Building Information Modelling for Construction Project Planning: Benefits to the South African Construction Industry

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Abstract

Building Information Modelling (BIM) is an intelligent environment utilised by the Architecture Engineering and Construction Industry (AEC) to simplify and improve sustainability in construction works. The construction industry suffers in terms of project performance and success rate on a global and national scale due to a lack of proper planning. To solve this problem, it is necessary to adopt the use of technology in carrying out tasks in the project planning phase of a construction project. Hence, BIM is taunted to be the bridging gap needed for this purpose. This study aims to assess the benefits of implementing BIM at the project planning stage of construction projects. To achieve this, a quantitative research methodology was employed in retrieving data. Data were retrieved using a questionnaire survey distributed to professionals in the South African built environment. The data retrieved were analysed using descriptive and inferential analysis. The study revealed that the top three benefits of implementing BIM for project planning in the construction industry are: competitive advantage, saving time and money, and increasing collaboration among AEC experts. The study further clustered the variables into three components namely “productivity, efficiency, and process improvement”, “information management and collaboration”, and “quality, safety, and competitive advantage”. The study concluded that the identified benefits of BIM implementation for project planning could serve as the drivers for its adoption among construction professionals in South Africa, considering the low adoption of BIM in the industry.

Keywords

BIM, Construction, Management, Planning, Project

1. Introduction

Before the pandemic, the construction industry employed about 7.7% of the worldwide workforce, with predictions for 2020 showing that it will generate 13.4% of global GDP (International Labour Organisation, 2021). However, the present crises facing the industry such as declining income and rising project delivery associated problems have led the industry to decline in most markets, negatively impacting the labour force, GDP, and employment figures (International Monetary Fund, 2021). The construction industry is saddled with the responsibility of delivering infrastructure projects to sustain daily human endeavours and livelihood. These infrastructure projects are executed in different phases. The Project Management Institute (PMI) outlines the five project management stages that can give a high-level perspective of the project and act as a path to completion (Pathak, 2021). These stages include initiation, planning, execution, controlling and close-out. It is this approach that project managers use to plan, monitor, and execute a project (Emuze & Mhlwa, 2015) since project management specifies the tools and procedures needed to design, plan and execute any project to bring it to a successful end (Demirkesen & Ozorhon, 2017). Review of various studies have shown that the construction industry suffers in terms of project performance and success rate on a global and national scale due to lack of proper planning (Bertelsen, 2003; Emuze & Mhlwa, 2015; Kwofie, et al., 2017; Akinradewo et al. 2022a) and thus the link between the project’s success and project planning is widely acknowledged. It is then important to focus resources for change related to digitisation and sustainability in the early stages of the project management phases. According to Sakikhales & Stravoravdis, (2017) these phases have a greater impact on the project’s success. In a bid to achieve improvement in these phases, various technologies with various digitalisation capabilities needs to be incorporated.

Olanrewaju et al. (2021) asserted that building information modelling (BIM) is at the forefront of technological developments, Furthermore, it may be integrated with the success method throughout the preliminary and overall phases of a project. BIM entails not only the use of dimensional intelligent models, but also major modifications to the workflow and project delivery procedures (Azhar, et al., 2012). The implementation of BIM as an umbrella for emerging technology in the construction industry in the early phases of a project will contribute to the efficiency of the adoption of digital technologies. This assumption is based on a myriad of literature (Wang & Chien, 2014; Gledson, 2016; Turka & Klincb, 2017), linking BIM with various digital technology. BIM will also increase the adoption rate for digitisation in the project planning phase as it is the most crucial phase (Sakikhales & Stravoravdis, 2017). Hence, this study is carried out to assess the benefits of adopting BIM for project planning phase in the construction industry. This research contributes to the body of knowledge by adopting a developing economy, in this case, South Africa, a context where BIM adoption is low. The study also provides a comprehensive and systematic understanding of how BIM can improve various aspects of construction project planning. The findings of the study is expected to serve as drivers for BIM adoption among construction professionals in South Africa, considering its low adoption in the industry..

2. BIM for Construction Project Planning

The current situation of the global construction sector needs continuous improvement which is advantageous to all interested parties in the pursuit for progress. This improvement measure has been characterised as innovation. In the construction business, the Building Information Model (BIM) is an example of such innovation (Odubiyi, et al., 2019). There are various benefits attached to the implementation of BIM for project planning as identified from extant literature. Studies have shown that that the solution to the fragmentation experienced among construction professionals is widely linked to the implementation of BIM (Migilinskas et al., 2013; Wang & Chien, 2014; Mehran, 2016). BIM is expected to enhance communication between project participants (Osunsanmi, et al., 2018). This will result in less effort on duplication of work, delayed communication and loss of information, less collision in project design, among others. Goedert and Meadati (2008) submitted that the difference with having digital information is the information can be queried, it is not kept static. Contrary to paper-based information where locating a specific document can be time consuming. Furthermore, BIM will transform the way construction work is organised, done, and documented, and will allow for significant improvements in the construction delivery process.

For project team members to properly gain the value from the relevant model information, BIM implementation necessitates careful planning and basic process adjustments (Messner, et al., 2019). Pilot projects can be carried out to optimise the construction sequence by various stakeholders allowing the project manager to have greater insight during the project planning stage (Kamyab, 2018). Also, by assisting architects, engineers, and other project participants in merging their models, identifying interdependencies and conflicts, and swiftly evaluating design iterations, BIM improves design and engineering processes and promotes their parallelisation. Simultaneously, increasing the quality of the final product (Gerbert, et al., 2016). Also, meeting performance criteria becomes difficult and costly if sustainability analysis is not performed early in the project planning phase. Sustainability and performance analyses may be performed throughout the design process by utilizing BIM technology with the objective is and the utilization of recycled resources (Bertin, et al., 2020). Furthermore, it can be deduced that implementing BIM during the planning stage presents the opportunity to utilise all BIM dimensions further enhancing interoperability amongst the industry and an eventual increase in the level of maturity from the users involved (Mahajan, 2018). To operationalise the benefits to the implementation of building information modelling for project planning, Table 1 itemises the identified benefits reviewed and their sources.

Table 1. Benefits of BIM for Project Planning.

S/N	Identified Benefits	Authors
1.	Collaboration	Migilinskas et al. (2013); Wang & Chien (2014); Mehran (2016)
2.	Less documentation	Goedert & Meadati (2008); Turka & Klincb (2017)
3.	Reduced documentation	Kamyab (2018); Messner et al. (2019)
4.	Improved quality	Gerbert et al. (2016)
5.	Improved health and safety	Ganah & John (2017)
6.	Increased sustainability	Bertin et al. (2020)
7.	Time and cost saving	Gerbert et al. (2016)

8.	Competitive edge	Gerbert et al. (2016); Awwad, Shibani & Ghostin (2020)
9.	Catalyst for digitalisation	Mahajan (2018)
10.	Project visualisation through 3D models	Akinradewo et al. (2021)
11.	Collaborative project delivery method	Adekunle et al. (2022)
12.	Improved investor influx	Wang & Chen (2014)
13.	Improved communication	Chan, Olawumi & Ho (2019)
14.	Project simulation	Kamyab (2018)
15	Boosts investor's confidence	Chan, Olawumi & Ho (2019); World Bank Group (2021)

3. Research Methodology

The rationale of the current study is to contribute to the body of knowledge on the benefits of BIM implementation in the planning phase of the construction project. To achieve this, the study adopted the quantitative research approach. A quantitative research method is useful in getting information from a sample of people and reporting on the questions posed by the researcher. When conducting a study that makes use of quantitative research, the numerical measurement of specific aspects of phenomena is imperative and should be precise. The study retrieved data through a structured questionnaire which was distributed to respondents which includes architects, construction managers, engineers, project managers, and quantity surveyors in the Gauteng province, South Africa.

A 5-point Likert scale questionnaire was developed using information obtained from reviewed literature with the questionnaire survey divided into two sections. The first section extracted information about the respondents' demographics in which three questions were asked. The second section focused on the identified latent variables to measure the benefits. The choice of Gauteng province was because it houses the majority of the professionals within the country who are adopting modern technologies for construction activities. About 6450 built environment professionals has been identified across Gauteng province but all of them cannot be adopted for the study due to time and cost constraints. 189 questionnaires were randomly distributed to professionals within the study area between September and November 2022, and 167 questionnaires were recovered totalling 83% response rate. All the questionnaires recovered were deemed to be suitable after being reviewed for completion. The data obtained from the questionnaire were evaluated using the Mean Item Score (MIS) and Standard Deviation (SD). Cronbach's alpha was adopted to determine the reliability coefficient of the data collection instrument. The adopted cutoff alpha for this study was 0.70, and the analysis result indicated 0.93 making all data retrieved reliable.

4. Findings and Discussions

According to the findings from the analysis conducted, majority of the respondents who were contacted and responded to the survey work at a consultancy firm with the data indicating a total of 48% while professionals working with contracting firm are 28% of the population sample. Also, tertiary students who are working and studying concurrently and government employees both make up 12% each. The most common qualification among respondents was the bachelor's degree (32%). In second place were Bachelor Honour's degree (28%) and Diploma (28%). Highest qualification possessed by the respondents was the master's degree (12%). An overwhelming majority of the respondents have worked for 0-3 years (60%), this indicates that the population sample is quite young in the industry, followed by 4-8years of experience (28%) while 8% of the sample has 9-15 years of experience. Only 4% of the respondents have worked for more than 15 years. This is an indication that the respondents possess above average knowledge to provide tangible answers to the research question.

4.1 Descriptive Analysis: Benefits of the Implementation of BIM for Project Planning

Based on the opinion of the respondents, the benefits of using BIM for project planning are summarized in Table 2. The highest ranked benefit is 'Gives a competitive edge' (MIS=4.56, SD=0.651), while 'Time and cost saving' ranked joint second (MIS=4.48, SD=0.714) with 'Increases collaboration' (MIS=4.48, SD=0.653). at the bottom of the ranking were 'Less documentation required' (MIS=4.04, SD=1.172) and 'Elimination of wastage' (MIS=4.04, SD=1.098) both ranked thirteenth while 'Boosts investor's confidence' (MIS=3.52, SD=1.418) ranked fifteenth and lowest. However, it was noted that all the variables had mean item scores above 3.00 which is adjudged the median for a 5-point Likert scale. Hence, it can be presented that the respondents agree that the identified benefits are applicable to BIM usage in the project planning stage. The standard deviation values in the table describe the amount of variability or spread in the responses received for each benefit of implementing BIM for project planning. The higher the standard deviation value, the more dispersed the responses were around the mean score. Looking at the table, it can be observed that the benefits with lower standard deviation values, such as "Gives a competitive edge," "Increases collaboration amongst AEC professionals," and "Improves quality of work," had more consistent ratings among the respondents. On the other hand, benefits with higher standard deviation values, such as "Less documentation required," "Elimination of wastage," and "Boosts investor's confidence," had more variability in the ratings, indicating that some respondents had significantly different views about the importance or effectiveness of these benefits compared to others. This can be attributed to their professional affiliation which determines how they perceive BIM and the identified benefits of it.

Table 2. Descriptive analysis result of benefits of the implementation of BIM for project planning.

Benefits	Mean Item Score	Std. Deviation	Rank
Gives a competitive edge	4.56	0.651	1
Time and Cost Saving	4.48	0.714	2
Increases collaboration amongst AEC professionals	4.48	0.653	2
On-site real time simulation	4.40	0.816	4
Better communication through enhanced quality information	4.36	0.810	5
Improves quality of work	4.36	0.638	5
Improves health and safety on site	4.24	0.831	7
Visualisation of project details through 3D models	4.24	1.052	7
Clash detection	4.24	0.879	7
Increases productivity	4.20	0.866	10
Provoking shift to a collaborative project delivery method	4.16	1.143	11
Increases rate of digitalisation in the construction industry	4.08	0.997	12
Less documentation required	4.04	1.172	13
Elimination of wastage	4.04	1.098	13
Boosts investor's confidence	3.52	1.418	15

4.2 Exploratory Factor Analysis: Benefits of the Implementation of BIM for Project Planning

Further to the descriptive analysis carried out on the retrieved data, exploratory factor analysis was done. Table 3 presents the results of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The KMO measure is 0.897, indicating that the data is generally suitable for factor analysis. Bartlett's test statistic is approximately 974.113 with 101 degrees of freedom, and the p-value is less than 0.001, which indicates that the correlations among the variables are sufficiently different from zero to justify factor analysis. Overall, the results suggest that the data is suitable for factor analysis, and there are likely to be underlying factors that can explain the patterns of correlation among the observed variables.

Table 3. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.897
Bartlett's Test of Sphericity	Approx. Chi-Square	974.113
	df	101
	Sig.	0.000

The table presents the communalities of the benefits of implementing Building Information Modelling (BIM) for project planning. Communalities are measures of the proportion of variance in each variable that is explained by the underlying factors extracted through principal component analysis. The values range from 0 to 1, with higher values indicating that the variable is more strongly associated with the underlying factor. In this case, all variables have an initial communalities value of 1.000, which indicates that each variable is perfectly correlated with itself. After extraction through principal component analysis, the communalities values range from 0.601 to 0.833, indicating that each variable is associated with one or more underlying factors. Overall, the communalities values provide information on the strength of the relationship between each variable and the underlying factors extracted through principal component analysis, and can be used to interpret the results of factor analysis.

Table 4. Communalities of benefits of the implementation of BIM for project planning.

	Initial	Extraction
Increases productivity	1.000	0.632
Time and Cost Saving	1.000	0.833
Less documentation required	1.000	0.815
On site "real time" simulation	1.000	0.631
Increases rate of digitalisation in the construction industry	1.000	0.710
Improves quality of work	1.000	0.615
Gives a competitive edge	1.000	0.683
Visualisation of project details through 3D models	1.000	0.715
Clash detection	1.000	0.712
Increases collaboration amongst AEC professionals	1.000	0.667
Provoking shift to a collaborative project delivery method	1.000	0.785
Elimination of wastage	1.000	0.623
Improves health and safety on site	1.000	0.635
Better communication through enhanced quality information	1.000	0.601
Boosts investor's confidence	1.000	0.684
Extraction Method: Principal Component Analysis.		

The variance of the components was extracted, and it was discovered that the first component has the highest initial and extraction sums of squared loadings, explaining 48.697% of the variance with eigen value of 7.305 in the data. The second and third components also have relatively high extraction sums of squared loadings, explaining 10.033% and 6.915% of the variance together with 1.505 and 1.037 eigen values, respectively. The remaining components explained less than 6% of the variance each. Hence, the three components were extracted as evident from the Scree plot shown in Figure 1.

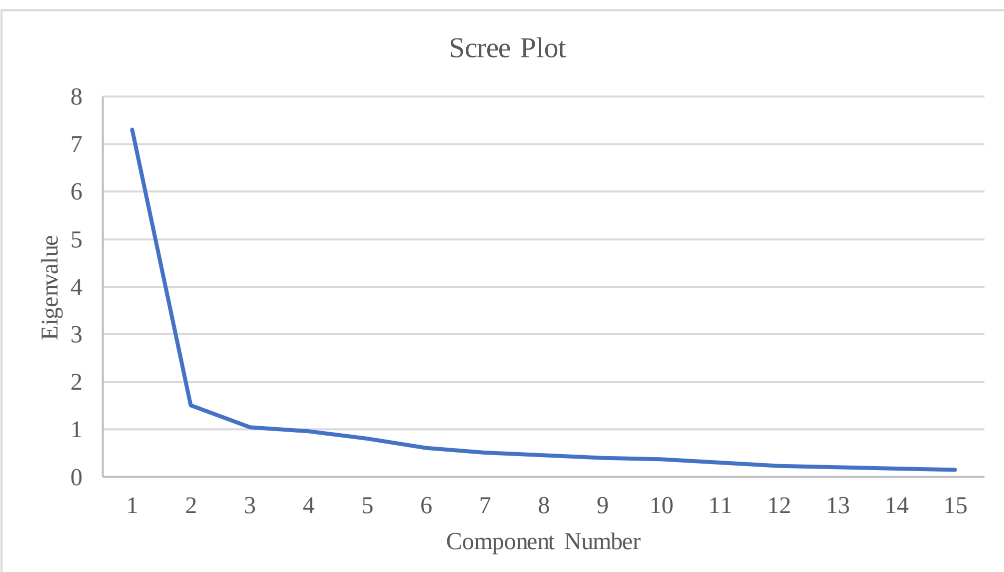

Fig. 1. Scree plot for benefits of the implementation of BIM for project planning.

The table presents the pattern matrix for benefits of implementing BIM for project planning. The pattern matrix shows the correlations between the observed variables and the underlying factors extracted through principal component analysis. In this case, three components were extracted, and the correlations between each variable and each component are displayed in the table. Variables with high correlation coefficients (0.7 or higher) with a particular component are considered to be strongly associated with that component. Variables with low correlation coefficients (less than 0.3) with all components are considered to be weakly associated with the underlying factors extracted through principal component analysis. The three components extracted in the pattern matrix provide a deeper understanding of the underlying factors that explain the correlations between the benefits of implementing BIM for project planning in South Africa.

Component 1 includes variables that are strongly related to productivity, efficiency, and process improvement. "Increases productivity", "Time and Cost Saving", "Less documentation required", and "On-site real-time simulation" are all highly correlated with Component 1. This suggests that BIM implementation can lead to significant improvements in productivity and efficiency by reducing documentation requirements, facilitating real-time simulations, and reducing costs and time associated with construction projects (Akinradewo et al., 2021).

Component 2 includes variables related to information management and collaboration. "Increases rate of digitalisation in the construction industry", "Increases collaboration amongst AEC professionals", "Provoking shift to a collaborative project delivery method", and "Better communication through enhanced quality information" are all highly correlated with Component 2. This suggests that BIM implementation can lead to better information management and collaboration among different stakeholders in construction projects, resulting in more efficient and effective decision-making and project delivery (Adekunle et al., 2022).

Component 3 includes variables related to quality, safety, and competitive advantage. "Improves quality of work", "Gives a competitive edge", "Improves health and safety on-site", and "Boosts investor's confidence" are all highly correlated with Component 3. This suggests that BIM implementation can lead to improvements in the quality of work, better safety on-site, and increased confidence among investors (Akinradewo et al., 2021; Adekunle et al., 2022). Moreover, BIM can provide a competitive advantage to construction companies by enabling them to deliver high-quality projects more efficiently and cost-effectively than their competitors (Awwad, et al., 2020).

Overall, the three components extracted from the pattern matrix provide a comprehensive view of the benefits of implementing BIM for project planning in construction projects. Understanding these underlying factors can help stakeholders to identify the areas where BIM can provide the most significant benefits and develop strategies to optimize its use in construction projects.

Table 5. Pattern Matrix for benefits of the implementation of BIM for project planning.

	Component		
	1	2	3
Increases productivity	0.933		
Time and Cost Saving	0.910		
Less documentation required	0.865		
On site "real time" simulation	0.802		
Visualisation of project details through 3D models	0.728		
Clash detection	0.676		
Elimination of wastage	0.610		
Better communication through enhanced quality information	0.548		
Increases rate of digitalisation in the construction industry		0.944	
Increases collaboration amongst AEC professionals		0.714	
Provoking shift to a collaborative project delivery method		0.625	
Improves quality of work			0.904
Gives a competitive edge			0.833
Improves health and safety on site			0.781
Boosts investor's confidence			0.624

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 8Dis iterations.

The adoption of BIM has given companies in the United Kingdom a competitive edge (Awwad, et al., 2020). These findings affirm the opinion of the respondents that the adoption of BIM for project planning will give companies a competitive edge. In the same vein, Wang and Chien, (2014) asserted that BIM will reduce costs and time. However, the improvement of collaboration among professionals was ranked third by the respondents. Migilinskas, et al., (2013) stated that collaboration is key to the usage of BIM. Hence, these findings are aligned with seminal literature. Less documentation required, elimination of wastage and boosting of investor's confidence were the three least ranked benefits by the respondents. In contradiction, Azhar, et al., (2012) reported that cost savings emanating from the reduction of printing costs due to the usage of BIM has aided in the elimination of waste. This suggest that these benefits are not witnessed by the sample or could be an indication of the low usage of BIM currently in South Africa as reported by Akinradewo et al. (2022b).

5. Conclusions and Recommendations

This study was set out to assess the benefits of BIM implementation at project planning stage in the construction industry using South Africa as a focus. The common benefit identified in the literature review was that BIM is a solution to the fragmentation that plagues the industry. Often, this fragmentation has birthed a myriad of problems in the industry. Other benefits identified include but not limited to improved quality of work, less documentation required and the fact that a BIM offers a competitive edge to the companies that adopt it. The study adopted a quantitative research methodology such that data were retrieved from professionals in the South African construction industry using a questionnaire survey. Based on the descriptive and exploratory analysis conducted, it can be concluded that the implementation of Building Information Modelling (BIM) in project planning has numerous benefits for the architecture, engineering, and construction (AEC) industry in South Africa. The highest ranked benefit identified by respondents was that BIM gives a competitive edge, followed closely by time and cost savings and increased collaboration among AEC professionals. While some benefits, such as less documentation required and elimination of wastage, were ranked lower, all identified benefits had mean item scores above 3.00 on a 5-point Likert scale. Exploratory factor analysis indicated that the benefits of BIM implementation can be grouped into three components: productivity, efficiency, and process improvement; collaboration and communication; and design and visualization. The findings suggest that BIM implementation can lead to significant improvements in productivity, efficiency, collaboration, and cost savings in the AEC industry in South Africa. This study concluded that the construction industry will benefit immensely from the early adoption of BIM for project planning. This is expected to promote project performance and efficiency in the construction industry. It was therefore recommended that architectural, engineering and construction professionals incorporate BIM into their construction project planning phase. The study was limited to professionals in Gauteng province of South Africa only. Hence, further study should be carried out using all the professionals from across South Africa to have a more general opinion of professionals.

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