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Adoption of Building Information Modelling in the construction industry in Kenya

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Abstract

The current implementation of Building Information Modelling (BIM) by construction professionals in the Kenyan construction industry is an area of concern. BIM is increasingly being applied worldwide to improve communication between project stakeholders, visualization of design, detect potential clashes, reduced redesign during project implementation, improve design quality, reduce costs, and improve the rate of return for projects. However, the application of BIM in the Kenyan construction industry is still lagging, resulting in poor co-ordination of information among construction project stakeholders. This study determines the current state of BIM application, the benefits of BIM application and the BIM application barriers in Kenya. A quantitative research approach was used and data was collected, using an online questionnaire survey from 310 registered construction professionals selected by stratified sampling. The benefits and barriers factors that influence BIM application in Kenya were rated and set as the independent variables with 'years of experience' and 'total completed projects' as the dependent variables. The data was analysed using the Statistical Package for the Social Sciences (SPSS) version 24. Principal components analysis (PCA) was used to extract the main factors for benefits and barriers of BIM implementation. *Chi-square* tests were used to determine relationships between independent and dependent variables. Improved communication was ranked as the most important BIM benefit, while the high cost of buying and updating software was ranked as the main barrier to the application of BIM. Based on the results of the study, improved design quality is influenced by the number of

years of experience one has in the building construction industry. The number of projects undertaken by a company using BIM in any capacity has an influence on greater productivity, due to easy retrieval of information. It is recommended that BIM training should be undertaken by software vendors in vocational and tertiary institutions as well as in construction firms. In addition, the government should formulate policies and standards to support the use of BIM. This study adds to the body of knowledge about BIM application in Nairobi, Kenya that is beneficial to developers, architects, engineers, quantity surveyors, project managers, contractors, and facility managers.

Keywords: Building information modelling (BIM), BIM adoption, Kenyan construction sector

Abstrak

Die huidige toepassing van Bou-Inligting Modellering (BIM) deur professionele konsultante in die konstruksiebedryf in Kenia is 'n bron van kommer. BIM word toenemend wêreldwyd toegepas om kommunikasie tussen projekbelanghebbendes te verbeter, ontwerpe te visualiseer, potensiële botsings te identifiseer, herontwerp tydens projekimplementering te verminder, ontwerpkwaliteit te verbeter, koste te verminder en die opbrengskoers van projekte te verhoog. Die stadige aanvaarding van BIM in die konstruksiebedryf in Kenia het swak koördinasie van inligting tussen betrokkenes in konstruksie-projekte tot gevolg. Hierdie studie ondersoek die huidige stand van BIM-toepassing, voordele van BIM-toepassing en BIM-toepassinghindernisse in Kenia. 'n Kwantitatiewe navorsingsbenadering is gebruik en data is ingesamel, met behulp van 'n aanlyn-vraelysopname van 310 geregistreerde konstruksie-werknemers wat gekies is deur gestratifiseerde steekproefneming. Die voordele en hindernisse wat BIM-toepassing in Kenia beïnvloed, is gemeet en gestel as die onafhanklike veranderlikes met 'jare ondervinding' en 'totale voltooide projekte' as die afhanklike veranderlikes. Die data is geanaliseer met behulp van die Statistiese Pakket vir die Sosiale Wetenskappe (SPSS) weergawe 24. *Principal component analysis* (PCA) is gebruik om die beangrikste faktore vir voordele en hindernisse van BIM-implementering te bepaal. *Chi-square* toetse is gebruik om verhoudings tussen onafhanklike en afhanklike veranderlikes te bepaal. Verbeterde kommunikasie is as die belangrikste voordeel van BIM beskou, terwyl die hoë koste van die aankoop en opdatering van sagteware as die belangrikste hindernisse tot BIM-toepassing beskou is. Volgens bevindinge word die verbeterde ontwerpkwaliteit beïnvloed deur die aantal jare ondervinding in die boukonstruksiebedryf. Die aantal projekte wat deur 'n maatskappy onderneem word met BIM in enige hoedanigheid beïnvloed groter produktiwiteit as gevolg van maklike herwinning van inligting. Daar word aanbeveel dat BIM-opleiding deur sagtewareleweransiers onderneem word in beroeps- en tersiêre instellings en konstruksiemaatskappye. Daarbenewens moet die regering beleide en standaarde formuleer om die gebruik van BIM te ondersteun. Die studie dra by tot die korpus van kennis oor die toepassing van BIM in Nairobi, Kenia, en behoort van waarde te wees vir ontwikkelaars, argitekte, ingenieurs, bourekenaars, projekbestuurders, kontrakteurs, en fasiliteitsbestuurders.

Sleutelwoorde: Bou-Inligtingsmodellering (BIM), aanvaarding van BIM, Keniaanse konstruksiebedryf

1.   Introduction

The construction sector is one of the key drivers of economic growth in Kenya, accounting for 7% of the gross national product (Turner & Townsend, 2017). Despite its critical role in the Kenyan economy, the construction sector is faced with various challenges that have decreased the productivity and the rate of return on investments. Among the most important challenges is the poor collaboration of information among stakeholders. This has led to increased wastage, cost overruns, rework, time overruns, and miscommunication among project stakeholders (Balah & Akut, 2015: 60). The old-fashioned two-dimensional (2D) approach to execute projects in the built environment industry impedes the efficient exchange of data among all stakeholders which occurs in all stages of the project development, namely from concept to construction and eventually to the management of the facility that is in operation (Rohena, 2011). The introduction of Building Information Modelling (BIM) in the construction industry brought about new ways of conceiving, designing, constructing, and operating new buildings (Azhar, Khalfan & Jaqsood, 2012: 15).

BIM is extensively used worldwide to design a visual presentation of the building process used to enhance the exchange of information among construction professionals (architects, engineers, quantity surveyors, and project managers) in digital format (Eastman, Teicholtz, Sacks & Sacks, 2008; Silva, Salvado, Couto & Vale e Azevedo, 2016: 476). Martínez-Rojas, Durán-Álvarez, Martínez-Aires & López-Alonso (2015) emphasize three major types of digital data involved in BIM: the three-dimensional modelling of a building (geometric), a description of the properties of the components (semantic), and details of the interrelationships between properties and components (topological).

Appropriate application of BIM by construction professionals (architects, engineers, project managers, and facility managers) allows for benefits relating to five main aspects, namely design, scheduling, documentation, budgeting, and communication (Azhar *et al.,* 2012). However, application of BIM is also subject to several obstacles, including (in order of importance) the high cost of execution, lack of awareness about the utilization of BIM, absence of government support for its application, absence of training facilities, deficient research and innovation, and absence of laws and policies mandating its use (Adebimpe & Etiene, 2016: 232).

BIM is a relatively new concept in Kenya and the adoption and implementation thereof is slow, because Kenya has different

regulation bodies for the different sections of the building industry. These professionals' bodies are the Board of Registration of Architects and Quantity Surveyors (BORAQS), the Engineers' Board of Kenya (EBK), and the Institute of Construction Project Managers in Kenya (ICPMK). The anticipated audience for BIM is, therefore, fragmented and lacking a united focus to adopt and implement BIM in large-scale and complex building projects (Njue & Musyimi, 2017: 86).

Communication failures between the design and construction teams, due to fragmented information, is an area of concern and highlights the need to determine the views of these professionals on the status of implementation of BIM in the Kenyan construction industry, as well as its benefits and impediments to its implementation.

2. Literature review

2.1 Building information modelling concept

Every single developing meaning of BIM depicts its transformative abilities and effect on the Architecture, Engineering, and Construction (AEC) industry and, very recently, on facility management (Kassem, Iqbal, Kelly *et al.*, 2014: 127). BIM is not a new idea; early investigations were done on BIM since the 1970s. For instance, the use of personal computers (PCs) as opposed to representations in building design was contemplated as early as 1970 (Matarneh & Hamed, 2017b: 326). Eastman, Teicholz, Sacks and Liston (2011) considered BIM as "…the key medium to plan critical thinking, coordination and for correspondence". Since then, several studies have been carried out on the application of integrated computer technologies in design and construction management (Matarneh & Hamed, 2017b: 327).

Eastman *et al.* (2008) note that, due to BIM innovation, a precise virtual model of a building is developed carefully and, once finalized, the computer-produced model contains the exact geometry and important information expected to help in the design, manufacture, and procurement of an actual building. BIM is not only a technology, but also a process. The technology part of BIM enables stakeholders to picture at an early stage any opportunities in the design, construction or functional issues, while the process segment allows for close cooperation and integration of roles played by all members of the design and construction team (Azhar *et al.*, 2012).

The BIM concept is based primarily on the reconciliation of procedures, upheld by an information-rich 3D display that permits one to clearly follow the entire life cycle of the project (Sampaio,

2017: 195). In addition, all factors considered, it is expected that the entire procedure is more direct and simpler in exchange of data among all stakeholders, in developing the design, and later in the administration of the building. The collaborative feature in BIM plays a vital role in all aspects of construction and project management, including design, scheduling, estimating, resource allocation, supply chain management, an account of deliverables during construction, and structural management (Bhuskade, 2015: 834; Kushwaha, 2016: 102). The ability of BIM to do parametric design and store data about the life cycle of buildings can be used to investigate and regulate energy consumption, initial costs, ongoing costs in a building, as well as the implementation of other sustainable design principles in the construction industry (Anbouhi, Farahza & Ayatollahi, 2016: 99).

Silva *et al*. (2016) provide a summary of the implementation of BIM in various countries (see also Khosrowshahi & Arayici, 2012; Hadzaman, Takim & Nawawi, 2015; Enshassi & AbuHamra, 2017; Telaga, 2018; Ahuja *et al.*, 2018).

2.1.1   Levels of Building Information Modelling maturity

The essence of categorising BIM into maturity levels from 0 to 3 is to substantiate the types of technical and collaborative working involved at each level and give a comprehensive explanation of the processes, tools, and techniques used (CDBB, 2011: 15-16). The United Kingdom adopted a unique system that describes the credentials of the designers and the design teams by assessing the BIM process applied against a diagram that outlines the four levels of BIM process maturity (Sacks, Gurevich & Shrestha, 2016: 491). The four levels include:

- 0 – CAD: Basic CAD features using only drawings, lines, arcs and text. Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism;

- 1 – 'Lonely BIM': Includes some basic 3D elements, beginning of BIM;

- 2 – 'Collaborative BIM': Includes the required information, supply chain management, and requires teams to be working together with 3D BIM, however with no obligation for the 4D programme, 5D cost and operation elements to be included within the model, and

- 3 – 'Intelligent BIM': Full integration of the BIM model into the life cycle management of the project.

2.2 Awareness level of Building Information Modelling

Adebimpe and Etiene (2016: 233) as well as Kugbeadjor, Suresh and Renukappa (2015: 540) emphasise that expanding awareness on BIM utilization and its advantages is the first and most vital stride to its implementation, to be done through government intervention, training, and retraining of building sector experts and association of the different expert bodies in the building industry. Although education and training assume a major part in the BIM appropriation process, a noteworthy number of associations are hesitant to invest in BIM, principally because of the cost involved (Kugbeadjor *et al.*, 2015: 533).

Adebimpe and Etiene (2016: 233) caution that expanded awareness in the application of BIM ought to be done by utilising reasonable means and by considering the unique nature of the national construction industry. Important professional bodies, agencies and associations, working together, ought to advise the legislature on the advantages of implementing BIM.

The following recommendations may be made on increasing the awareness of BIM in the construction industry (Matarneh & Hamed, 2017b: 333):

- Government should set standards and codes for BIM industry;
- Proper and open standards have a noteworthy part to play in the achievement of BIM as a development factor. There is a requirement for all-encompassing co-appointment among the business' partners, including the administration, business, BIM vendors, customers, and instructional associations;
- To address the deficiency of BIM professionals, the industry and scholastic foundations should come together to create syllabuses that are in accordance with improvements in industry practice and techniques, and
- To establish a framework within each firm to guarantee that the professionals hold, really apply and likewise share the information picked up from such BIM projects.

2.3 Application of Building Information Modelling

BIM offers a variety of applications in the construction industry (Shaikh, Raju, Malim, & Jayaraj, 2016: 206). Three-dimensional modelling and rendering can be produced, design drawings and shop drawings

can be generated, and construction standards can be reviewed by examining object parameters, while cost estimates and construction schedules can be applied in renovations, maintenance, and operations to make facility management more efficient (Sarkar & Modi, 2015: 54). In addition, various examinations and simulations can be carried out on the model to enhance the overall performance of any project (Azhar, Nadeem, Mok & Leung, 2008). In summary, BIM projects facilitate efficient administration of construction projects and can be applied in all construction project stages: pre-construction stage, construction stage and post-construction stage (Latiffi, Mohammed, Kasim & Fathi, 2013: 3).

2.3.1 Pre-construction stage

The use of BIM during the pre-construction stage is more visible than during the construction and post-construction stages, considering the executions associated with this stage, for example, design, scheduling and estimating (Latiffi *et al.,* 2013: 3). Sarkar and Modi (2015: 55) conclude that BIM can be applied in the pre-construction phase for conceptual design, sketching, space planning, site inventory, and guaranteeing programme consistency with respect to site-related variables.

2.3.2 Construction stage

Yamazaki, Tabuchi, Kataoka and Shimazaki (2014) note that challenges in the construction procedure are quickly compre-hended and tackled by reviewing forms generated by BIM during the construction phase. In addition to creative engineering and enhanced construction innovations, basic investigation in the construction procedure, mechanized crash checking innovation, continuous construction simulation, and 3D estimation innovation are keys to productively utilizing BIM during construction (Yamazaki *et al.*, 2014).

2.3.3 Post-construction stage

In the post-construction stage, BIM keeps track of built asset, manages facilities proactively, enables scheduled maintenance, and provides a review of maintenance history (Latiffi *et al.,* 2013: 3). Sarkar and Modi (2015: 55) emphasise that, in this stage, BIM allows facility management to be implemented in relation to renovations, maintenance, operation, cost estimation by investigating the quantities of materials, and construction sequencing to make scheduling more consistent.

2.4   Benefits of using Building Information Modelling

Application of BIM in the construction industry can help overcome most of the challenges encountered in the process of design and construction relating to the exchange of data between members of the project team. Latiffi *et al.* (2013: 4) emphasise that the benefits of implementing BIM in construction projects are related to five main aspects: design, scheduling, documentation, budget, and communication.

Generally, BIM technology allows for efficient collaboration of project stakeholders by allowing changes done by members of the design team to be updated in real-time and shared to all project stakeholders (Doumbouya, Gao & Guan, 2016). BIM has the capacity to minimize rework, design errors, omissions, design conflicts, and changes during construction processes (Matarneh & Hamed, 2017b: 332).

Table 1 illustrates BIM applications for all stakeholders in the building construction industry.

Table 1:   BIM applications for project stakeholders in the building construction industry

BIM application	Owners	Designers	Contractors	Facility managers
Visualization	X	X	X	X
Options analysis	X	X	X	
Sustainability analysis	X	X		
Quantity surveying		X	X	
Cost estimation	X	X	X	
Site logistics			X	
Phasing and 4D scheduling		X	X	
Constructability analysis		X	X	
Building performance analysis	X	X	X	X
Building management	X			X

Source: AWzhar *et al.,* 2012: 22

In summary, the benefits of adopting BIM and using BIM technology on projects in the construction industry are:

- Reduce rework during construction;
- Maximize productivity;
- Reduce conflict/changes;
- Clash detection;
- Enhance collaboration and communication;
- Improve visualization;
- Improve project documentation;
- Enhance design review;
- Faster and more effective method;
- Improve quality;
- Reduced construction time;
- Reduce contingencies, and
- Reduce construction cost (Azhar *et al.,* 2012: 22; Adebimpe & Etiene, 2016: 233; Matarneh & Hamed, 2017b: 332; Chan, 2014: 31; Gerges, Austin, Mayouf *et al.,* 2017: 7; Shaikh *et al.,* 2016: 207; Eastman *et al.,* 2008; Silva *et al.,* 2016: 479).

2.5 Barriers to the implementation of Building Information Modelling

The implementation of any innovation technology is confronted with difficulties prior to full implementation (Matarneh & Hamed, 2017a: 189). Like any other innovative technology, several obstacles hamper the implementation of BIM in the building construction industry. Azhar *et al.* (2012: 25) classify BIM application-related challenges in two broad categories: technology-related challenges and process-related challenges. The following are some of the key technology- and process-related challenges encountered in BIM adoption in the building construction industry:

- Lack of support and incentives from construction policymakers to professionals and experts using BIM;
- Lack of standards and codes for BIM application;
- Lack of awareness about BIM, resulting in professionals comparing BIM to CAD;
- Lack of client demand;
- Lack of a BIM specialist in the region and majority of non-expert staff in architectural firms;

- High costs (software, hardware upgrade, training, and time);
- BIM requires radical changes in workflow, practices, and procedures and, therefore, resistance to change from design and construction firms;
- Too many legal barriers;
- Lacking due to exchange and interoperability;
- Inadequate BIM application research and development;
- Lack of IT infrastructure to successfully implement BIM, and
- Professionals in the industry entrenched in the current 2D drafting practices and the steep learning curve to develop BIM expertise (Adebimpe & Etiene, 2016: 233; Matarneh & Hamed, 2017a: 189; Chan, 2014: 32; Gerges *et al.,* 2017: 9; Shaikh *et al.,* 2016: 207; Eastman *et al.,* 2008; Silva *et al.,* 2016: 479).

The review of the literature on BIM revealed that application of BIM in the construction industry helps overcome most of the challenges encountered in the process of design and construction relating to exchanging data between members of the project team (project owners, designers, contractors, and facility managers). The benefits of implementing BIM in construction projects relate to five main aspects: design, scheduling, documentation, budget, and communication (Azhar *et al.,* 2012; Latiffi *et al.,* 2013: 4).

Despite these benefits, the application of BIM encounters a number of obstacles, including, in order of importance, the high cost of execution; lack of awareness on the utilization of BIM; absence of government support for its application; absence of training facilities to promote its utilization; deficient research and innovation, and absence of laws and policies mandating its utilization (Adebimpe & Etiene, 2016: 232). These barriers have contributed to the low level of BIM application and awareness in the construction industry (Matarneh & Hamed, 2017a: 189; Balah & Akut, 2015).

3.   Research

The purpose of the research was to determine the current status of implementation of BIM in the Kenyan construction industry, as well as its benefits and impediments to its implementation. A quantitative research design was adopted. This type of design allows for the use of structured questionnaire surveys, enabling researchers to generalise their findings from a sample of a population (Creswell, 2003: 5). In the questionnaire, two constructs (*benefits* [consisting of 25 measurements] and *barriers* [consisting of 16 measurements]) were extracted and set respectively as the variables for the benefits

and barriers of BIM application in the Kenyan construction industry (Netemeyer, Bearden & Sharma, 2003). Exploratory factor analysis (EFA) *was used* to assess these measured variables in terms of their validity and reliability. *EFA is a technique that analyses* the characteristics of each of the defined BIM benefits and barriers (original variables), *in order to* reduce it to a common score (smaller number of factors), by examining relationships among these quantitative factors (Pallant, 2013: 192; Yong & Pearce, 2013: 80; Rossoni, Engelbert & Bellegard, 2016: 200). Several factor analysis methods are available, but principle component analysis (PCA) was used, because the Eigenvalues could be extracted, which explains whether the factors tested had or had not a noticeable effect on people's responses to the variables in the original test (analysed construct) (Rossoni *et al.*, 2016: 201; Yang, Shen & Ho, 2009: 163-164; Pallant, 2013: 192). Inferential analysis was used to establish the degree of association respectively between the number of *years* and the number of *projects* undertaken, tested against the application of BIM technology in the Kenyan construction industry (Fisher, 1978).

3.1   Sampling method and size

A combined list of 1 599 members, registered in Kenya, was obtained from official bodies of the Board of Registration of Architects and Quantity Surveyors (BORAQS); the Engineers' Board of Kenya (EBK) and the Institute of Construction Project Managers in Kenya (ICPMK). The list was stratified between those members involved in architecture (736), quantity surveying (397), engineering (376), and project management (90).

Stratified sampling was used to divide the population in smaller proportional groups, Shi (2015: 3) resulting in a sample size of 310 representing architects (163), quantity surveyors (51), engineers (65), and project managers (31). The advantage of this method is that it narrows the difference between different types of individuals in the sample through classification (Shi, 2015: 3). The sample size for research done in construction-related populations was calculated in accordance with the table recommended by Krejcie & Morgan (1970: 608). From the table, the recommended sample size for a population of 1 000 is 278, and for 10 000, 370. This recommendation validates the sample size of 310 as efficient for the population of 1 599.

3.2   Response rate

Out of the 310 questionnaires sent out, a total of 195 completed questionnaires were returned, resulting in a high response rate of 63%.

3.3 Data collection

An online structured questionnaire survey was distributed to 310 participants by sharing the questionnaire link (https://freeonlinesurveys.com/s/AfUfnTRr) through text messages and social media platforms such as Facebook, WhatsApp, LinkedIn, Twitter, Google and Yahoo e-mail. The survey was opened on 26 September 2017 and closed on 1 December 2018.

Topics on BIM application used in the questionnaire were extracted from reviews of the literature, resulting in the formulation of a questionnaire divided into four sections. Section one on respondent's profile elicited personal information on years of experience in the construction industry as well as in the use of BIM, number of projects undertaken using BIM, software based for projects, and the type of tools used for BIM. It also obtained information on the type of employer and the nature of the job of the respondents. Section 2 set four questions on the awareness of BIM, in general, as perceived by the participants. Section 3 set one question on the benefits of BIM, consisting of 25 measures. Section 4 set one question on the barriers of BIM implementation, consisting of 15 measures. The respondents were required to indicate their level of agreement, in practice, with these measures defining the importance of BIM application. The data from these measurements forms the variables used in the EFA, which tested the validity and reliability of the measured factors. To reduce the respondent's bias, closed-ended questions were preferred for Sections two, three and four (Vicente & Reis, 2010: 260).

3.4 Data analysis and interpretation of findings

The Statistical Package for Social Science (SPSS) version 24 was used to determine the factor analysability of the BIM application variables, using inferential statistics (Pallant, 2013).

Descriptive statistics based on frequencies and percentages was used to measure central tendency and dispersion in order to describe the characteristics of the respondents as well as the current status of BIM application in the construction industry (Naoum, 2007: 103).

To rank the importance of the barriers and benefits of BIM application respectively, the measures on barriers (15) and benefits (25) were rated on a five-point Likert scale. Likert-type or frequency scales use fixed choice response formats and are designed to obtain levels of agreement by measuring attitudes or opinions (Bowling, 1997). The following scale measurement was used regarding mean scores, where 1 = least important ($\geq 1.00 \leq$ and < 1.80), 2 = somewhat important

(≥ 1.81 and ≤ 2.60), 3 = neutral (≥ 2.61 and ≤ 3.40), 4 = important (≥3.41 and ≤ 4.20), and 5 = most important (≥4.21 and ≤ 5.00).

Cronbach's *alpha* values were extracted to analyse the internal consistency of reliability of the variables in the questions on BIM application (Kolbehdori & Sobhiyah, 2014: 347; Wahab, Ayodele & Moody, 2010: 67). Acceptable values of Cronbach's *alpha* would range from 0.70 to 0.95 (Tavakol & Dennick, 2011: 54-55, Garson, 2013: 30). In the current study, a cut-off value of 0.70 was preferred.

To confirm whether the data from the measurements was sufficient for factor analysis (test the validity), the Kaiser-Meyer-Olkin (KMO) test (Lorenzo-Seva, Timmerman & Kiers, 2011) and the Bartlett's sphericity test (Hair, Black, Babin *et al.*, 2006: 110) were performed. In the KMO test, as the values of the test vary from 0 to 1, values above 0.7 are recommended as being desirable for applying EFA (Hair *et al.,* 2006). A statistically significant Bartlett test ($p < 0.05$) indicates that sufficient correlations exist between the variables to continue with the factor analysis (Hair *et al.*, 2006: 110; Pallant, 2013: 190).

For factor extraction, Principal Components Analysis (PCA) was used, as this method allows for extracting Eigenvalues where the highest Eigenvalues in the data are, therefore, the principal components in the data, and they are retained to form a set of variables with new names/labels (Rossoni *et al.*, 2016: 102). PCA also allows for running Scree tests to determine the number of factors to retain. For this study, all components extracted that are above the initial Eigenvalue of 1 are retained (Kaiser, 1960). Components were chosen according to the correlation between the variables. For something to be labeled as a component (and give a new name), it should have at least 3 representative variables (Tabachnick & Fidell, 2013).

The Pearson's *chi*-square (*P*-value) test for independence was used to determine if there was a relationship between the number of *years* and the number of *projects* (dependent variables) undertaken and the application of BIM technology (independent variables) in the Kenyan construction industry.

- Null hypothesis H_0: There is no association between the two statements.
- Alternative hypothesis H_1: There exists at least some significant association.

The *P*-value (or the calculated probability) is the probability of the event occurring by chance, if the null hypothesis is true (Kamanga & Stern, 2013: 82). The pairs of variables analysed were limited to

those with an observed *P*-value less than 0.100 (p < 0.100) with the significance level of (0.100). All pairs of variables with *P*-values above 0.100 were not considered and thus not included in this article.

3.5 Limitation of the study

It should be noted that, although the study was not conducted throughout Kenya, all professionals in the construction industry are registered in Nairobi. In addition, the professionals in the sample population are active across the country and hence the data is representative of the whole of Kenya.

3.6 Ethical clearance

The online questionnaire was circulated with an introductory message stating the aim, purpose, and confirmation that all information received will be treated with strict confidentiality and for academic purposes only. Prior to data collection, a formal request in writing to get authorization to collect data from construction professionals was done to relevant professional bodies in Kenya.

4. Results and discussion

Although 195 completed responses were received, only 146 responses were valid for reporting results on the barriers, and 137 responses were valid for reporting the results on the benefits of applying BIM in the construction industry.

4.1 Respondent's profile

Tables 2 and 3 show the general demographic and work experience data of the respondents. Based on frequency of occurrence, the vast majority of the respondents have 0-2 years' (45.8%) experience of BIM in the construction industry and (30.7%) have between 6-8 years' experience. Of the respondents, 47.3 % are consultants and 35.5% work for private clients. The vast majority (52.1%) of the respondents are in the field of architecture. Whereas most of the professionals (42.8%) had undertaken a fairly limited number of projects (less than 5), nearly a third (32.7%) had completed 9 or more projects using BIM. Archicad was used predominantly as software as well as BIM tool.

Table 2:   Respondent's profile on employer and experience

Respondent's profile	Categories	Frequency	Percentage	Std deviation
Type of employer	Public client	17	10.1	1.586
	Private client	60	35.5	
	Contractor	11	6.5	
	Subcontractor	1	.6	
	Consultant	80	47.3	
	Total	169	100.0	
Experience in the construction industry	0-2 years	22	13.3	1.221
	3-5 years	49	29.5	
	6-8 years	51	30.7	
	9-11 years	21	12.7	
	12 or more	23	13.9	
	Total	166	100.0	
Experience in using BIM	0-2 years	77	45.8	1.166
	3-5 years	43	25.6	
	6-8 years	29	17.3	
	9-11 years	10	6.0	
	12 or more	9	5.4	
	Total	168	100.0	

Table 3:   Respondent's profile on occupation and BIM use

Respondent's profile	Categories	Frequency	Percentage	Std deviation
Nature of present job	Architecture	87	52.1	1.172
	Project management	20	12.0	
	Engineering	33	19.8	
	Quantity surveying	27	16.2	
	Total	167	100.0	
Projects undertaken using BIM	0-2	74	44.0	1.318
	3-5	32	19.0	
	6-8	7	4.2	
	9 or more	55	32.7	
	Total	168	100.0	
Software used for projects	ArchiCAD	96	58.5	0.872
	Revit	26	15.9	
	AutoCAD	41	25.0	
	Google Sketchup	1	0.6	
	Total	164	100.0	
Type of BIM tool used for projects	ArchiCAD	98	60.9	0.843
	Revit	25	15.5	
	AutoCAD	38	23.6	
	Total	161	100.0	

4.2   Current status of the implementation of Building Information Modelling

Based on the frequency results from Table 3, very few respondents have undertaken projects using BIM. This confirms that the current adoption of BIM is still very low. These findings agree with results obtained by Matarneh & Hamed (2017a: 189), which indicate that the current state of BIM implementation in Jordan is still lagging, since only large AEC organisations (5%) have prompted a serious move towards BIM in certain categories, while 95% of organisations are not using BIM in any capacity.

Table 4 shows the current status of BIM application as perceived by the respondents.

Table 4:   Current status of BIM application in the construction industry

Respondent's profile	Categories	Frequency	Percentage	Std deviation
Awareness of BIM and its benefits	Yes	149	88.7	0.408
	No	15	8.9	
	Unknown	4	2.4	
	Total	168	100.0	
BIM is the future of project management	Agree	161	95.8	0.379
	Disagree	1	0.6	
	Unknown	6	3.6	
	Total	168	100.0	
Stakeholders not clear on the role of BIM in project management	Agree	152	90.5	0.501
	Disagree	6	3.6	
	Unknown	10	6.0	
	Total	168	100.0	
Additional training on BIM application is necessary	Agree	167	100	0.000
	Disagree	0	0	
	Unknown	0	0	
	Total	167	100.0	

Based on frequencies, results show that most of the stakeholders are not yet clear about the role of BIM in project management and thus require additional training. These findings are also consistent with the results obtained by Abuhamra (2015) and Shaikh *et al.* (2016: 207), confirming that the level of BIM awareness is low among

construction professionals. Balah and Akut (2015) carried out a similar study in Nigeria and found that only 30% of stakeholders claimed to be aware of BIM, with only 7% of the respondents having a proper understanding of BIM.

4.3   Benefits of implementing Building Information Modelling

Table 5 ranks the mean scores to show which of the 25 variables measuring the benefits when applying BIM applications in construction are considered important by construction professionals.

Table 5:   Ranking of benefits using BIM

Kaiser-Meyer-Olkin value = .810	Bartlett's Test of Sphericity = 1,478.553 (p-value is 0.000)		
	Cronbach-alpha .907		
Variable measure benefits of BIM implementation (N=137) (1= least important ….. 5= most important)	*Rank*	*Mean*	*Std. deviation*
V12 Improved management of projects schedule milestones	12	4.18	.756
V13 Improved design quality	4	4.36	.716
V14 Efficiencies from reuse of data or details (enter once use many)	14	4.14	.778
V15 Enhanced energy efficiency and sustainability of the building	10	4.20	.839
V16 Allowing increased energy analysis of the building	16	4.04	.839
V17 Reduced redesign challenges during project implementation	=3	4.39	.825
V18 Fewer change orders at the construction stage	14	4.14	.917
V19 Earlier and more accurate design visualization	2	4.46	.675
V20 Generation of accurate and consistent 2D drawings at any stage	8	4.23	.675
V21 Improved site analysis	=20	3.82	.972
V22 Improved communication between project parties	1	4.47	.718
V23 Improved communication among various divisions of the same company	7	4.29	.749
V24 Improved project information management	=3	4.39	.634
V25 Potentially improved whole life asset management	17	4.01	.840

Kaiser-Meyer-Olkin value = .810	Bartlett's Test of Sphericity = 1,478.553 (p-value is 0.000)		
	Cronbach-alpha .907		
Variable measure benefits of BIM implementation (N=137) (1= least important ….. 5= most important)	Rank	Mean	Std. deviation
V26 Enhanced management of security and safety information	=20	3.82	.865
V27 Improved maintenance due to Building Automation System	15	4.07	.763
V28 Enhanced project information collaboration among stakeholders	6	4.30	.679
V29 Potentially improved maintenance of the facility, due to the as-built model	13	4.16	.797
V30 Enhanced work coordination with subcontractors/supply chain	10	4.20	.784
V31 Allowing accurate site logistics plans	18	3.98	.870
V32 Improved coordination in the construction phase	5	4.34	.701
V33 Greater predictability of project time and cost	=9	4.22	.846
V34 Greater productivity, due to easy retrieval of information	=9	4.22	.694
V35 Improved conflicts detection	11	4.19	.896
V36 Improved human resources management	21	3.81	.912

The respondents indicated the most important benefits of applying BIM in the construction industry in Kenya, with mean score ratings above >4.21 as: improve communication (4.47); accurate design visualization (4.46); improve project information management (4.39); reduce redesign challenges during project implementation (4.39); improve design quality (4.36), improve coordination in the construction phase (4.34); enhance project information collaboration among stakeholders (4.30); improve communication among various divisions of the same company (4.29); generation of accurate and consistent 2D drawings at any stage (4.23); greater predictability of project time and cost (4.22), and greater productivity, due to easy retrieval of information (4.22).

The Cronbach *alpha* was greater than 0.70 at .907, indicating acceptable internal reliability as recommended by Hair *et al.* (2006: 102). The Kaiser-Meyer-Olkin (KMO) measure was .810, indicating that the data were sufficient for factor analysis. The Bartlett's Test of Sphericity (*p*=0.00) with significance of *p*<0.05 showed that there is some relationship between the variables. These results suggest that the data on the benefits of BIM can be used for factor analysis.

4.3.1 Factor analysis of Building Information Modelling benefits

The 25 benefits variables were subjected to component analysis in order to study the trend of inter-correlations between variables and to group these variables with similar characteristics into a set of reduced variables according to the hidden components in the collected data. The results report the component extraction, Eigenvalues, correlation and interpretation.

In Figure 1, the scree plot consists of the Eigenvalues and the data points above the break (point of inflexion), which are the components that are meaningful to retain. Using a cut-off value of initial Eigenvalues greater than one (>1.0), there were 7 components that explain a cumulative variance of 66.07%.
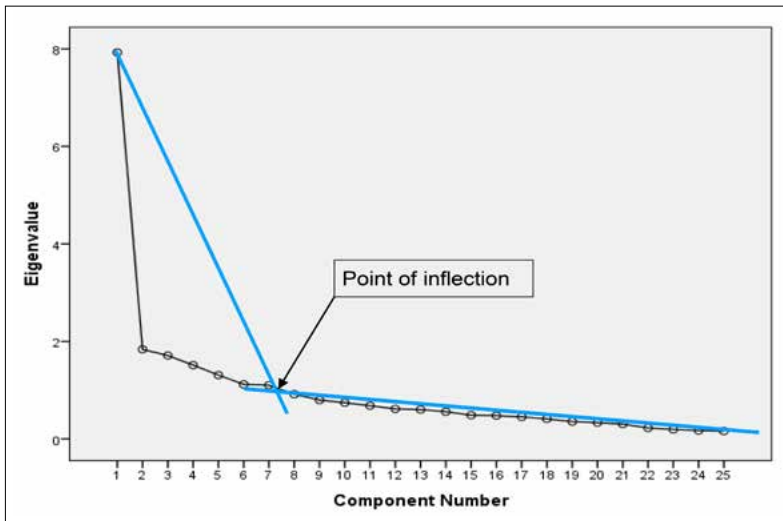

Figure 1:   Scree plot for factors of BIM benefits

The scree plot confirms the finding of retaining seven components. As a result, components from eight to twenty-five are not significant and thus not included for analysis. Table 6 shows the seven components that are meaningful to retain, where component 1 explains 31.716% of the total variance; component 2, 7.344%; component 3, 6.840%; component 4, 6.058%; component 5, 5.232%; component 6, 4.474%, and component 7, 4.409%.

Table 6:   Total variance explained – extraction method: Principal component analysis

Component	Initial Eigenvalues		
	Total	% of variance	Cumulative %
1	7.929	31.716	31.716
2	1.836	7.344	39.059
3	1.710	6.840	45.899
4	1.514	6.058	51.957
5	1.308	5.232	57.189
6	1.119	4.474	61.664
7	1.102	4.409	66.073

Using Varimax rotation method with significant factor of .04, Table 7 shows the component loadings of correlation between components and variables after rotation. V12 Improved management of projects milestones (0.391) was removed from the analysis, as it was not significant in the model. Correlation exists between variables in components 1, 2 and 7 labelled as **Factor 1: Comprehensive project management**. Correlations were identified between variables in components 3, 5 and 7 labelled as **Factor 2: Design and building performance analyses**, and correlations were identified between variables in component 4 labelled as **Factor 3: Project data management**.

Table 7:   Rotated component matrix for BIM benefits

Variables	Components						
	1	2	3	4	5	6	7
	1, 2, 7 = Factor 1: Comprehensive project management 3, 5, 6 = Factor 2: Design and building performance analyses 4 = Factor 3: Project data management						
V12 Improved management of projects milestones							
V13 Improved design quality						.424	.446
V14 Efficiencies from reuse of data or details				.673			
V15 Enhanced energy efficiency and sustainability					.859		
V16 Increased energy analysis of the building					.820		

Variables	Components						
	1	*2*	*3*	*4*	*5*	*6*	*7*
	1, 2, 7 = Factor 1: Comprehensive project management *3, 5, 6 = Factor 2: Design and building performance analyses* *4 = Factor 3: Project data management*						
V17 Reduced redesign challenges during construction			.836				
V18 Fewer change orders during construction			.824				
V19 Earlier and more accurate design visualization						.801	
V20 Generation of accurate and consistent drawings						.743	
V21 Improved site analysis			.516				
V22 Improved communication between project parties	.606						
V23 Improved communication within companies	.763						
V24 Improved project information management	.602						
V25 Potentially improved whole life asset management	.655						
V26 Enhanced management of data (security and safety)	.696						
V27 Improved maintenance				.598			
V28 Enhanced collaboration of data among stakeholders				.508			.468
V29 Improved maintenance using as-built model				.573			
V30 Enhanced work coordination with subcontractors		.748					
V31 Allowing accurate site logistics plans		.743					
V32 Improved coordination in the construction phase		.695					

Variables	Components						
	1	2	3	4	5	6	7
	1, 2, 7 = Factor 1: Comprehensive project management 3, 5, 6 = Factor 2: Design and building performance analyses 4 = Factor 3: Project data management						
V33 Greater predictability of project time and cost		.512					.584
V34 Greater productivity							.721
V35 Improved conflicts detection				.620			
V36 Improved human resources management		.421	.437				
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.							

In **Factor 1: Comprehensive project management** (components 1, 2 and 7), the variables that had high loading are: Communication (0.763); work coordination (0.748); greater productivity (0.721), and accurate site logistics plans (0.743). Studies on the benefits of implementing BIM in construction projects show similarity to variables in Factor 1: Enhance collaboration and communication (Eastman, Teicholtz, Sacks, & Sacks, 2008); enhance design efficiency, scheduling, and documentation; reduces budget and reduced construction time (Adebimpe & Etiene, 2016); better communication, and efficient administration of construction projects (Latiffi *et al.*, 2013).

In **Factor 2: Design and building performance analyses** (components 3, 5 and 6), the variables that scored high weights were: Enhanced energy efficiency and sustainability (0. 859); reduced redesign (0.836); fewer change orders during construction (0.824), and increased energy analysis of the building (0.820). These findings are consistent with similar results obtained for BIM benefits such as greater efficiency in change-order management (Brown, 2015); enhance design review (Shaikh *et al.*, 2016); reduce rework during construction (Matarneh & Hamed, 2017b), and site analysis - reduction of expenses incurred on utility and demolition (Latiffi *et al.*, 2013); energy optimization of the building (Abuhamra, 2015), and building performance analyses (*e.g.*, energy modelling) (Azhar *et al.*, 2012).

In **Factor 3: Project data management** (component 4), the variables with high scores were: Efficiencies from reuse of data or details (enter once use many) (0.673); improved conflicts detection (0.620); improved maintenance (0.598), and with the available building data (as-built model), BIM enables easier facility management

(0.573). This finding agrees with similar studies that identified BIM benefits such as BIM enhances collaboration and communication among stakeholders (Eastman, Teicholtz, Sacks & Sacks, 2008); clash detection (Shaikh *et al.*, 2016), and BIM allows for easier facility maintenance, due to existing building data (Ahn & Cha, 2014).

4.4 Barriers in the implementation of Building Information Modelling

Table 8 ranks the mean scores to show which of the 15 variables measuring the barriers when applying BIM applications in construction are considered important by construction professionals.

Table 8: Ranking of barriers in implementing BIM

Kaiser-Meyer-Olkin value = .829	*Bartlett's Test of Sphericity = 734.417 (p-value is 0.000)*		
	Cronbach-alpha 0.856		
Variable measure barriers of BIM application (N=146) (1 = least important …..5 = most important)	*Rank*	*Mean*	*Std. deviation*
V37 High cost of buying and updating software	1	4.32	.909
V38 Lack of awareness of BIM by stakeholders	4	4.10	.938
V39 Lack of knowledge of BIM application by stakeholders	=5	4.08	.903
V40 Lack of awareness of benefits of BIM by stakeholders	8	3.95	.985
V41 Lack of government regulations to support implementation of BIM	12	3.60	1.218
V42 Lack of training at the university and colleges on BIM application	3	4.16	1.044
V43 Poor collaboration of BIM information among stakeholders	7	4.01	.887
V44 Resistance to adopt new technology due to change in workflow system in companies	6	4.06	.948
V45 Inadequate finance in small firms to start new workflow system for BIM	2	4.18	.902
V46 Lack of government regulations to support implementation of BIM	14	3.49	1.188
V47 Lack of demand and interest from the clients on the application of BIM in the design and construction of projects	13	3.55	1.192

Kaiser-Meyer-Olkin value = .829	Bartlett's Test of Sphericity = 734.417 (p-value is 0.000)		
	Cronbach-alpha 0.856		
Variable measure barriers of BIM application (N=146) (1 = least important …..5 = most important)	Rank	Mean	Std. deviation
V48 Lack of case studies in Nairobi, Kenya that have implemented BIM and realised positive investment returns	11	3.65	1.124
V49 Lack of training for architects and engineers, due to costly training requirements in terms of time and money	=5	4.08	.851
V50 Uncertainties over interoperability of BIM software with other software	10	3.68	.995
V51 Lack of BIM standards	9	3.75	1.062

The respondents indicated the most important barrier when implementing BIM in the construction industry in Kenya, with mean score ratings above (>4.21) as high cost of buying and updating software (4.32), and important barriers as inadequate finance to start new workflow system for BIM (4.18); lack of training at the university and colleges on BIM application (4.16); lack of awareness of BIM by stakeholders (4.10); lack of knowledge of BIM application by stakeholders (4.08); lack of training for architects and engineers due to costly training requirements in terms of time and money (4.08); resistance to adopt new technology, due to change in workflow system in companies (4.06), and poor collaboration of BIM information among stakeholders (4.01).

The Cronbach *alpha* was greater than 0.70 at 0.856, indicating acceptable internal reliability as recommended by Hair *et al*. (2006: 102). The Kaiser-Meyer-Olkin (KMO) measure was 0.829, indicating that the data were sufficient for factor analysis. The Bartlett's Test of Sphericity (p=0.00) with significance of $p<0.05$ showed that there is some relationship between the variables. These results suggest that the data on the barriers of implementing BIM can be used for factor analysis.

4.4.1 Factor analysis of Building Information Modelling implementation barriers

Fifteen variables on BIM implementation barriers were subjected to component analysis to study the trend of intercorrelations between variables and to group these variables with similar characteristics into a set of reduced variables according to the hidden components in

the collected data. The results report the component extraction, Eigenvalues, correlation, and interpretation.

In Figure 2, the scree plot consists of the Eigenvalues and the data points above the break (point of inflection), which are the components that are meaningful to retain. Using a cut-off value of initial Eigenvalues greater than one (>1.0), three components explain a cumulative variance of 53.16%.
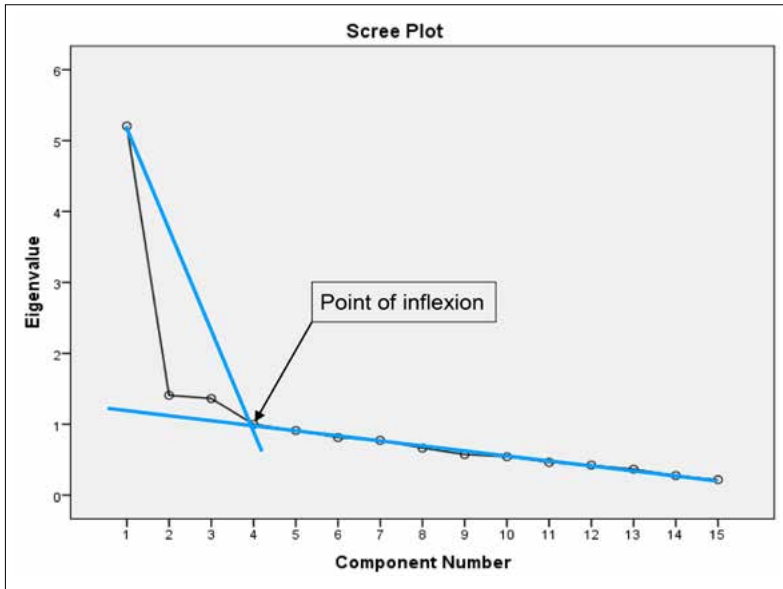

Figure 2:   Scree plot for factors for BIM application barriers

The scree plot confirms the finding of retaining three components. As a result, components from four up to fifteen are not significant and thus not included for analysis. Table 9 shows the three components that are meaningful to retain, where component 1 explains 34.695% of the total variance; component 2 explains 9.386%, and component three explains 9.088% of the variance.

Table 9: Total variance explained: Extraction method (principal component analysis)

Component	Initial Eigenvalues		
	Total	% of variance	Cumulative %
1	5.204	34.695	34.695
2	1.408	9.386	44.081
3	1.363	9.088	53.169

Using Varimax rotation method with significant factor of .04, Table 10 shows the component loadings of correlation between components and variables after rotation. Correlation exists between variables in component 1 labelled as **Factor 1: High cost of buying software and lack of training.** Correlations were identified between variables in components 2 labelled as **Factor 2: Lack of BIM standards and regulations,** and correlations were identified between variables in component 3 labelled as **Factor 3: Lack of BIM awareness and inadequate finance**.

Table 10: Rotated component matrix[a] for BIM application barriers

Variables	Components		
	1	2	3
	Factor 1: High cost of buying software and lack of training	Factor 2: Lack of BIM standards and regulations	Factor 3: Lack of BIM awareness and inadequate finance
V37 High cost of buying and updating software			.606
V38 Lack of awareness of BIM by stakeholders			.648
V39 Lack of knowledge of BIM application by stakeholders			.793
V40 Lack of awareness of benefits of BIM by stakeholders			.545
V41 Lack of government regulations to support implementation of BIM		.876	
V42 Lack of training at the university and colleges on BIM application	.504		
V43 Poor collaboration of BIM information among stakeholders	.604		

Variables	Components		
	1	*2*	*3*
	Factor 1: High cost of buying software and lack of training	Factor 2: Lack of BIM standards and regulations	Factor 3: Lack of BIM awareness and inadequate finance
V44 Resistance to adopt new technology, due to change in workflow system within companies	.674		
V45 Inadequate finance in small firms to start new workflow system for BIM	.689		
V46 Lack of government regulations to support implementation of BIM		.861	
V47 Lack of demand and interest from the clients on the application of BIM in the design and construction of projects		.546	
V48 Lack of case studies in Nairobi, Kenya that have implemented BIM and realised positive investment returns	.489	.464	
V49 Lack of training for architects and engineers, due to costly training requirements in terms of time and money	.615		
V50 Uncertainties over interoperability of BIM software with other software	.631		
V51 Lack of BIM standards	.454		
Extraction method: Principal Component Analysis Rotation method: Varimax with Kaiser Normalization			
a. Rotation converged in 4 iterations.			

In **Factor 1: High cost of buying software and lack of training** (component 1), the variables that had high loading were inadequate finance in small firms to start new workflow system for BIM (0.689); resistance to adopt new technology, due to change in workflow system within companies (0.674); uncertainties over interoperability of BIM software with other software (0. 631), and lack of training for architects and engineers, due to costly training requirements in terms of time and money (0. 615). Studies on the barriers of implementing BIM in construction projects show similarity to variables in Factor 1: Lack of awareness about BIM resulting in professionals comparing

BIM to CAD (Gerges *et al.*, 2017); high costs (software, hardware upgrade, training, and time) (Shaikh *et al*., 2016), and the majority of service providers are not actively using BIM technologies on their projects due to increased costs (Eastman *et al.*, 2008).

In **Factor 2: Lack of BIM standards and regulations** (component 2), the variables that scored high weights were lack of government regulations to support implementation of BIM (0.861), and lack of government regulations to support implementation of BIM (0.861). These findings concur with results obtained from similar studies such as lack of standards and codes for BIM application (Chan, 2014), and absence of government support (Matarneh & Hamed, 2017b). In their study, Matarneh & Hamed (2017a) recommend that governments should set standards and codes for BIM industry at both the hierarchical and undertaking store network level.

In **Factor 3: Lack of BIM awareness and inadequate finance** (component 3), the variables with high scores were lack of knowledge of BIM application by stakeholders (0.793); lack of awareness of BIM by stakeholders (0.648), and high cost of buying and updating software (0.606). These findings concur with results from other studies on BIM awareness. Abuhamra (2015) and Shaikh (2016) confirm that the level of BIM awareness is low among the construction professionals in Gaza strip and Mumbai (India), respectively. Balah and Akut (2015) state that only 30% of stakeholders in Nigeria were knowledgeable of BIM, with only 7% of the respondents having a proper understanding of the concept of BIM. These findings confirm that the level of BIM awareness is still very low in the Nigerian construction industry.

4.5   Inferential analysis

The main objective of this analysis was to establish the degree of association between the number of *years* and the number of *projects* undertaken by AEC professions and some of the application of BIM technology by constructing two hypotheses (null and alternative). The hypotheses will be stated as follows:

- Null hypothesis H_0: There is no association between the two statements.
- Alternative hypothesis H_1: There exists at least some significant association.

For purposes of this article, only the pairs of variables with **Asymptotic Significance (2-sided)** (*P*-values) below 0.100 (p < 0.100) were considered, because it shows that the null hypothesis is rejected and that the association between two variables is statistically significant.

All pairs of variables with *P*-values above 0.100 were not considered and thus not included for analysis in this article. The *chi*-square test found an association between the number of projects undertaken and greater productivity (Table 11). An association between the number of years of experience and improved design quality was also observed (Table 12).

4.5.1   The number of projects undertaken versus greater productivity

Figure 3 illustrates the cross-tabulation percentages of the number of projects undertaken using BIM and greater productivity, due to easy retrieval of information.

The proportion of professionals from all the project groups who perceived the use of BIM in projects as important was 52.44%, whereas the proportion of project groups who perceived the use of BIM in projects as unimportant was only 9.76%. The difference in proportions is significant, $\chi^2(9, N = 164) = 21.04$, p = .012 (p < 0.100).
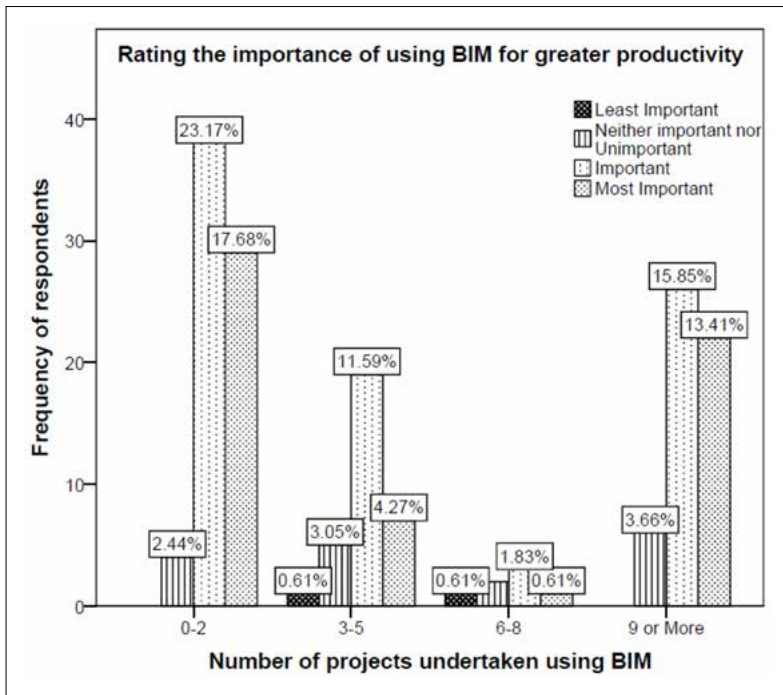

Figure 3:   Projects undertaken using BIM versus greater productivity

Table 11 shows the calculated results of the *chi*-square test of independence comparing the frequency of number of projects undertaken by a company using BIM in achieving greater productivity, due to easy retrieval of information. The *chi*-square test found an association between the number of projects undertaken and greater productivity, x^2(9, N = 164) = 21.046, p = .012 (p < 0.100).

The observed *P*-value (0.012) is far less than the level of significance (0.100) and thus the number of projects undertaken by a company using BIM in any capacity has an influence on greater productivity, due to easy retrieval of information.

Table 11:   Projects undertaken using BIM versus greater productivity.

Chi-square test	Value	df	Asymptotic significance
Pearson *chi*-square	21.046ᵃ	9	.012
Likelihood ratio	15.565	9	.077
Linear-by-linear association	.295	1	.587
N of valid cases	164		
a.8 cells (50.0%) have expected count less than 5. The minimum expected count is .09			

4.5.2   Number of years of experience versus improved design quality

Figure 4 illustrates the cross-tabulation percentages of the number of years of experience in the construction industry and improved design quality. The proportion of professionals from all the years of experience groups who perceived improved design quality as important was 44.57%, whereas the proportion of all the years of experience groups who perceived improved design quality as unimportant was only 5.41%. The difference in proportions is significant, x^2(16, N = 166) = 28.380, p =.028 (p < 0.100)

Table 12 shows the calculated results of the *chi*-square test of independence comparing the frequency of years of experience in the construction industry in achieving improved design quality. The *chi*-square test found an association between the number of years of experience and design quality, x^2(16, N = 166) = 28.380, p =.028 (p < 0.100).

The observed *P*-value (0.0208) is far less than the level of significance (0.100) and thus the null hypothesis is rejected in favour of the alternative hypothesis. Based on the results of the study, improved design quality is influenced by the number of years of experience one has in the building construction industry.
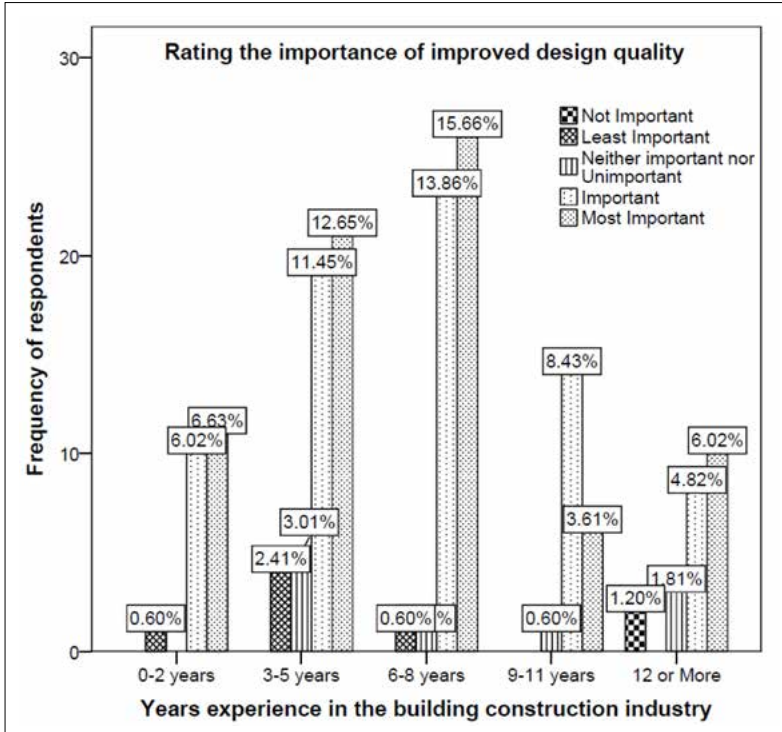
Figure 4: Years of experience versus improved design quality

Table 12:   Years of experience versus improved design quality

Chi-square tests	Value	Df	Asymptotic significance
Pearson *chi*-square	28.380ᵃ	16	.028
Likelihood ratio	25.782	16	.057
Linear-by-linear association	.824	1	.364
N of valid cases	166		
a.8 cells (50.0%) have expected count less than 5. The minimum expected count is .09.			

5.   Conclusions and recommendations

The study established that the current status of BIM application among professionals in the Kenyan construction industry is still lagging. Based on the results obtained, the vast majority (90.5%) of the respondents agree that construction industry stakeholders are not yet clear about

the role of BIM in project management. This finding indicates that BIM is still a very new concept in the Kenyan construction industry.

Most of the benefits of BIM application were rated as highly important, with a weighted average score higher than 4.0 (80.0%). Among all indicators, improved communication between project parties with a mean of 4.47 (89.4%) had the highest rating and hence, was regarded as the most important indicator. Correlation of BIM benefit variables using factor analysis identified factors 1, 2 and 7 as 'Comprehensive project management', factors 3, 5, and 6 as 'Design and building performance analyses', and factor 4 as 'Project data management'.

The majority of the BIM application barriers were rated as highly important, with a weighted average score higher than 4.0 (80%). Among all indicators, the high cost of buying and updating software with a mean of 4.32 (86.4%) had the highest rating and hence, the most important indicator. Correlation of BIM application barrier variables using factor analysis identified factor 1 as 'High cost of buying software and lack of training"', factor 2 as 'Lack of BIM standards and regulations', and factor 3 as 'Lack of BIM awareness and inadequate finances'.

Based on inferential analysis, the results indicate that the number of projects undertaken using BIM has a considerable influence on greater productivity, due to easy retrieval of information. In addition, improved design quality is influenced by the number of years of experience one has in the building construction industry.

It is recommended that construction firms explore available subscriptions for BIM products that allow a more flexible way to purchase the software through affordable instalments (monthly, quarterly, or annual subscription fee). Tertiary institutions and small firms should also sign up for free versions of BIM software. In addition, BIM training by software vendors should be undertaken in vocational and tertiary institutions as well as construction firms. The government should also formulate policies, BIM standards and regulations to support BIM implementation by introducing state incentives such as tax credit for clients, professionals and contractors using BIM in their projects. This will enhance the application of BIM in the Kenyan construction industry.

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