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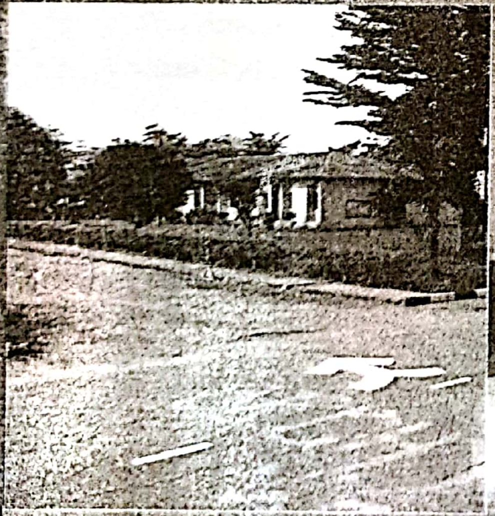
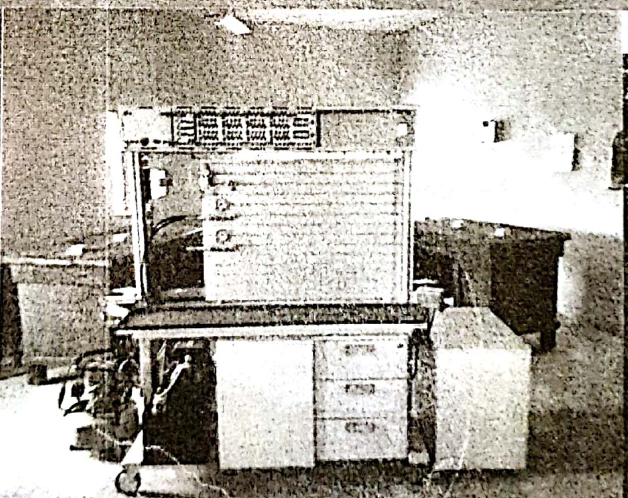
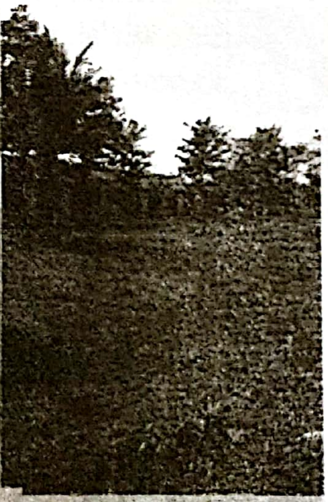

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Quantity Surveying Practice and Evolution of 5D Building Information Modelling

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Abstract
Manual quantification by Quantity Surveyors (QS) from two dimensional drawings is complex and prone to human error because of technological and organizational problems. Building Information Modelling (BIM) is an emerging technology with potentials for automation of quantity take-off and estimating process. This study examines barriers to five dimensional (5D) BIM adoption by Nigerian QS. Purposive sampling approach was used to administer questionnaire to practitioners in construction, consulting and clients' organizations in Nigeria. A total of 53 validly completed questionnaire were returned and analyzed using Statistical Package for Social Sciences. The five most important barrier factors to 5D BIM adoption by QS are: lack of collaborative initiatives from industry stakeholders; problems of communication and data sharing among firms; lack of government support and clear roadmap for BIM implementation; BIM model is not compatible with traditional take-off/estimating software tools; and non-alignment of current rules of Building and Engineering Standard Method of Measurement. The 5-dimensional BIM have tremendous potentials to increase the communication efficiency and interpretation ability of quantity surveyors. However, there is need for construction industry stakeholders to formulate strategies to develop and implement information exchange system that can support collaboration.

Keywords: *Building Information Modelling, Building and Engineering Standard Method of Measurement; Collaboration, Nigeria, Quantity Surveying*

1.0: Introduction

The process of manual quantification in the traditional practice from 2D drawings is complex and is prone to human error because of technological and organizational problems (Boon and Prigg, 2011). As a result, achieving detailed cost estimates requires significant amount of time for visualization, interpretation and clarification of drawings, specification of information and calculations of aggregated quantities of labour, materials, and equipment (Shen and Issa, 2010). Akintoye (2002) noted that the primary cause of poor estimates by Quantity Surveyors includes poor documentation, insufficient time and lack of effective communication with another project team member. Unreliable estimates exposed industry clients to significant financial risk which could lead to project abandonment (Ashworth, et al., 2013), delays, disputes, over budget, cost and time overruns (Mansfield and Ugwu, 1994; Abinu and Jagboro, 2002; Omoregie and Radford, 2006). In addition, time spent on quantity take – off in the traditional paper-based, detailed estimating process, can be categorized into three: identifying items and their interrelationships on the drawings and specifications; finding dimensions (reading directly or inferring from other drawings); and calculating and aggregating the quantities, lengths, areas, and volumes of the identified items

(Firat, Arditi and Hamalainen, 2010). Previous studies reveal that, Quantity Surveyors spend about 50-80% of their time on quantity take-off when preparing cost estimates Matipa, Wilfred, Cunningham and Naik (2010) and variation of over 40% from the initial budget is frequent in these cases Winch (2010). As a result, the use of Information Technology (ICT) is inevitable in the cost consultancy sector of any construction industry because it increases the speed to capture, analyze and share data to facilitate decision making (Matipa, Kelliher and keane, 2008). Building Information Modelling (BIM) is the emerging ICT that possess the capabilities to improve and revolutionize the ways Quantity Surveyors work through process automation (Harison and Thurnell, 2015).

BIM is a methodology to integrate digital descriptions of all the building objects and their relationships to others in a precise manner, so that stakeholders can query, simulate and estimate activities and their effects on the building process as a lifecycle entity (Arayici, Egbu, Coates, 2012). The multi-dimensional nature of BIM, often referred to as 'nD BIM', allows for modelling in an infinite number of dimensions (Harison and Thurnell, 2015). For instance, the introduction of Computer Aided Design (CAD) software facilitates the use of 3D models between planning and design phases (Goedert and Meadati, 2008). The four – dimensional (4D) models refers to 3D models linked to a schedule and is used for interference analysis and space conflict identification (RIBA, 2012). The five – dimensional (5D) model integrates a 3D drawing with time and cost estimates and could help in accelerating design process and ensuring that client's budget is not exceeded (Boon and Prigg, 2012). The 6D relates to facility management, 7D is sustainability and 8D relates to safety (Harison & Thurnell, 2015).

Cartlidge (2011) posit that adoption of BIM by QS is slow in countries where it is being implemented. If adopted the 5-dimensional BIM have tremendous potentials to increase the communication efficiency and interpretation ability of quantity surveyors, but there are limited studies on the use of 5D BIM by Quantity Surveyors in Nigeria as a result of low level of awareness and lack of clearly defined roadmap to BIM adoption in the country (Abubakar, Ibrahim and Kado, 2014; Kori and Kiviniemi, 2015). This research seeks to explore industry's perception on BIM evolution and the potential barriers to 5D BIM adoption by Quantity Surveying practice in Nigeria. It is believed that, understanding how BIM affects Quantity Surveyors, will offer guidance for the Nigerian Quantity Surveyors to create enabling environment through training of existing professionals and suggest what curriculum development is required by the NQS to fill the BIM skill gap. This will also assist to develop strategies that will help to facilitate more effective use of BIM and the process solutions that it offers. This proposition is considered important because, to ensure successful acceptance and adoption of innovation in construction industry, there is need to identify the characteristics of innovation adopters, individual and managerial factors that impact on intention to accept and utilise a specific information technology (Gambatese and Hallowell 2011)

2.0: BIM and quantity surveying practice

Quantity Surveying is the independent and impartial estimating and control of the cost of construction projects with due care, skill and diligence through accurate measurement of works and application of expert knowledge of costs and prices of construction resources to construction projects so as to achieve value for money for the construction industry clients Watermeyer (2012). Measurement is central to the financial management of construction projects and it involves the Quantity Surveyors in measuring different types of work as shown on the drawings produced by the architect or engineer. The quantities are prepared in line with the rules of accepted Standard Method of Measurement and the tender document prepared is referred to as BoQ. The completed BoQ is then forwarded along with other documents for the contractor to price (Hore, et al., 1997).

However, adoption of BIM throughout the lifecycle of a building project will transform modes of working in construction industry in terms of ways in which design data are generated, shared and integrated as well as creating a requirement for new protocols, activities and definitions (RIBA, 2012). For instance the trade based Standard Method of Measurement used by Quantity Surveyors as basis for quantity take-off and basis for cost management of construction will require modification to be adaptable to BIM quantity extraction. Similarly, RIBA, (2012) pointed out that the methodology adopted by cost consultants to provide and integrate cost information into the BIM model will need consideration along with common methods of outputting area and quantity information. But this will have to be done in a manner which can be converted into a robust cost plan that also takes due cognisance of project-specific cost drivers and market trends (RIBA, 2012).

BIM conveys two concepts which include the process of a shared development of the design and the collective object and the 3D virtual model produced using BIM enabled technologies. This model is composed of objects that represent the different elements of the building, and data related to each object. It is posible to reuse these data to simulate the construction of the building (4D BIM) or to provide quantities in 5D BIM. Secondly, model-based cost estimating is possible after the implementation of object-based parametric modeling in the building-modeling software. BIM-enabled software programs use parameters and rules to determine the geometry, as well as non-geometric properties and features of objects (Eastman et al., 2011). The type and cost of materials, cost of elements or assemblies are features which can be assigned to each object of a BIM (model). On the basis of the model, quantities and numbers can be extracted. But, according to Eastman et al. (2011) there is no BIM tool that provides the full capabilities of estimating package, so estimators must identify a method that works best for their specific estimating process.

Boon & Prigg (2012) considered three sub – processes surrounding cost modelling and management from BIM models that can be applied at any stage of the design development from concept design to construction details. These three sub–processes are:

(i) The extraction of the quantities of work to be done from the 3D model and arranging those quantities for estimating purposes.

(ii) The addition of costing data and the calculation of cost

(iii) The derivation of costing data from libraries (or databases)

In Finland, Firat et al. (2010) reported two case studies where quantity take-off was obtained smoothly from model based system, but they further observed that the quantity take –off obtained was not considered to be reliable enough for use as the only source of information for ordering materials. Firat et al. (2010) pointed out that, the main problems and challenges associated with quantity take – off in model – based systems are:

(i) Resistance to change (i.e., transition to model- based quantity take – off) by project participants

(ii) The suitability of classification systems into BIM applications

(iii) Determination of the level of detail of the building models in different project phases.

(iv) Data exchange between BIM and quantity take – off (e.g., application programme interface – API, Industry Foundation Class – IFC)

3.0: Research Methodology

The primary aim of the study is to explore the perception of Quantity Surveyors on the potential barriers of 5D BIM adoption. The study consisted of two Phases which include gathering qualitative data in the first phase and quantitative data in the second phase. This paper relates to the second phase with the objectives of determining the potential barriers to BIM adoption by QS as identified from literature review on BIM, ICT and new technology adoption in construction industry (Ugwu and Kumaraswamy 2007; Matipa, et al., 2008; Boon & Prigg, 2012; Eadie, et al., 2013; RICS, 2014; Stanley & Thurnell, 2014; RICS, 2015), a list of barriers were identified and classified under 4 headings: Technical; Organizational; Process and External. Based on the identified barriers, a purposive non-probabilistic sampling approach was adopted to ensure that Quantity Surveyors with BIM experience/awareness are selected for the survey. A total of 166 questionnaires were sent out to Quantity Surveyors in client, consulting and contracting organisations. In the questionnaire, respondents were requested to provide information about their knowledge of BIM evolution and whether they have actually been involved in a project that utilises BIM. The section on the potential barriers to 5D BIM adoption by QS, a four (4) choices response options (1 = not a barrier, 2 = somewhat of a barrier, 3 = moderate barrier and 4 = extreme barrier) was adopted. The rationale for this was that, having an even number of choices forces the respondents to decide whether a particular factor constitute a barrier or not without giving them an option to choose a neutral position (Cummins & Gullone, 2000). A total of 53 questionnaires were returned representing 32% response rate. Majority of the respondents are principals and managing partners of their firms with real industry experience. 31% have over 20 years' experience and only 7% has 6 to 10 years' experience. The survey was conducted between April to August 2016. The details and distribution breakdown of the questionnaires sent and the corresponding response rate from consultants, contractors, private and public client organisations are presented in Table 1.

Table 1: Distribution of questionnaires to sample groups based on organisations

Organisations	No. of Questionnaires sent	Percentage of total sent (%)	No. of response	Percentage of response (%)
Consultants	54	32.53	21	38.88
Contractor	42	25.30	11	26.19
Private Client	31	18.67	12	38.71
Public Client	39	23.50	9	23.01
Total	166	100	53	31.92 (approx. 32%)

4.0: Research results and discussion of findings

4.1 Research results

The results of this survey are shown in Table 2. The average scores given by respondents for each potential barrier factors to 5D BIM adoption by Quantity Surveyors were computed. The five most important barriers based on the highest mean score are:

i. P1 - Lack of collaborative initiatives from industry stakeholders (3.811);

ii. O4 - Problems of communication and data sharing among firms (3.698);

iii. E3 - Lack of Government support and clear roadmap for BIM implementation (3.528);

iv. T5 - BIM model is not compatible with traditional take-off/estimating software tools (3.491); and

v. P3 -Non-alignment of current rules of Building and Engineering Standard Method of Measurement (BESMM4) with BIM model (3.358).

The t=test results showed that 19 out of 23 variables constitutes potential barrier to 5D BIM adoption by quantity Surveyors. The four variables that are not considered as barrier factors to 5D BIM adoption are:

i. T3 – Extremely expensive to support 5D BIM (p=.252);

ii. E1 - Local institution do not promote the use of BIM (p=0.07);

iii. E5 - Construction industry does not see the need for BIM implementation (p=0.17); and

iv. O5 - Uncertainty about the benefits of BIM (p=0.674).

Table 1. Mean ratings and t-test results

S/No.	Rank	Potential barrier factors to 5D BIM adoption by QS	Mean	T Value	p
Technical Barriers (T)					
T1	4	BIM model is not compatible with take-off/estimating software tools	3.4906	12.184	.000*
T2	9	Lack of hardware infrastructure	2.8868	6.915	.000*
T3	14	Extremely expensive to support 5D BIM technology	2.1509	1.158	.252
T4	11	BIM models used by designers is not compatible with elemental cost planning	2.7170	6.385	.000*
T5	20	BIM compactible software is not known	1.4906	-4.784	.000*
T6	23	Lack of knowledge about BIM technology	1.2075	-10.175	.000*
Process Barriers (P)					
P1	1	Lack of collaborative initiatives from industry stakeholders	3.8113	23.689	.000*
P2	6	Absence of required standard to support QS collaboration in BIM	3.3396	20.398	.000*
P3	5	Non alignment of current rules of Building and Engineering Standard Method of Measurement (BESMM4) with BIM model	3.3585	20.428	.000*
P4	22	Lack of Protocols for Coding BIM Objects	1.4717	-6.328	.000*
P5	7	Resistance to change	3.3019	11.867	.000*
External Barriers (E)					
E1	13	Local institution do not promote the use of BIM	2.2642	1.848	.070
E2	12	Firms are not aware of the benefits of BIM	2.4151	6.075	.000*
E3	3	Lack of government support and clear roadmap for BIM adoption	3.5283	14.846	.000*
E4	17	Client does not appreciate the benefits of BIM to organisations	1.6226	-3.281	.002*
E5	16	Construction industry does not see the need for BIM implementation	1.8113	-2.468	.017
Organisational barriers (O)					
O1	18	Professional background of industry players	1.6226	-3.195	.002*
O2	8	Different organisation culture	3.1509	7.285	.000*
O3	10	Training and learning curve	2.7925	6.087	.000*
O4	2	Problems of communication and data sharing among firms	3.6981	26.674	.000*
O5	15	Uncertainty about the benefits of BIM	1.9623	-.423	.674
O6	19	Traditional roles and organisation structure of firms	1.5283	-4.060	.000*
O7	21	Leadership styles	1.4717	-5.317	.000*

*Significant at $p<0.05$)

4.2 Discussion of Results and Potential Barriers to 5d BIM Adoptions

Basically, from the t-test result shown in Table 2, respondents felt that 19 factors constitute potential barrier to 5D BIM adoption ($p<0.05$) by Quantity Surveyors. The most important barrier factor is lack of collaborative initiatives from the entire industry stakeholders for BIM implementation. Collaboration is said to be key to BIM implementation and for collaboration to be efficient and effective in BIM environment, there is need for partners to be able to share their models; the object-based data exchange need to include geometric shape, appropriate levels of details regarding embedded components, building piece structure and assembly property data (Eastman, et al., 2011). This requires collaborative efforts by industry stakeholders which seem not to be in place in Nigeria. As construction industry experts still works in isolation and there is no synergy between design and cost management of construction works. Interoperability is essential for collaboration among industry players and interoperability issues in cannot be easily resolved in the construction industry without a set of rules and principles for classification of information requirements into data exchange specifications. However, in the Nigerian construction industry, the use of information classification and information standards as a means of information exchange among project participants is not widely practice. If available, it is used at individual organisation level and not generally adopted.

The problem of communication and data sharing is the second most important barrier factor to 5D BIM adoption by Quantity Surveyors. This may be a result of interoperability of applications and software used by different industry practitioners. This finding corroborate the observations made by Matipa, et al., (2008), that BIM modelling had huge potential to facilitate designing to a budget but that quantity surveyors encountered serious software interoperability problems that needed to be overcome before the potential could be realized. Kraus *et al.* (2007) said that for efficient estimating in a BIM environment there is a need to be able to develop and adhere to standards for mapping the objects from the BIM model to the estimating database. The only standard available and widely used in the industry is the measurement standard which is used by QS to provide basis for tender bills of quantities and estimating. However, the measurement standard in use by QSs is not based on any common specification or classification standards.

Lack of government support for BIM implementation is the third most important barrier factors hindering 5D BIM adoption. BIM implementation in the Nigerian construction industry is inevitable but government support is key to successful BIM implementation. However, respondents to the survey felt that government support is a major requirement for 5D BIM adoption by Quantity Surveyors in the Nigerian construction industry. The importance of BIM and associated benefits has led to many governments and authorities calling for the acceptance of BIM within the construction industry to provide the required information exchange between stakeholders (Succar, 2009; Cartlidge, 2011; Ashworth, et al., 2013). This is apparent in efforts by government agencies in more developed countries like the USA, UK, Singapore and South Korea which have already established plans for the mandatory use of BIM for public projects, and the government agencies of these countries pressurizes construction industry to invest in and adopt BIM in order to win public sector contracts (Eadie, et al., 2013). Currently, in Nigeria there is no clearly defined road map by the government or her agencies f or BIM implementation and adoption by construction industry stakeholders. Another important barrier factor to 5D BIM adoption by QS is that, BIM model is not compatible with available take-off/estimating software tools. Quantity surveyors perceived that the software currently available and used for take-off and estimating process is not compatible for BIM model. This is a major barrier to 5D BIM adoption by quantity surveyors as those that have invested in different software to facilitate the traditional QS practice may be reluctant to embrace another new ICT technology.

The fifth most important barrier factor is the non-alignment of current rules of Building and Engineering Standard Method of Measurement (BESMM4) with BIM model. This is also considered as an important barrier factor by Quantity Surveyors. This finding is important and corroborates the observation by Amuda-Yusuf, et al., (2013) that the structure and term of set-out of the Nigerian Building and Engineering Standard Method of Measurement (BESMM3) is based on RICS SMM7 and is not aligned with any local classification systems which will make it difficult to support collaboration by QS in BIM models. Similarly, Boon and Prigg (2012), said that there is a significant non- alignment between the object in BIM models and the traditional trade items in standard method of measurement because the objects in BIM 3D model represent components of the finished product whereas the SMM calls for quantification of the work to create that component.

5.0: Conclusion

This study examined the potential barriers to 5D BIM adoption from the perspectives of a sample of Nigerian Quantity Surveyors. The findings suggest that the level of awareness of BIM use among Quantity Surveyors is generally low and BIM is mostly used at project and organisation level. The five most important barrier factors include: lack of collaborative initiatives from industry stakeholders; problems of communication and data sharing among firms; lack of government support and clear roadmap for BIM implementation; BIM model is not compatible with traditional take-off/estimating software tools; and non-alignment of current rules of Building and Engineering Standard Method of Measurement (BESMM4) with BIM model. The effective adoption of 5D BIM by Nigerian Quantity Surveyors will be dependent on collaboration of the construction industry professional to develop and adopt a platform for information exchange. The government must ensure that all necessary infrastructures required to support BIM uptake are provided

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