ARCHISEARCH

BIM-BASED COST ESTIMATING USING THE NIGERIAN BUILDING AND ENGINEERING STANDARD METHOD OF MEASUREMENT (BESMM): INFORMATION REQUIREMENTS IDENTIFICATION

M. Abdullahi[1]*, M. Abubakar[2], Peter Gangas Chindo[1], U. Musa[3] & A. Aminu[1]
[1]Department of Quantity Surveying, Ahmadu Bello University, Zaria-Nigcria
[2]Department of Building, Ahmadu Bello University, Zaria-Nigeria
[3]Due Process and Project Monitoring Bureau, Dutse, Jigawa State
Correspondence email: *bnabdallah02(a),gmail.com*

Abstract

Conventionally, construction cost estimates are prepared manually using paper-based, CAD-based or semi-automated approaches. These methods have been criticised for being labour intensive and error prone. However, with the advent of Building Information Modeling (BIM), researchers have proposed BIM-based costing frameworks based on which several cost estimating software applications have been developed. Despite the proliferation of these software tools, studies have reported slow pace of adoption of these tools by Quantity Surveyors globally. One of the major challenges hindering the widespread of usage and application of BIM-based estimating systems is the differences in cost estimating practices and measurement standards which differ from one country to another. Most of the current BIM tools are based on standards that do not adequately capture local cost estimating requirements, hence making the full adoption of these BIM tools difficult and unrealistic. The Industry Foundation Classes (IFC) as the major BIM data standard being utilised by various software vendors has been reported to be inadequate and insufficientbecause it doesnot capture most local requirements. This paper therefore aims at identifying the information requirements that support BIM-based cost estimating using the Nigerian local standard for estimating. This is with the view to establishing information needs for software developers to improve their cost estimating software applications. Using a qualitative research approach, a total of five (5) experienced consultant Quantity Surveyors were interviewed and data collected was analysed using content analysis. The study identified six (6) categories of information required to support BIM-based cost estimating using the Nigerian BESMM as a local cost estimating standard. The study concludes that unless these local are comprehensively captured by the IFC schema, the full benefits and potentials of BIM-based cost estimating tools will not be achieved.

Key Words: BIM-based estimating, IFC, BESMM, Information requirements, Quantity Survevors

INTRODUCTION

Several predictions suggest the extinction of Quantity Surveying profession with the emergence of BIM. This largely has been due to lack of BIM awareness and the conservative attitude to change exhibited by Quantity Surveyors (QS). However, this prediction turned out to be wrong as BIM's capability of automating measurements through extraction of

quantities has enhanced QS estimating processes and has shifted their attention to providing knowledge and expertise-intensive advice to the project team. QS Firms are now beginning to embrace BIM in their practices globally (McGraw-Hill Construction, 2014). For instance, Pittard and Sell (2016) reported widespread BIM practice by UK firms in the areas of cost planning; risk management; whole life cycle costing, procurement, contract administration and information management. "HC QS"; a major QS consultancy in UK engages its junior QSs in developing BIM models of highest level of detail for cost planning and estimating using simple BIM authoring tools (Pittard & Sell, 2016). This development is quite evident in the proliferation of BIM-based cost estimating frameworks and software application in recent times (Ma, Zhang, Wu, Wei, & Lou, 2010; Ma, Zhenhua, Wu, & Zhe, 2011; Wan, Chen, & Tiong, 2004).

To effectively leverage the potentials of these BIM-based cost estimating applications, software vendors have explored and adopted neutral file formats that facilitate interoperability among heterogeneous systems and applications with Industry Foundation Classes(IFC) considered as the most popular and widely adopted data model currently implemented in the industry. For example, Faraj, Alshawi, and Aouad (2002) developed a Web-based IFC Shared Project Environment (WISPER)that facilitates Web basedproject stakeholders'integration and sharing of the design, budget, schedule andother information in construction projects. Fu, Aouad, Lee, Mashall-Ponting, and Wu (2006) developed an IFC based life-cycle cost assessment that automatically generate cost data from 3D Models. Staub-French, Fischer, and Kunz (2003) developed IFC-based cost estimating system that supports the preparation of cost estimates from BIM models. Furthermore, using IFC standard and 4D model, Yabuki and Shitani (2005)developed a cost estimating prototype system that extracts quantities and generate cost estimates of construction projects .

Despite the significant contributions made by these research works towards the improvement of the accuracy and speedy production of estimates using BIM, studies (Ma et al., 2011; Madugu, Abdullahi, & Musa, 2016) observed that the IFC standard is inadequate, lacking the capacity to sufficiently capture local standards for cost estimating which varies from one country to the other (e.g. the BESMM in Nigeria; and the Quota/BOQ method in China). Ma et al. (2011) argued that, extending the IFC standard to accommodate the standards of each country so that all the relevant local information can be captured and shared efficiently by different application software through an IFC file presents a better solution than extracting applicable data fromthe IFC file and supplementing it in the application software as highlighted by existing research works (Faraj et al., 2002; Fu et al., 2006; Staub-French et al., 2003; Tanyer & Aouad, 2005; Yabuki & Shitani, 2005).

This paper therefore identifies the information requirements that support BIM-based cost estimating using the Nigerian local standard for estimating, specifically the BESMM. This is with the view to establishing information needs for software developers to improve the scope and capacity of their cost

estimating applications. The paper commenced by reviewing extant literature on current BIM-based cost estimating methods and the Nigerian Building and Engineering Standard Method of Measurement (BESMM). Subsequently, the research method adopted in the study; the results and discussions; and conclusions were finally presented. Results of this study provide software vendors with useful information for improving their products for wider acceptability and adoption.

LITERATURE REVIEW

Methods of BIM-based Cost Estimating

Although BIM platforms have the capacity of generating quantities automatically, they however lack capacity to produce cost estimate. To prepare estimates, the quantities generated from BIM models are assigned prices/rates and descriptions based on a standard format. Therefore, researchers suggest the following three approaches as methods of performing BIM-based cost estimating:

i. Exporting building object quantities to estimating software

In this approach, quantities generated from 3D BIM are exported into spread sheets where pricing and other estimating activities are carried out. Eastman, Teicholz, and Sacks (2011) reported that most BIM-based estimating tools are capable of exporting the quantities to a spreadsheet or external databases, where Quantity Surveyors could do their pricing work. Using the exported quantities, Quantity Surveyors can be able to prepare BOQs in any format they decide to. However, a major weakness of this approach is that there is lack of bi-directionality between the BIM model and the spreadsheet, which prevents changes made into the model to be directly reflected on the exported quantities. Even so, this approach still offers the simplicity and control that matches certain workflows. Example of BIM software capable of performing this approach are the Autodesk Quantity Take-off, and all BIM design authoring tools, such as Revit, ArchiCAD, Bentley systems, etc.

ii. Bridging the BIM Tool Directly with Estimating Software

This method involves the use of BIM estimating software plug-ins such as TocomaniLink which are linked to 3D Models in BIM design tools through application programming interfaces. With this approach, measurement rules are set by Quantity Surveyors using plug-ins and then quantities are automatically generated from the models. A typical example of this approach was demonstrated by Aiyeleso, Ibrahim, Abdulrazaq, and Kolo (2014) where an application was developed as an ad-on to Revit to automatically extract material quantities and specifications from a BIM. BIM objects can then subsequently be mapped to rates/prices in an external price database such as the RS-Means cost database. Using this approach, BIM design tools mainly serve to provide model visualisation to aid the cost estimating processes.

ii. Using BIM Quantity Take-off Tools

This involves the use of specialised quantity take-off (QTO) software, e.g. Autodesk QTO, Vico Office, ExactalCostX, and Innovaya. These software have the ability to transfer the BIM models and their embedded parameters from BIM design tools into their system, extract quantities from the models and then generate estimates.

These tools can support both the automated extraction and manual take-off features. They can generate visual take off diagrams while providing visualisation of models whereby the Quantity Surveyor can mark off the building components using colours, enabling the Quantity Surveyor to cross check the take-off lists and to see which components have or have not been included in the estimate (Eastman et al., 2011).

Challenges for BIM-based Cost Estimating

Despite the huge benefits derived in using BIM for estimating and cost planning purposes, a number of challenges continue to hinder its successful adoption by Quantity Surveyors. The following are some of the challenges acknowledged by researchers:

i. Substandard BIM Models and Inadequate Information

The accuracy of estimates depends on many factors among which are detailed information and specifications. BIM models of various categories of details known as Level of Developments (LODs) are developed by designers. However, models of LOD 500 provide adequate information that ensures accurate estimates are prepared. LOD 500 models contain details of size, shape, location, quantity and orientation that have been verified in the field (RICS, 2014). Therefore, where substandard models of lower level of details are prepared, the accuracy and reliability of estimates generated by the BIM models become questionable and unreliable.

ii. Interoperability Challenges (Issues Related to Data Exchange)

BIM-based estimating software currently do not provide bi-directional data exchange with other relevant applications. For example, estimates prepared now cannot capture later changes made to BIM models except if the updated models are imported into the BIM tool and new estimates are prepared(Eastman et al., 2011; Sabol, 2008).

iii. Lack of Standardisation and Inappropriate Pricing Format

As methods of estimating vary from one country to the other, there is lack of standard formats suitable for automated quantity take-off and pricing that is universally applicable. Standards currently in use in most BIM applications are the Uniformat, Uniclass, Omniclass classification systems which do not capture local in most cases (Ma et al., 2011). In Nigeria, the different versions of the BESMM are the standards used by Quantity Surveyors to prepare cost estimates. However, these standards do not support BIM based Quantity take-off in many aspects because they are not based on any classification standards (Uniformat, MasterFormat,Uniclass, and Omniclass). Madugu et al. (2016) developed information requirements that supports BIM-based QTO using BESMM 3.

iv. Legal & liability issues

Confusion as to whether or not the BIM model is a contract document needs resolution, particularly as sub-contractors are now beginning to price directly from BIM models (RICS, 2014).

v. Manual review of extracted quantities necessary:

Quantities extracted using some BIM software such as Autodesk Quantity Take-off need to be manually checked to ensure all items of works are completely captured (Eastman et al., 2011)

The Nigerian Building and Engineering Standard Method of Measurement (BESMM 4)

The first edition of the Nigerian Standard method was produced by the Nigerian Institute of Quantity Surveyors in 1988, and the document was titled Standard Method of Measurement of Building Works and Services (SMMBWS)(Nigerian Institute of Quantity Surveyors, 2015). In 2002, improvement were made to upgrade the SMMBWS to second edition which encompasses rules for the measurement in line with technological development of both building and engineering works. However, method of measurement of engineering was incorporated into the second edition and was titled Building and EngineeringStandard Method of Measurement 2 (BESMM2). Since then, the BESMM has gone through revisions and modification twice to produce the BESMM 3 and BESMM 4. Today, the current document that specifies the local standards for the measurement of building and engineering works in Nigeria is the BESMM 4.

The BESMM 4 is a holistic review of the BESMM3 along the principles of the New Rules of Measurement 2 (NRM2), Civil and Engineering Standard Method of Measurement 4 (CESMM4) and Industrial Standard Method of Measurement (ISMM) with adjustments intended to suit the main contracting culture in the Nigerian Construction Industry.

Unlike the BESMM3, the BESMM4 classification and coding system is different, in that the manner of classification of components/items is not as complex as in the former. Components/items of similar work characteristics are grouped under one section(Nigerian Institute of Quantity Surveyors, 2015). The section is no longer tagged with alphabets as in BESMM3, but with numerals. At the beginning of every work section, some major components/items are mentioned just to indicate the type/nature of work measured under such section.

Measurement rules in the BESMM4 are set out in tables with a view to enhancing comprehensive description without difficulties. Each section of the rules comprises of Information (to be) provided, classification tables and supplementary rules. Information (to be) provided ensures that details about the work at hand which the tenderer requires for preparing accurate estimates are provided either in drawings, specifications or any other form that will allow the extraction of the necessary information. The classification tables have five columns similar to that in the BESMM3. The second column from the left which contains units of measurement is usually not referred to when cross-referencing. For this reason, the classification table is in some texts said to have four columns. Unlike in the BESMM3.

The classifications tables are classified in the BESMM4 as: Item listing column, list building components/items commonly encountered in building works. Example of such items include disposal, painting, excavations. The unit column, specifies the unit of measurement appropriate for each item or work to be measured. Column 3 (level 1) lists the information, including any dimension , that shall be included in the description of the building components/items. Column 4 (level 2) lists the supporting information, including any additional dimension , which shall be

included in the description of the building components/item. Column 5 (level 3)lists the further supporting information,including any additional dimension , which shall be included in the description of the building components/item. Column 6 (notes, comments and glossary) gives explanations on what work is deemed to be included in specific building components/items, clarifies the approach to quantification and description of building components/items, and contains definitions of specific terms and phrases used in connection with the building components/items.

Table 1 shows classification for Support to face(s) of excavation where not at the discretion of the contractor. The building components/items listed in the BESMM4 tables comprises those commonly encountered in building, civil engineering and industrial works; the lists are designed not to be too exhaustive.In addition to the classification tables for works there is also supplementary rules which aremeant to guide the user of the BESSM4 to properly measure the physical quantities and to compose and phrase the work item descriptions appropriately.The section on supplementary rules is made up of a further four columns namely: Measurement rules, definition rules, coverage rules and supplementary information. Column 5 - Measurement Rules these set out when work is to be measured and how the quantities are to be calculated. It states for instance the voids in quantities that are to be deducted and those to be ignored, when to measure an item separately or when to treat as part of some other item, etc. Column 6 - Definition rules define the extent and limits of the work represented by a word or expression used in the rules and in the bills prepared in accordance with the rules. Column 7 – Coverage Rules draw attentions to incidental work which shall be deemed to be included in the appropriate items in a bill of quantities to the extent that such work is included in the tender documents. Where the coverage includes materials, they shall be measured in the item description.Column 8 – Supplementary rules contain rules governing the information which shall be given in addition to the information guiding the composition of bill of quantities.

Table 1: Classification for Support to face(s) of excavation where not at the discretion of the contractor

Item or work to be measured	Unit	First division	Second division	Third division
Support to face(s) of excavation where not at the discretion of the contractor	m^2	Max. depth stated	Location Stated	Method of forming support where not left to the discretion of the contractor

Information Requirements for Cost Estimating

Studies have identified various information needs that support quantity take-off and cost estimating of building works. Some of the information required to leverage BIM models for cost estimating and QTO are as follows (Eastman et al., 2011; Ma et al., 2010; Ma et al., 2011; Madugu et al., 2016; Pittard & Sell, 2016):

Building Product information: This refers to the various components of the design based on which the different elements to be considered in the estimate are derived. It varies from one project to the other. In a BIM-based estimating system,

quantities of work items are usually extracted from objects which are the major components of the building products. These products contain virtually all the semantic and geometric information required for developing cost estimates.

Work items information: This represents individual work items that constitute each building element (Product). The general structure of estimates in the form of work break down structure (WBS) are derived from the various work sections where these work items are defined in the standard methods of measurements they use. The provision of local standard method of measurement in most cases are captured by this category of information.

Quantity information: This information is obtained from the geometric properties extracted from the building products. Using the geometric properties of the BIM components from the product information, computations are done based on geometry calculation rules to obtain the quantities used in preparing estimates. The quantity information provides the item units, geometry and brief descriptions.

Resource information: This constitutes the materials, labour and plants consumption required for the execution of construction projects. It is obtained from the quantity information and specifications embedded in the building products.

Price information: This provides prices to the various resources identified in the market. Unit rates used in developing bill of quantities solely rely on current market prices as prices fluctuate sporadically in most developing economies.

Cost information: This corresponds to the costs of all the building elements estimated, including the cost of the temporary components, and provisions that eventually make up the total cost of the project.

RESEARCH METHODS

A qualitative research approach using structured in-depth interview technique was chosen as the preferred method of this research. In-depth interview is a qualitative research technique that involves conducting intensive face-to-face interviews with a small number of respondents to explore their perspectives on a particular idea, program, or situation(Boyce & Neale, 2016). Qualitative method was employed basically on the premise that similar studies (Ma et al., 2011; Madugu et al., 2016) adopted same approach and also consideringthe natureof the research problem that seeks to investigate how cost estimating is practiced in the Nigerian construction industry (NCI).

The study commenced with an extensive literature review basically to provide an overview of the concept of BIM and construction cost estimating practices in the NCI. The review also identified information requirements that support BIM-based cost estimating generally. The outcome of the review guided the development of an interview guide used for data collection. The main purpose of the interviews was to identify the prevalent cost estimating methods practiced with their associated information needs; the challenges faced by Quantity surveyors using BIM for cost estimating; and lastly to validate the established information requirements identified in literature.

The interview was comprised of three (3) broad components. The first component basically appraised the prevalent cost estimating practices adopted by Quantity surveyors in Nigeria, while the second component was undertaken to validate the information requirements necessary for the estimating practice identified. A total number of nine (9) interview request letters were distributed to Quantity Surveyors (interviewees) purposively selected from different Quantity Surveying firms in Nigeria. The selection was based on a pre-defined criteria that the prospective interviewee must have practiced Quantity Surveying for over ten years, used any QS based software before and is aware and relatively familiar with the concept of BIM. Data collected was analysed using constant comparison content analysis technique. However, the interview involved only five experienced Consultant Quantity Surveyors who were eventually available to participate in the study. Only registered QS who have BIM knowledge or considerable amount of experience in some of the BIM-based estimating tools were chosen for the survey. Consultant QS working with QS firms were considered as the preferred respondents because they more often prepare cost estimates than their contractor QS counterpart. Also, Olatunji and Sher (2014) observed that cost estimating practices between estimators who work in client organizations, contracting organizations, consulting practices and those who work in specialist project organizations differ subtly in terms of procedure, not on the requisite information needed for the estimating.

RESULTS AND DISCUSSIONS

The interviews were conducted by the researcher and the length of time taken on each respondent varied from one hour to two and half hours. The interview themes are as follows:

1. Background information of the interviewees and their firms
2. Cost estimating practices of the surveyed firms;
   a. *Cost estimating methods/approaches adopted by the Firms;*
   b. *Challenges encountered with the use of estimating software; especially the BIM tools*
   c. *Standard Method of Measurement adopted by the firms*
   d. *Quantity Surveyors perception of the current measurement standards (BESMM).*
3. The information requirements for the cost estimating methods adopted by the firms

Characteristics of the surveyed Respondents and their firms

As shown in Table 2, a total number of five (5) respondents representing 55.55% response rate were interviewed. All the interviewees are registered QSs with at least a Bachelor of Science/Technology degree in Quantity Surveying and have worked on virtually all types of construction projects. Their years of experience in Quantity Surveying practice ranged between 8 to 18 years, and are in the middle and top management levels in their respective organizations. Similarly, the firms have adequate experience in construction business and undertake both building and civil engineering works for both public and private sector institutions in Nigeria (Table 3).

Table 2: Background information of the respondents

Firm	Academic Qualification	Professional qualification	Position	Years of experience
PJR 1	BSc. Qs, MSc. Project Management	MNIQS	Director	8 years
PJR 2	BSc. Qs, MSc. Project Management	MNIQS	Senior Quantity Surveyor	10 years
PJR 3	B.Tech. Qs	MNIQS	Quantity Surveyor	5 years
PJR 4	BSc. Qs, MSc. Project Management	FNIQS	Partner	18 years
PJR 5	BSc. Qs	MNIQS	Senior Quantity Surveyor	8 years

* PJR refers to Interviewee

Table 3: Background information of surveyed firms

Firm	Nature of Works	Years of Experience	Major Client
PJR 1	Building and Civil Engineering	15	Both Public and Private
PJR 2	Building and Civil Engineering	12	Both Public and Private
PJR 3	Building and Civil Engineering	10	Both Public and Private
PJR 4	Building and Civil Engineering	25	Both Public and Private
PJR 5	Building and Civil Engineering	23	Both Public and Private

* PJR refers to Interviewee

Cost estimating practices

Cost estimating methods/approaches adopted by the Surveyed Firms

All the respondents agreed that the manual based estimating methods are still the predominant approaches they use in preparing cost estimates. Estimating in these firms is largely paper-based, and where CAD designs and models are available, they are only used to extract dimensions, in some cases quantities. According to the interviewees, their firms' choice of a particular type of estimating method for a project always depends on various factors such as; the level of information available, project type, the time available to prepare estimate and sometimes the type of estimate required, and the type of client/employer. Availability of information and period of time to prepare the estimate were identified as the most important factors that determine the most suitable estimating method applied in most cases. However, the 'elemental approach' to analytical estimating was found to be the most predominant method used by Quantity Surveyors, especially on public client projects. Elemental estimating method as defined by the interviewee involves the breaking down of projects into elements, by categorizing associated work items together.

Furthermore, the interview confirmed that the firms surveyed have not fully incorporated BIM into their service delivery processes. Although all the firms use one software tool or the other, only three (3) of them use BIM tool in some aspects of their estimating process. The respondents acknowledged the use of estimating software applications such as spreadsheets, AQTO (Autodesk Quantity Take-off), CATO (Computer Aided Take-Off), CAD measure, and Vector-X. Some of these software are BIM-based applications.

Also, regarding the procedure followed in preparing Bills of Quantities (BoQ), results from the interview describes the procedure as getting the design (2D CAD or BIM) in electronic or hard form; reading and understanding the design to ensure that all necessary information and specifications are provided; taking off quantities; squaring; building-up unit

rates using current market prices; and the final BoQ preparation as the case may be.

Challenges encountered with the use of estimating software

The interviewees were asked about the challenges and difficulties they encounter when using both the BIM-based and non-BIM-based software in their estimating process. The interviewees' all reported that the estimating packages they adopt had improved the accuracy of their estimates. However, for those using BIM-based applications, their major challenge was lack of alignment of the BIM models with the standard method of measurement they adopt and the immaturity of the models, mostly of Level of Development (LOD 200). Another major concern was that most of the tools available do not have information and object libraries that suit local users' requirements. The existing libraries have to go through some rigorous process of adjustment before the desired results are obtained. More so, interoperability challenge was also highlighted as a major hindrance to the successful adoption of the tools. This is because some of the BIM-based tools do not interoperate seamlessly with the BIM authoring tools used in creating the 3D BIM. This necessitates the need for an improved data model that eases data exchange among the diverse stakeholders in the construction industry.

Standard Method of Measurement adopted by Quantity Surveying Consultancies Surveyed

Majority of the firms adopt the RICS Standard Method of Measurement 7 (SMM7) and rarely make reference to Building and Engineering and Standard Method of Measurement (BESMM). Their major argument was that the BESMM are direct replications of the UK standards of measurements (mostly the SMM7, and the NRM; new rules of measurement) and therefore using the RICS SMM 7 still amounts to the use of the BESMM. The respondents claimed that a lot of omissions were made in the process of preparing the BESMM just to make it look different from the foreign SMMs. Some of the respondents opined that some additions in the document (BESMM4) are not worthy and necessary. The respondents believed that unless major clients in the industry such as Government establishments demand and legislate the use of these documents the rate of adoption of these new standards will continue to be slow and insignificant.

Identification of Cost Estimating Information Requirements

The major purpose of this study is to appraise the estimating approaches used by Quantity Surveying firms' visa-vis identifying the information requirements of the most widely adopted method. The interviewees were requested to validate the information requirements for all the stages they undergo in preparing cost estimates. During the interview session, a list of information requirements for BIM-based cost estimating identified by researchers (Ma et al., 2011; Madugu et al., 2016; Ombugadu, 2016) was put forward to the respondents for critical evaluation and validation. A total number of six (6) information requirements were confirmed by the interviewees as thenecessary information they always require to prepare cost estimates. The information according to the interviewee are as follows:

1. **Building Product information:** All the interviewees confirmed product information as a major information requirements they rely on in

preparing cost estimates. This corroborates Ma et al. (2011) findings that product information is a major information requirements for BIM-based cost estimating using the Chinese standard. Similarly, Ombugadu (2016) in his effort to assess IFC's capabilities to support Quantity take-off using BESMM4, identified twenty eight (28) building products in the Nigerian BESMM and observed that the current IFC4 Add 1 Data Schema still doesn't cover all the items of work as required by the BESMM 4 for the purpose of quantity take-off of building works in Nigeria. The study reported that only 24 IFC entities correspond with the identified building products. This clearly confirms building product as a major information requirements for cost estimating.

2. **Work items information:** The interviewees opined that the work items of each element are generated from designs/models and the various sections of the BESMM. However, building products in BIM are structured and arranged based on standard classifications such as MasterFormat, Omniclass and Uniclass which do not directly align with the BESMM standard used by QSs in Nigeria (Amuda-Yusuf & Mohamed, 2015). This further explains why the direct adoption of existing BIM-based estimating software for estimating purposes by Nigerian QSs cannot be fully achieved.

3. **Quantity information:** The interviewees all mentioned quantity information as a fundamental requirements for preparing cost estimates. Geometric information which form the basis of all quantities are extracted from BIM models. However, the conventional BIM-based estimating applications do not fully generate quantities in all the formats and rules defined by the BESMM; the local standard for cost estimating of building works used by Quantity surveyors in Nigeria. Ma et al. (2011) made similar observation in their attempt to extend the IFC schema to capture local estimating requirements in the Chinese construction industry.

4. **Resource information:** Resource information was also identified as a requirement for cost estimating by the respondents. The computation of resources is done using productivity rates which are obtained from price books and other cost databases such as the BCIS. Although industry wide standard cost databases are not available in Nigeria Construction Industry, price books such as the CONSOLS and the cost books by Newpro Quants Consultants that document price information and productivity rates relevant to the industry need to be explicitly captured by BIM models to ensure effective adoption and utilization of BIM-based cost estimating by Quantity surveying firms. Most BIM-based cost estimating software are linked to external cost databases such as the RS-means, and BCIS databases (Eastman et al., 2011).

5. **Price information:** The respondents identified prices of material, labour, plants, and subcontractors among the key information they always need to

prepare estimates. These prices could be obtained directly from the market or through online cost databases and construction price books. Ma et al. (2011), Madugu et al. (2016) and (Eastman et al. (2011)) identified price information as a major requirements for all BIM-based cost estimating applications.

6. **Cost information:** Cost information depicted as cost centres in the BoQ are collected as summaries, which give the estimated total cost of projects.

CONCLUSION

This paper has appraised cost estimating practices in the Nigerian Construction industry and in the process the information requirements for cost estimating using BIM was identified. The study identified six (6) categories of information required to support BIM-based cost estimating of which current BIM-based tools do not fully support. The elemental cost estimating approach which is currently the widely adopted estimating format can only be supported by the existing BIM applications if the six information entities: Product information, Works item information, Quantity information, Resource information, Price information, and Cost information are fully integrated into the BIM tools. The study concludes that unless these local information are comprehensively captured, the full benefits and potentials of BIM-based cost estimating will not be achieved. Furthermore, to support the application of BIM estimating tools, it is recommended software vendors should develop applications that incorporate all the information entities that support local estimating standards.

REFERENCES

Aiyeleso, A. K., Ibrahim, Y. M., Abdulrazaq, M., & Kolo, B. A. (2014). Development of an Automated Program for Extracting Materials' Quantities from Building Information Models. *Journal of Environmental Studies (ENVIRON). Faculty of Environmental Design, A.B.U., Zaria, Nigeria, 3*(7 and 8), 63-75.

Amuda-Yusuf, G., & Mohamed, S. F. (2015). Essential features of a building services standard method of measurement in Malaysia. *Engineering, Construction and Architectural Management, 22* (6), 749-770.

Boyce, C., & Neale, P. (Producer). (2016, May 3). Pathfinder International. *Conducting In-Depth Interviews: A Guide for Designing and Conducting In-Depth Interviews for Evaluation Input*. Retrieved from http://www.pathfind.org/site/DocServer/m_e_tool_series_indepth_interview

Eastman, C., Teicholz, P., & Sacks, R. (2011). *BIM Handbook; A Guide to Building Information Modeling to Owners, Designers, Engineers and Contractors* (2nd ed.). Canada: Wiley & Sons Inc.

Faraj, I., Alshawi, M., & Aouad, G. (2002). An industry foundation classes Web-based collaborative construction computer environment : WISPER *Automation in Construction, 10* (1), 79-99.

Fu, C., Aouad, G., Lee, A., Mashall-Ponting, A., & Wu, S. (2006). IFC model viewer to support nD model application. *Automation in Construction, 15*, 178-185.

Ma, Z., Zhang, X., Wu, S., Wei, Z., & Lou, Z. (2010). *Framework Design*

for BIM-based Construction Cost Estimating Software. Paper presented at the CIB W78 , International Conference 16-18 November, Cairo, Egypt.

Ma, Z., Zhenhua, W., Wu, S., & Zhe, L. (2011). Application and Extension of the IFC Standard in Construction Cost EStimating for Tendering in China. *Automation in Construction, 20*, 196-204.

Madugu, A. A., Abdullahi, M., & Musa, U. (2016). *Developing Information Requirements Model for BIM-Based Quatity Take-off Using Building and Engineering Standard Method of Measurement 3(BESMM 3)*. Paper presented at the International Conference of Nigeriaan Building and Road Research Institute, Abuja, Nigeria.

McGraw-Hill Construction. (2014). The business value of BIM for construction in major global markets: How contractors around the world are driving innovation with building information modelling. New York.

Nigerian Institute of Quantity Surveyors. (2015). Building and Engineering Standard Method of Measurement (BESMM 4) Fourth Edition. Abuja, Nigeria: Emirati Innovative Services.

Olatunji, O. A., & Sher, W. (2014). Perspectives on modelling BIM-enabled estimating practices. *Australasian Journal of Construction Economics and Building, 14*(4), 32-53.

Ombugadu, J. T. (2016). *Assessing Industry Foundation Classes (IFC) Capabilities for Supporting Quantity Take-off of Building Works Using BESMM4*. (Undergraduate), Ahmadu Bello University, Zaria.

Pittard, S., & Sell, P. (2016). *BIM and Quantity Surveying*. New York: Routledge.

RICS. (2014). International BIM Implementation Guide (First ed.). Parliament Square, London.

Sabol, L. (2008). Challenges in Cost Estimating with Building Information Modelling. Retrieved 18th October, 2016, 2016, from http://www.dcstrategies.net/files/2_sabol_cost_estimating.pdf

Staub-French, S., Fischer, M., & Kunz, J. (2003). A Generic Feature-driven Activity-based Cost Estimation Process. *Advanced Engineering Informatics, 17*(1), 23-39.

Tanyer, A. M., & Aouad, G. (2005). Moving Beyond the fourth dimension with an IFC-based single project database. *Automation in Construction, 14*(1), 15-32.

Wan, C., Chen, P.-H., & Tiong, R. L. K. (2004). Assessment of IFCs for Structural Analysis Doamian. *Journal of Information Technology in Construction, 4*, 75-95.

Yabuki, N., & Shitani, T. (2005). *A management system for cut and fill earthworks based on 4D CAD and EVMS, Computing in Civil Engineering,*. Paper presented at the ASCE International Conference on Computing in Civil Engineering.