innovative solution to solving the many problems. It then speaks on BIM adoption and the degree to which it has been implemented globally, and the capability factors that influence this adoption. These capability factors were stated and discussed in detail before categorizing them into three main capability factors: people, process, and technology. Different authors have defined BIM in different ways; BIM is seen as a single project database in the form of an electronic data model to which professional bodies collaborate throughout the design to operation and maintain the building (Gann et al. 1996).

2.1 Challenges faced in the Architectural, engineering and Construction Industry

The construction industry has been facing challenges over the years, and one of the main challenges has been the fragmented nature of the industry (Nawi et al., 2014). Fragmentation in this respect means the separation of the design stage and construction stage, including the actual construction of the structure itself. Fragmentation also relates to the construction procurement process itself, which separates designers, contractors and facility managers in the initial stages of a project (Nawi et al., 2014). Owolabi et al. (2014) identified delay as a major challenge faced by the AEC worldwide. Owolabi et al. (2014) mentioned the factors that affect delays, including changes in drawings, a lack of communication amongst project participants, incomplete work from consultants, and variations. Architects, engineers and contractors use BIM to help overcome some of the stated challenges. Building information modelling (BIM) seeks to integrate processes throughout the entire lifecycle and is seen as a tool to improve or look upon some of the challenges faced in the AEC industry (Aouad and Arayici, 2010).

2.2 Overview of BIM adoption

BIM adoption has been generally slow worldwide (Gu and London 2010; Azhar, 2011; Elmualim, 2014; Jung, 2015). In the South African context, BIM has predominantly been adopted by organizations in KwaZulu-Natal, Western Cape, and Gauteng provinces in commercial and residential building projects. The research also showed that the most prevalent software used are ArchiCAD, Autodesk Revit, WinQS and QSPlus (Ogwueleka, and Ikediashi, 2017; Abubakar, 2014; Jung, 2011; Kouch, 2018; Liu, 2015). Kekana et al. (2015) investigated the level of BIM adoption in three key South African areas: Johannesburg, Tshwane, and Ekurhuleni. Of the questionnaires sent, the fifty that returned revealed that the usage of BIM, amongst those participants, was at 80%. BIM experience was also found since BIM usage was common amongst management and designers in construction organizations.

2.3 Capability factors influencing BIM adoption in South Africa

The introduction and adoption of any new technology such as BIM require the capability factors that will positively affect the adoption to be identified and addressed for the successful take-up of the innovations (Abubakar et al., 2014). These capability factors that lead to the adoption of BIM are documented in the previous literature above. These capability factors are of different categories as defined by different experts. Eastman et al. (2011) categorized these capability factors according to process and technology. The process factors deal with the business, including legal and organizational issues that influence the adoption of BIM, while technology factors relate to the readiness and implementation of the actual BIM processes. Sun et al. (2017) had a third category: personnel; the personnel factor refers to the professional-related capability factors. Table 1 below shows a summary of the capability factors identified in the literature review when categorized according to process, technology and human resources:

Table 1: Capability factors

Category	Capability Factors	References
Process	• Presence of standards or guidelines • Cost • Business Environment • Organizational Structure	Azhar et al. (2012); Gu and London (2012); Hong et al. (2016)
Technology	• Interoperability between software platforms and users • Hardware and Software	Sun et al. (2017); Liu et al. (2015); Succar et al. (2013); Hong et al. (2016); Ezeokoli et al. (2016); Gardezi et al. (2014); Memon et al. (2014)
Human resources	• Attitude towards BIM • Structure/culture of the industry • Level of knowledge and awareness	Succar and Sher, (2014); Barison and Santos, (2011); Succar and Kassem (2015); Arayici et al. (2011)

2.4 Main Capability Factors

2.4.1 Process

The process relates to the number of activities an organization does in successfully implementing BIM. A capability factor that influences processes in BIM adoption is cost. Cost, in this context, refers to the cost of software, licenses and cost of the staff implementing BIM processes. Hong et al. (2016) mention that costs can influence the adoption of BIM by organizations.

2.4.2 Technology

The BIM-based software packages are also called BIM tools. The technological factors refer to BIM tool-related factors limiting BIM application, such as the cost of the technology, maintenance of the hardware and software, and interoperability between software platforms and users (Sun et al., 2017).

2.4.3 Human resources

For the Human factor of BIM, construction organizations speak of the promotion of an educational principle that looks at how to create a framework with components that help in enabling BIM adoption within an organization. The attitude of individuals influences their willingness to learn and practice improving their skills and knowledge. The skills and knowledge were identified as capability factors that influence adoption (Barison, 2011; Kassem, 2015). In terms of expertise, Arayici (2011), Barison (2011) and Eastman (2011) note that a competent BIM Manager knows about Information Technology, design and construction processes, management, BIM standards, BIM workflow, coordination practices, project management, construction drawings and costs, schedules and financial risks, parametric object-based design and other disciplines.

3 Research Methodology

This study employed semi-structured interviews to elicit research information from the case study participants. The chosen approach for this research was the case study design, which involved interviews and observations in collecting data. This approach required a constructive approach that required more interaction between the researcher and the participants. In addition, the questions were framed in a way that would help the researchers in answering the three research objective as well as determine the key capability factor influencing BIM adoption. This would be possible through a thematic analysis of the data.

This research method was employed because of the three distinctive characteristics that were outlined by Hancock and Algozzine (2017). The first characteristic is that it describes the social phenomena as they occur naturally with no attempt to manipulate the study; secondly, it looks at the collection of the qualitative data, and the last characteristic looks at the qualitative sampling techniques that are concerned with seeking information from specific groups and subgroups within a population. For the purposes of this study, the study population consists of all Architectural, Engineering and Construction (AEC) organisations based in South Africa that have adopted BIM. A purposive sampling technique was used in selecting AEC firms based in South Africa and in identifying BIM managers, architects, engineers, construction managers, quantity surveyors who work for these organisations.

All interviews were recorded on smartphones after consent from participants, and the recordings were then manually transcribed through listening to the voice recording and manually typing word for word. In addition, the researchers had to visit the actual workplaces of the interviewees, which also allowed brief observations of the area in terms of actual hardware and software implemented and BIM models and applications used. The interviews were conducted on three AEC firms in Cape Town that have adopted BIM, and the selection criteria for the firms was that the firm must have: adopted BIM for more than five years; implement BIM on all projects; a cidb Grade of 8 or 9 and been practising architecture, engineering or construction. Based on the criteria outlined above, the firms interviewed were two architectural firms and one engineering firm. Research participants were chosen from architects, BIM managers, and quantity surveyors and the main requirements were BIM competency and at least five years of BIM experience.

For Case Study 1, referred hereafter as CS1, the organization has adopted BIM for ten years now, and they have a footprint in six continents. CS1 is an architectural organization and develops high-end residential and commercial building in South Africa. They are currently on Level 3 of BIM adoption, and the one interviewee has been BIM manager for ten years now for the organization. Case Study 2, referred hereafter as CS2, conducted a group interview style. CS2 is an architectural organization that also adopted BIM in 2009. CS2 does architectural and design work in the urban commercial spectrum as well as individual and interior design. CS2 volunteered to have their whole BIM team interviewed, a total of five architects, which included an eight-year-BIM manager veteran as well as four architects who have been using BIM since 2009. While Case Study 3, referred hereafter as CS3, the organization is an infrastructure firm providing planning, designing, engineering, construction and consulting solutions worldwide. CS3 adopted BIM for all of its projects since 2014 and has been ranked in the top three in the Transportation and General Building in *Engineering News-Record's* 2018 and 2019 "Top 500 Design Firms". The interviewee has been a lead BIM expert for projects all around the African continent for CS3 and a quantity surveyor for the past thirty years.

A thematic analysis of the interviewee responses was done to determine the findings of the investigation. First, each interview's responses were grouped into their respective questions. Then, the semi-structured questions and the responses received each interview's key responses that answered the questions, and the research objectives were highlighted to separate relevant responses from less relevant information. The same was done for each interview, and a final document that listed all the questions responses from the three case studies were then drafted into three columns. This then allowed a cross-reference of the information to evaluate the responses and check for any similar themes, contradicting themes and entirely new insight.

4 Findings and Discussion

Table 2 provides a summary of the findings within the three case studies.

Table 2. Summary of Findings

Findings	CS1	CS2	CS3
Year of adoption	2009	2009	2014
BIM Level of maturity	Level 3	Level 1	Level 3
Employee training	In-house training	One-off BIM training courses Weekly workshops	In-house training
BIM Standards	UK BIM standards	UK BIM standards South African standards	UK BIM standards
Hardware and Software	Revit and ArchiCAD In-house software maintenance	Revit Outsource software maintenance	wings, DivX, CostX, Tekla, ArchiCAD and Revit In-house software maintenance
Technology	i7 processors and cloud sharing system virtual reality	i7 and i9 processors, advanced RAM, graphics cards and cloud sharing system	i7 and i9 processors, BIM 360, virtual reality and cloud sharing system
Cost	Licensing and subscriptions Hardware	Licensing and subscriptions Cloud services	Software updates and licenses
Organizational Structure	Inclusion of BIM manager and collaborative decision-makers	Inclusion of BIM manager	Senior BIM leader and inclusion of BIM manager

It emerged that each case study was on different levels of BIM adoption (Maturity level). For example, while CS1 and CS3 were on Level 3, CS2 was on Level 1. Furthermore, as outlined by the three case studies, the training of employees is a significant factor. The interviewees within the three case studies emphasized how the training of employees was of the essence for the successful adoption of BIM. The three case studies had different

strategies for training the employees. The most common one within the case studies was the in-house training; this supports what was stated in literature by Sacks et al. (2010) that the implementation of BIM has a ninety per cent success rate; there is extensive training of employees to avoid any potential errors or misuse. All three case studies had advanced technology, hardware and software within their organization. The technology included high-speed fibre, real-time collaboration, storage, powerful graphics card, and software used by various organizations such as Revit, WinQS, DivX and ArchiCAD.

Table 2 indicates that all three case studies use the same BIM standards, which were the UK BIM standards; the respondents reasoned that the UK already established UK standards, similar to that of South Africa. At a later stage, CS2 was able to adopt the South African BIM standards. The use of standards supports previous studies (Bin Zakaria et al., 2013; Abubakar et al., 2014; Ezeokoli et al., 2016) that government should support BIM adoption. This support should be in the form of standards/implementation guidelines. The costs of adoption identified by the interviewees within the three case studies were the cost of the software's license. The cost was referred to as being expensive, and a considerable expense for the organization, and this supports what was stated by Sureman et al. (2008) that an organization must have the necessary funds required to buy the software needed for BIM. CS2 also incurs the cost of the skilled staff because these employees require high salaries.

After adopting BIM, new roles and responsibilities were established within the organizations of the three case studies. CS1 had a BIM manager and sub-leaders who had the knowledge required to make decisions, and this responsibility was taken away from the directors as they were initially responsible for all the decision making. CS2 and CS3 also had a new role for BIM manager; in CS2, the BIM manager was responsible for the project design team. CS3 had a senior leader who was responsible for developing the organizations BIM vision and goals.

There are attitudinal differences to implementing new technology within an organization towards the new change (Brewer and Gajendran 2012), which was similar to the research findings. For example, CS1 and CS3 had employees who wanted to adhere to the traditional ways of doing things, while in CS3, it was a mixed bag comprised of some employees who embraced the new technology and others who preferred doing things the old way.

Overall, the findings suggest that cost is the key capability factor in BIM adoption in an organization. Therefore, an organization should cover the hardware, software, and implementing BIM costs to adopt BIM successfully.

5 Conclusion and Further Research

The low adoption levels of BIM within the South African AEC context, despite the benefits of adopting the technology, were the driving factors for this research. The research aimed at determining the key capability factor that influences the adoption of BIM in the AEC industry in South Africa. However, to achieve this primary aim, firstly, the research looked at the capability factors influencing BIM adoption through a literature review and, after that, personal interviews and a qualitative cross-case data analysis. The study found that the level of BIM adoption was low across the three cases and that BIM capability factors could be classified under three main categories: human resources,

technology, and process. The process factor was identified as the main capability factor influencing BIM adoption within South African AEC organizations. It also emerged that attitude towards BIM adoption, costs of training employees, maintaining software and hardware, and licensing are capability factors towards BIM adoption, and the cost of adopting BIM processes was identified as the main capability factor.

This research adds to the body of knowledge by determining the factors influencing BIM adoption in South Africa, particularly by AEC firms. This research provides an understanding of why BIM adoption is low amongst AEC firms in South Africa and factors that need to be considered in adopting the software technology. Further research can examine how best software and hardware maintenance strategies can be conducted to mitigate the costs of BIM processes. The main limitation of this study is the relatively small sample size used for this investigation. The reliability of the findings can be improved by investigating more organizations.

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