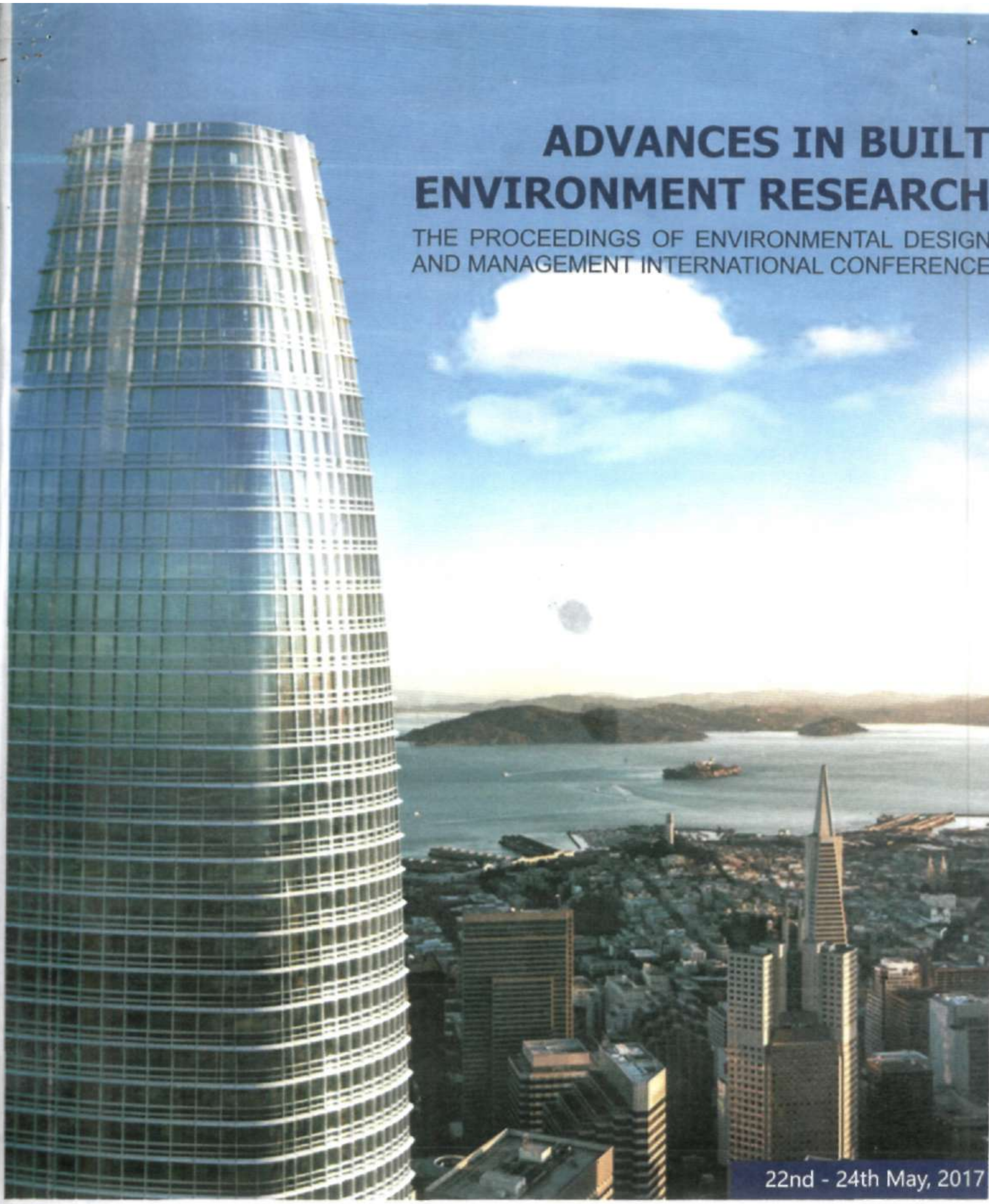
ADVANCES IN BUILT ENVIRONMENT RESEARCH

THE PROCEEDINGS OF ENVIRONMENTAL DESIGN AND MANAGEMENT INTERNATIONAL CONFERENCE



22nd - 24th May, 2017

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EDMIC2017

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FOREWORD

It is with great delight and immeasurable pleasure that I warmly welcome you all, distinguished participants, to this historic edition of the Environmental Design and Management International Conference (EDMIC 2017), organized by the Faculty of Environmental Design and Management, Obafemi Awolowo University, Ile-Ife, Nigeria. EDMIC is a biennial conference, and EDMIC 2017 is the sixth in the series. Without being immodest, I want to state with confidence that the Faculty, though comparatively young in the University, has always maintained the lead in teaching, research, and scholarship in the University. Lending credence to this is the fact that EDMIC has been growing in every ramification ever since its maiden edition held in the year 2002. All the past editions of EDMIC have contributed immensely to and enhanced the teaching and practice of the professions in the built environment faculties in and even beyond the shores of Nigeria. EDMIC 2017 no doubt constitutes another feather on the cap of the Faculty as it has again brought together experts, scholars, researchers, academics and professionals in the built environment from several continents of the world.

One endearing attribute of EDMIC is that it particularly encourages the interaction of graduate students, nascent researcher, and budding academics with the more established academics in a quasi-formal setting to present and discuss current topics with a view to keeping them abreast of the requisite state-of-the-art knowledge and ideas in the contemporary built environment academic disciplines. These contributions help in making EDMIC outstanding and keeping it in vogue as papers presented contribute the most recent scientific knowledge and up-to-the-minute global best practices in the fields of Architecture, Building, Estate Management, Fine and Applied Arts, Surveying and Geoinformatics, Quantity Surveying, and Urban and Regional Planning.

EDMIC 2017 is truly international on several grounds. In addition to the contributed papers, there are two keynote presentations by Prof. Moyo Okediji, a Professor of Art and Art History from Texas University, USA and by Prof. Lukuman Oyedele, a Professor of Technological Enterprise and Project Management from the University of West of England, Bristol, England. Both speakers are alumni of this great university and erudite scholars of unquestionable international repute. Definitely, they will enrich our knowledge as we draw from their wealth of experience. It is noteworthy that Prof. Oyedele came with three additional research fellows who will be facilitating hands-on Building Information Modelling (BIM) seminars and workshops. Expectedly, the seminars and workshops will engender desirable capacity building as well as enhancing the professional competence of a good number of participants.

Specifically, EDMIC 2017 has grown from a collection of 65 peer reviewed papers in 2015 to a collection of 93 peer reviewed research papers authored by seasoned scholars and researchers based in the UK, US, South Africa, Hong Kong and Nigeria. As such, the proceedings will no doubt furnish the scholars and practitioners in the built environment domain with an excellent reference book. I trust also that this will be an impetus to stimulate further academic study and research in all the disciplines in the built environment.

Once again, all the pleasures are mine to welcome you to EDMIC 2017. It is my sincere hope that you will enjoy your stay on the estate of Obafemi Awolowo University, Africa's most beautiful campus. I also wish you journey mercies on your way back to your respective destinations.

Thanks and God bless!

Prof. Bioye Tajudeen ALUKO
Dean, Faculty of Environmental Design and Management
Obafemi Awolowo University, Ile-Ife, Nigeria

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CONTENTS

Theme 2: ADVANCES IN ARCHITECTURE AND HOUSING RESEARCH (170-200)

IDENTIFYING BUILDING PRODUCTS THAT SUPPORT BIM-BASED QUANTITY TAKE-OFF USING THE NIGERIAN BESMM 4

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ABSTRACT

The Industry Foundation Classes (IFC) data schema developed by the BuildingSMART International has been the major and most widely used solution to interoperability challenges in Architecture Engineering and Construction (AEC) industry. Despite its wide acceptance by software vendors and the industry in general, studies have reported the schema to be inadequate as it does not fully cater for local requirements/standards which vary from one country to the other and, therefore, researchers have developed schema extensions to capture local requirements of different countries across various domains. In Nigeria, the Building and Engineering Standard Method of Measurement (BESMM 4) is currently the standard of measurement of construction works and, to date, an assessment of how well the IFCs data schema supports the measurement of construction works using the BESMM 4 is not known. Therefore, this paper as part of a study proposing schema extensions for cash flow management identifies building products that support BlM-bascd quantity take-off with their corresponding IFC entities, classes and attributes based on the current IFC Data Schema (IFC4 Add 1). Qualitative research approach based on desktop studies and document analysis was employed in identifying building products as contained in the BESMM 4, and then the corresponding IFC specifications that describe these building products were similarly identified in the most recent of IFC Data Schema (IFC4 Add 1). The study concludes that current BIM platforms and software application cannot adequately support quantity take-off of building works using BESMM **4.**

Key Words: IFC, BESMM, Building Information Modeling (BIM), Quantity Take-off, BuildingSMART

INTRODUCTION

Interoperability challenges have been reported to be among the major barriers to the successful implementation of Building Information Modeling in the AEC Industry (BSI, 2016; Eastman, Teicholz, & Sacks, 2011; McGraw-Hill Construction, 2014; RICS, 2014). To address this challenge, various solutions have been advanced by researchers, ranging from proprietary based solutions, model based approaches to semantic web-based methods. Although, Industry Foundation Classes (IFC) schema has been reported to be the major and most commonly applied solution to address interoperability challenges among heterogeneous software applications in the construction industry, studies have reported them to be inadequate as they do not fully cater for local requirements/standards which vary from one country to the other (Ma *et al.*, 2011). Therefore, studies have proposed various schema extensions to capture local requirements of various countries across diverse construction domains (Ma, Zhenhua, Wu, & Zhe, 2011; Madugu, Abdullahi, & Musa, 2016). For example, Ma *et al.* (2011) developed an information requirement model for construction cost estimating and tendering in China that comprised of seven aspects of information entities with each information entity expressed in IFC standard to verify the completeness of the IFC standard and to establish the IFC-based information model. Similarly, Madugu *et al.* (2016) analysed and established the information requirement that support BIM-based quantity take-off using the Nigerian Building and Engineering Standard Method of Measurement (BESMM 3). However, in Nigeria, the Building and Engineering Standard Method of Measurement 4 (BESMM 4) is currently the standard for measurement of construction works and, to date, an assessment of how well IFCs data schema supports the QTO of construction works using the BESMM 4 is not known. Therefore, this paper, as a part of a schema extension study underway, identifies building products that support BIM-based quantity Take-off with their corresponding schema representations (entities, properties and attributes) in the current IFC Data Schema (IFC4 Add 1). This is done with the sole view of developing schema extensions that support cash flow management based on the local standards of cost estimating in Nigeria.

LITERATURE REVIEW

Interoperability challenges

Despite the tremendous benefits associated with the adoption of BIM in the AEC industry, the industry faces low rate of adoption with high rate of implementation only visible in the US and the Scadinavian regions where BIM originated (McGrawhill, 2014). One of the major barriers to successful BIM implementation as reported by McGrawhill (2014) is 'Interoperability Challenges', resulting from the use of different software applications that do not interoperate among each other. Eastman *et al* (2011) described interoperability as the ability to pass data between applications, and for multiple applications to jointly contribute to the work at hand. In addition, interoperability eliminates the need to manually copy data already generated in another application which is highly attributed to errors, inconsistencies, information loss and distortion. In this paper, interoperability is considered as the capacity of various heterogeneous software applications to communicate and exchange electronic information seamlessly with no information loss or distortion. Researchers view interoperability from two perspectives: data interoperability and frameworks interoperability. Data interoperability is the ability of data generated by a software system to be exchanged and properly interpreted by all other similar or related applications (Shen *et al.*, 2010). Data interoperability is supported by data modeling technologies which are either proprietary based developed by software vendors, or neutral based developed as an open source for all. On the other hand, frameworks interoperability focuses on the communication protocols and languages that guide and support various software applications.

To overcome data interoperability challenges, proprietary solutions, neutral file formats and semantic web based solutions have been used. However, the open neutral file formats have so far been the most widely applied solution recording over 50 software vendors'implementations recently (BuildingSmart International, 2016). Several efforts were made to develop neutral standards that support heterogeneous applications in the Architectural Engineering Construction (AEC) Industry. Notable and earliest neutral file format solutions developed to overcome interoperability issues include the Initial Graphic Exchange Specification (IGES) and PDDI, the VDA-FS developed, and Standard for the Exchange of Product Model Data's (STEP) Building Elements Using Explicit Shape Representation (Part 225 of STEP), and the Plant Spatial Configuration (Part 227 of STEP). Similarly, in the construction industry, various standard data models in addition to STEP have been developed. These include early models such as; General AEC Reference Model (GARM) (Gielingh, 1988), the RATAS building data model (Bjork, 1989), and the CIMSteel model (Watson & Crowley, 1994);these have been developed for structural works. However, the most significant international data modeling standardization effort in the construction industry is the BuildingSMART International (BSI) and Industry Foundation Classes (IFCs). BSI is a subdivision of ISO and has made tremendous progress since its inception in the year 1999 with several chapters and more than 600 member organizations around the globe (BSI, 2016).

Industry Foundation Classes (IFC)

The Industry Foundation Classes (IFC) is a neutral open data standard developed by the BuildingSMART International. The sole goal of the IFCs is to develop and maintain an open data model standard that serves the BIM interoperability needs of the construction industry (BSI, 2016). Industry Foundation Classes (IFC) has been endorsed as an ISO (International Standards Organization) standard with the current version of the IFC known as IFC4 and it carries full international standard as ISO 16739. IFC standard owns a hierarchical and modular framework, which is divided into four bottom-up layers, that is, resource layer, core layer, interoperability layer and domain layer; each layer consists of a number of modules which further contain various entities, types, enumerations, rules and functions. Among them, the entity represents the abstraction of objects which have the same properties, and it is the information agent to describe the information of building and surrounding components when the IFC standard is used. Over the last two decades, the IFC schema has undergone series of transformation in the form of improvement in terms of scope and complexity with eight major releases made (Ma *et al*, 2011).

The major improvements made in the IFC 4 Add 1 focuses on enhancing the capability of the specification in its main architectural, building service and structural elements with new geometric, parametric and other features. In addition, the IFC4 enables numerous new BIM workflows including 4D and 5D model exchanges, manufacturer, product libraries, BIM to GIS interoperability, enhanced thermal simulations and sustainability assessments, links all IFC property definitions to the BuildingSMART data dictionary, improves readability and ease of access to the documentation with numerous implementation concepts. It also contains an XML version called the ifcXML4 schema. The ifcXML is fully integrated into the IFC specification in addition to the EXPRESS schema. Similarly, new mvdXML technology that allows easy definition of data validation services for IFC4 data submissions has been integrated.

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

Standard method of measurement (SMM) of construction works is a formal document that sets out the conventions for defining the nature of construction works, how the work is measured or taken – off and quantified. It defines a uniform basis for the measurement of construction works through the preparation of Bills of Quantities (BOQ). The BOQs provide succinct and accurate description of works and the amount of money required to execute works to a required level of quality standard (RICS, 2014). The use of SMM in the procurement of building projects is common in common-wealth nations where most countries adopt the British SMM. About 20% of the common wealth countries adopt the RICS SMMs, while about 80% use local SMMs for measuring construction work. Nigeria as one of the common wealth countries have over the years produced its own locally based SMM which although is principled in the RICS SMMs but still captures some local content and practices of its construction industry. The Nigerian Institute of Quantity surveying (NIQS) being the professional body that regulates the practice of Quantity Surveying alongside the Quantity Surveyors Registration Board of Nigeria (QSRBN) in Nigeria has successfully produced four versions of the SMM called the BESMM.

The latest standard measurement for construction works in Nigeria is the Building and Engineering Standard Method of Measurement (BESMM4). BESMM 4 was published in 2015 by the Nigerian Institute of Quantity Surveyors. It is a review of BESMM3 that combines the method of measuring building, civil and industrial engineering installations with similar rules of measurement as in the Australian Standard Method of Measurement (ASMM5).

The BESMM 4 was developed in principle with the RICS New Rules of Measurement 2 (NRM 2), Civil Engineering Standard Method of Measurement(CESMM 4) and the Industrial Standard Method of Measurement(ISMM) with some slight adjustment intended to suite the main contracting culture in the Nigeria construction industry (BESMM 4, 2015). The document is divided into Work Sections and measurement rules which are presented in a tabulated format and are classified under the following headings:

i. Item of work to be measured
ii. Unit of measurement
iii. Classification table
iv. Measurement rules
v. Definition rules
vi. Coverage rules
vii. Supplementary information

It, however, significantly differs from the BESMM 3 in some areas such as the Highways in BESMM 3 being replaced with roads and Pavings, and some areas that were left out in Part 2 of the BESMM 3 such as Piling, Piling Accessories, Masonry, Painting, Sewers, Water Main Renovation, etc have been included in the Section 2 of the BESMM 4. Another area of difference is the rearrangement in the sequence of the Classification Table with the column for brief description of work coming first, followed by the column for unit of measurement, then columns for division 1, division 2 and division 3 respectively. Hence the measurement of building, civil and industrial works shall be done with easc002E

RESEARCH METHOD

The research adopted qualitative approach on the ground that similar schema extension studies used the same approach (Amor, 2015; Chen, Wan, Tiong, Ting, & Yang, 2004; Ma *et al.*, 2011; Ombugadu, 2016). Qualitative data in the form of work items that define building products or elements were collected through document analysis, specifically the BESMM 4. The BESMM 4 was chosen because it is the Nigerian Standard of Measurement of Construction Works currently approved by the Nigerian Institute of Quantity Surveyors (NIQS). The data obtained were analysed by matching the extracted building products from the BESMM 4 with their corresponding IFC entity and checking if the existing IFC Entities adequately define the building products. The results obtained from the document analysis were subsequently validated through a validation workshop whose participants are knowledgeable on and conversant with BIM, specifically the IFC, and the BESMM 4.

Building products in the context of this research refer to the assembly of work items that define a particular functional unit of a facility. For example, the object 'foundation' as a building product depending on the type comprises of the concrete, formwork and reinforcement and all associated work items. In view of that, the various work sections of the 'Building works' component of the BESMM4 were critically examined to identify building products which correspond to objects in the form of entities in the IFC schema. For each building product, associated work items with their respective quantity information and measurement rules were identified. The building products and their respective work items were extracted from the forty (40) work sections of the 'Building Works' part of the BESMM 4. However, temporary products mostly in the form of preliminary items of work (scaffolds, temporary structures, etc.) were not considered within the scope of this work as Ma *et al.* (2011) have already established the IFC's deficiency in their coverage. The IFC standard does not directly support the expression of the construction temporary products.

RESULTS AND DISCUSSION

Identification of Building Products in the BESMM 4

Table 1 shows building products with their associated work items as identified in the BESMM 4. A total of twenty-eight (28) building products were identified to be associated with items of work for the measurement of building works in Nigeria using BESMM 4. The building products were arrived at by critically examining the individual Work Sections under the Building Works Part of the BESMM 4. The work items were extracted basically from the first column of the classification table of the BESMM 4, while the units of measurements in the Quantity Unit Column for each item of work took cognisance of the requirements under the classification table (in terms of works to be measured, Division 1, Division 2 and Division 3) as contained in the BESMM 4. The building products, however, were derived from the Supplementary Table and in some instances from the classification table of the BESMM 4. For every building product, all associated work items that make up the product are identified and documented. For example, as shown in Table 1, 'Roof' as a building product is a functional unit of a building made up of assembly of items: covering, ridges, hips, valleys, eave flashings - aluminium, tile, slate, grass; carcassing - steel, timber.

Table 1: Building Products contained in the BESMM 4

S/No	Name	Components (Type, Material, Geometry)
1	Earthwork	Excavation, site clearance, site preparation, trees removal, surface treatment and the likes
2	Foundation	Blinding, bases, strip, grillages; concrete, steel
3	Pile	Interlocking piles, sheet piles, bored piles, driven piles; concrete, metal
4	Wall	Gabion walls, crib walls, retaining walls, parapet, curtain walls, partitions; stone, concrete, blocks, bricks, boards
5	Beam	Ground beams, attached beams; concrete, steel
6	Column	Attached columns, isolated columns, concrete, steel
7	Slab	Beds, coffered slabs, troughed slabs, landings; insitu concrete, precast concrete
8	Ramp	Flight, landing, balustrade; insitu concrete, steel
9	Staircase	Flight, landing, balustrade; insitu concrete, pre-cast concrete, steel
10	Roof	Covering, ridges, hips, valleys, eave flashings - aluminium, tile, slate, grass; carcassing - steel, timber
11	Door	Door shutters, sliding doors, folding doors, partition grilles, collapsible doors, strong room doors, door frame/lining, ironmongery, door set; timber, metal, glass
12	Window	Shutters, louvres, canopies; glass, timber, plastic, metal
13	Chimney	Stone, insitu concrete, blocks, bricks
14	Water proof	Damp proof course, bituminuous felt,
15	Fasteners and fittings	Ties, rods, bolts, straps, brackets, grids and the like
16	Finishes	Wall/columns/beams - cladding, painting, tiles, decorative paper /fabrics; floor/skirting - screeds, tiles; ceiling - suspended ceiling, boarding/linings, decorative paper /fabrics; etc
17	Furniture, fitting and fixture	Kitchen cabinet, catering equipment, work tops, shelves, seats, tables, picture rails
18	Pipes	Sanitary pipes, drain (waste pipes), conduits; ancillaries - valves, non return valves, non return flaps, tapers, hoppers, bends, tundishes, rodding eyes, pipe sleeves, traps, gullies, bosses, tappings, reducers, test points and the like
19	Cable	Cables, cable terminations/joints - pots, seals, glands, lugs, connector blocks, shrouds
20	Fire insulator/protector	Fire spread/stops (hose reel, fire extinguisher) and the like
21	Primary equipment	Electrical - main switch board, main control box, and the like; mechanical - boiler, mains to storage tank, air handling unit, fan and the like
22	Terminal equipment and fittings	Electrical - Luminaires, switches, actuators and the like; mechanical - heat emitters, grilles, fan coil units and the like
23	Drainage chamber	Soak away pits, manhole, inspection chambers, septic tanks, cesspits, and the like
24	Transport system	Elevators, lifts and the like
25	Fence	Walls, gates, posts
26	Road / paving and walkway	Coated macadam and asphalt finish, gravel, hoggin and wood chip, interlocking, brick and blocks, cobbles and the like
27	Kerb / edge	Precast concrete
28	Soft landscaping	Surface application, seeding, turfing, trees and the like

Corresponding IFC Entities Defining the Identified Building Products

Comparing the building products identified, to the existing entities in the IFC 4 schema as shown in Table 2 revealed that a total of 24 IFC entities correspond to the identified building products. This implies that 24 out of the 28 building products identified in the BESMM 4 can be defined and represented using existing entities and their sub-classes in the IFC 4 schema. This situation is, however, not a good omen for quantity take-off of building works and therefore attests to the statement by Ma *et al.* (2011) that the IFC is not sufficient in meeting local standards. Hence, the IFC's capability in supporting quantity take-off of building works in Nigeria could be said to be inadequate.

Table 2: Corresponding IFC entities in the IFC4 Schema

Products	Corresponding IFC Entity	Schemas Layer
Earthwork	Not defined	N/A
Foundation	Ifcfooting	Domain/ IfcStructuralElementsDomain
Pile	Ifcpile	Domain/ IfcStructuralElementsDomain
Wall	Ifcwall	Shared element/ IfcSharedBldgElements
Beam	Ifcbeam	Shared element/ IfcSharedBldgElements
Column	Ifccolumn	Shared element/ IfcSharedBldgElements
Slab	Ifcslab	Shared element/ IfcSharedBldgElements
Ramp	Ifcramp	Shared element/ IfcSharedBldgElements
Staircase	Ifcstair	Shared element/ IfcSharedBldgElements
Roof	Ifcroof	Shared element/ IfcSharedBldgElements
Door	Ifcdoor	Shared element/ IfcSharedBldgElements
Window	Ifcwindow	Shared element/ IfcSharedBldgElements
Chimney	Ifcchimney	Shared element/ IfcSharedBldgElements
Water proof	Ifccovering	Shared element/ IfcSharedBldgElements
Fasteners and fittings	Ifcfastener	Shared element/ IfcSharedBldgElements
Finishes	Ifccovering	Shared element/ IfcSharedBldgElements
Furniture	Ifcfurniture	Shared element/ IfcSharedBldgElements
Pipes	IfcFlowSegment	Shared element/ IfcSharedBldgElements
Cable	IfcFlowSegment	Shared element/ IfcSharedBldgElements
Fire insulator/protector	IfcFireSuppressionTerminal	Domain/ IfcPlumbingFireProtectionDomain
Primary equipment	IfcDistributionElement	Core/IfcProductExtension
Terminal equipment	IfcFlowTerminal	Shared element/ IfcSharedBldgElements
Drainage chamber	Not defined	N/A
Transport system	IfcTransportElement	Core/IfcProductExtension
Fence	Not defined	N/A
Road / paving and walkway	IfcSite	Core/IfcProductExtension
Kerb / edge	Not defined	N/A
Soft landscaping	IfcSite	Core/IfcProductExtension

Validation of Results

The results of this research were validated through a focused group workshop with four participants who are experts in BIM from academia and industry. The results of the research were presented to the participants together with questionnaire asking them to validate the results by indicating their level of agreement with the listed items as building products. A total of twenty-six (26) representing 96.4% of the building products identified were confirmed as building products by the experts (Table 3). Considering the fact that only two products were disputed upon by the respondents, the results of the research were adjudged to be valid and realistic. It was observed that even the two building products disputed had at least one of the participants attesting to it as being building products.

Table 3: Validation of building products

S/NO	Building Products	Frequency		Percentage (%)	
		Yes	No	Yes	No
1	Earthwork	3	0	100	0
2	Foundation	3	0	100	0
3	Pile	3	0	100	0
4	Wall	3	0	100	0
5	Beam	3	0	100	0
6	Column	3	0	100	0
7	Slab	3	0	100	0
8	Ramp	3	0	100	0
9	Staircase	3	0	100	0
10	Roof	3	0	100	0
11	Door	3	0	100	0
12	Window	3	0	100	0
13	Chimney	3	0	100	0
14	Water proof	2	1	66.7	33.3
15	Fasteners and fittings	3	0	100	0
16	Finishes	3	0	100	0
17	Furniture, fitting and fixture	3	0	100	0
18	Pipes	3	0	100	0
19	Cable	3	0	100	0
20	Fire insulator/protector	3	0	100	0
21	Primary equipment	3	0	100	0
22	Terminal equipment and fittings	3	0	100	0
23	Drainage chamber	3	0	100	0
24	Transport system	3	0	100	0
25	Fence	3	0	100	0
26	Road / paving and walkway	3	0	100	0
27	Kerb / edge	3	0	100	0
28	Soft landscaping	1	2	33.3	66.7
	Total	81	3	96.4	3.6

CONCLUSION

This paper has identified building products that support BIM-based quantity take-off with their corresponding IFC entities by extracting the building products with their associated items of work and quantity information based on the BESMM 4. The study found a total of 28 building products in the BESMM 4 and concludes that even though the BESMM 4 do not completely align with existing classification system (Omni class, Uniclass, Uniformat, and Master format), they do define building components as products which could support BIM-based quantity take-off depending on the number of products directly defined by the IFC schema.

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