INTRODUCTION TO BUILDING INFORMATION MODELLING

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1.0 The History and Evolution of BIM

The history of Building Information Modelling (BIM) can be traced back to the early 1960s when efforts were made to digitalize the paper based communication system widely used in the Architectural, Engineering and Construction (AEC) industry. Then, the industry was sturdily criticized of being too fragmented in its delivery process; depending tremendously on paper-based modes of communication which lead to tons of errors and omissions that often caused unanticipated field costs, delays, and eventual lawsuits between the various parties in a project team. Efforts to eliminate paper-based approach resulted in the development of Computer Aided Design (CAD) whose foundation triggered the evolution of BIM.

SKETCH PAD was the first CAD system developed by Ivan Sutherland in 1962. Subsequently, AUTODESK developed the 2D system AUTOCAD which was a 2D system similar to hand drafting but in electronic form that allows for revisions and archiving. The first commercial CAD applications were released in the seventies for mainframe computers and workstations. However, because these machines were very expensive then, computer-aided drafting remained the privilege of state institutions and large design firms (mainly in the engineering industry). The breakthrough in CAD maintained its pace until the early eighties, when the 3D CAD emerged and personal computers became readily available in the market for smaller Architectural firms to start experimenting with CAD drafting.

Despite the benefits of the 2D & 3D CAD systems, they were criticized of being 'dumb' and unintelligent with no parametric behaviour. They lack the ability to detect conflicts, constructability issues, collaborate, and share ideas, communicate with all participants with the same model; simulate project objectives of cost, schedule, scope and quality as there is no central data repository that can cross-link all project stakeholders when changes arise. Moreover, CAD only creates isolated design information without linking between the various design fragments (views, elevations, plans and sections). This made CAD nothing but a computerised drafting tool. These challenges among several others led to the development of BIM as the successor of 2D/3D CAD.

The term BIM was first conceptualised by Charles Eastman at Georgia Tech and has been around as a concept since the 1970s. BIM is the most recent technological innovation developed to support designs, construction and operation of building and engineering projects in a virtual environment using intelligent objects. With BIM, both 2D and 3D drawings can be created as by-products of its design process. Design views can automatically be generated from single foundational database; and all other form of analysis such as clash detection, constructability analysis and more, can be undertaken in a BIM environment. Figure 1 represents the evolution of BIM over time.

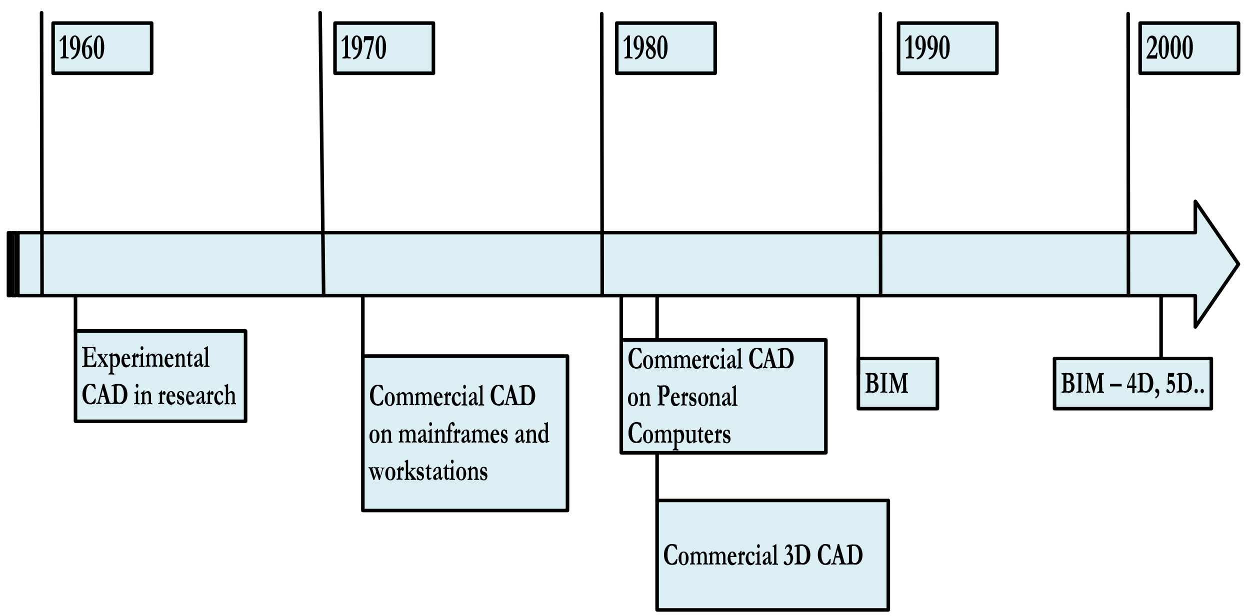

Figure 1: AEC CAD Timeline (Source; Eastman et al. (2011))

1.1 The Concept of 2D CAD

Before discussing about the BIM concept, let us take a closer look at the earlier CAD methods. The 2D applications are nothing more than "electronic drafting boards" capable of providing only two-dimensional drawings. The 2D drawings are usually made up of two dimensional geometric entities in the form lines, arcs, dots circles, etc. 2D CAD have the following characteristics:

- Designs are represented in two dimensions only (X and Y dimensions)
- Drawings are made up of unintelligent and unsmart geometries
- Drawing components (elevations/sections/plans) developed separately
- Design changes maintained manually on every drawing
- No 3D model is created

Although 2D CAD has major advantages of speed and accuracy compared to hand drafting, it could not provide solutions for many problems facing designers. The most critical drawback of 2D CAD is the lack of automatic change management among multiple drawings, making it quite difficult to identify design problems proactively.

1.2 The Concept of 3D CAD

The 3D CAD programs allow users to create a spatial model of the building that represents three dimensions/views of a model (X, Y and Z). With a 3D CAD, other drawings parts (e.g. sections or elevations) can be partially derived from the 3D model but in most cases the documentation is kept in a separate file (or set of files) from the model. Most 3D applications offer built-in visualisation tools and basic quantity calculation features (e.g. floor areas, roof areas).

The main features of 3D CAD are:

- The application has both 2D and 3D capabilities
- Buildings can be modelled in three dimensions
- 3D and 2D information can be included in a single file
- Drawings are (partially) derived from the model
- No automatic documentation

- Application mostly works with 2D and 3D drawing tools instead of real Architectural elements
- Additional content can be created, including visualisation and basic quantity take-offs

Major draw-backs of 3D CAD are centred on the inability of the 3D models to create automatic documentation of building information and the lack of parametric characteristics of components.

2.0 The Concept of BIM

The basic concept of BIM is underpinned on the need to provide a platform that addresses the weaknesses of the previous CAD technologies by providing collaborative platform that integrates all building information in a single file which can be exchanged and shared by all relevant project stakeholders. BIM in this respect is an extended 3D model that stores all building information of a project. With a 3D BIM, all the required project drawings (sections and elevations), presentation drawings, renderings and detailed construction drawings, as well as quantity calculations and price estimations could be directly extracted, especially if the model is at the highest level of details. Consequently, changes to the model are instantly updated on all drawings. The most significant highlights of the BIM methods are; single file concept; use of real Architectural elements for modelling, parametric capabilities where changes to the model affect all related drawings (and vice versa) and the automatic generation and updating of documentation among several others(Abdullahi, Ibrahim, & Ibrahim, 2014; Aouad, Wu, & Lee, 2006; Aouad, Wu, Lee, & Onyewobi, 2014; Aranda-Mena, Crawford, Chavez, & Froese, 2008).

BIM has successfully moved the AEC industry forward from current task automation of project and paper-centric processes (3D CAD, animation, linked databases, spreadsheets, and 2D CAD drawings) to an integrated and interoperable workflow where these tasks are collapsed into a coordinated and collaborative process that maximizes computing capabilities, Web communication, and data aggregation into information and knowledge capture (Eastman et al, 2011). All of these are used to simulate and manipulate reality-based models to manage the built environment within a fact-based, repeatable and verifiable decision.

2.1 BIM Definition:

The Acronym 'BIM' has many interpretations depending on the context in which it is used: It could be 'Building Information Modelling'; 'Building Information Model'; or 'Building Information Management'. The term BIM is considered to be ambiguous and has no universally accepted definition. Hence, the proliferation of definitions in literature (Aranda-Mena et al., 2008). According to RICS (2014b), the concept of BIM has no accepted definition due to its ever-evolving nature where new areas and frontiers are creeping into the boundaries of what it could be defined as.

There are definitions that present BIM as a 'Process', a 'Product', a 'technology', an 'innovation', or a 'Strategy'. However, simpler definitions consider BIM as a digital representation of the physical and functional characteristics of a facility. Whatever definition is given to BIM, the major function and goal of BIM involves the detailed and complete replication of a building in a digital environment with the sole goal of providing a collaborative platform for managing Building information throughout the lifecycle of a facility (Aouad et al., 2014) . The terms '*Building Information Model*' and '*Building Information Modelling*' are often used interchangeably, basically referring to a way of creating, using, and sharing building lifecycle data.

The following are some of the most notable definitions of BIM in literature

1. ***US National BIM Standards (NBIMS):*** **"***Building Information Modelling is digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition."(NBIMS, 2007)*

2. ***AGC (Associated General Contractors of America):*** *A Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and to improve the process of delivering the facility (AGC, 2005).*
3. ***Autodesk (2016)*****:** *BIM is an integrated process for sharing key physical and functional characteristics digitally before it is built. With BIM, AEC professionals can deliver projects faster and more economically while minimising environmental impact.*
4. ***Gu and London (2010)):*** *Building Information Modelling (BIM) is an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository*
5. ***Kymmell (2008)****: A building information model is a project simulation consisting of the 3D models of the project components with links to all the required information connected with the project's planning, construction or operation, and decommissioning*
6. ***Eastman, Teicholz, and Sacks (2011)***: define BIM as a modelling technology and associated set of processes to produce, communicate, and analyse *building models.*

In the US the National Building Information Modelling Standard (NBIMS) Committee of the National Institute of Building Science's (NIBS) Facility Information Council (FIC) is a major industry actor that regulates and promotes BIM implementation and application. The NBIMS vision for BIM is *"an improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle." (NBIMS, 2007).*

NBIMS categorises BIM in three ways; as a product, a process and as a technology (Eastman et al., 2011). As a product, BIM is an object-based digital representation of the physical and functional characteristics of a facility that serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward. BIM as a process is a collection of defined model uses, workflows, and modelling methods used to achieve specific, repeatable, and reliable information results from the model. As a technology, BIM is an ICT that is driven by the fundamental principles of CAD. It uses the technological advances made in the area of 3D modelling, especially from the product development and manufacturing sector. The principal difference between BIM technology and conventional 3D CAD is the parametric modelling approach used in BIM models. While 3D CAD is made up of geometric entities, the constituents of BIM are parametric.

2.2 Is BIM a software?

BIM is not a software as so many people perceive it to be. BIM is a terminology, an idea, a concept NOT a software. However, many software vendors adopt BIM concepts in their design. This software are called BIM-based applications. These BIM-based software are digital environments set up by software vendors with appropriate tools within their interfaces that support building information modelling. For example, Revit adopts BIM (e.g. parametric object modelling) concept but BIM is not Revit.

2.3 The Dimensions of BIM

A BIM model starts with a parametrically enriched 3D which has both geometric and non-geometric information embedded into its various components. However, as more information is added (see Figure *2*) to the parametric objects in a 3D BIM model, the model becomes richer and more robust featuring other information dimensions. Researchers classify BIM as 3D, 4D, 5D, 6D, 7D and nD (Aouad et al., 2006):

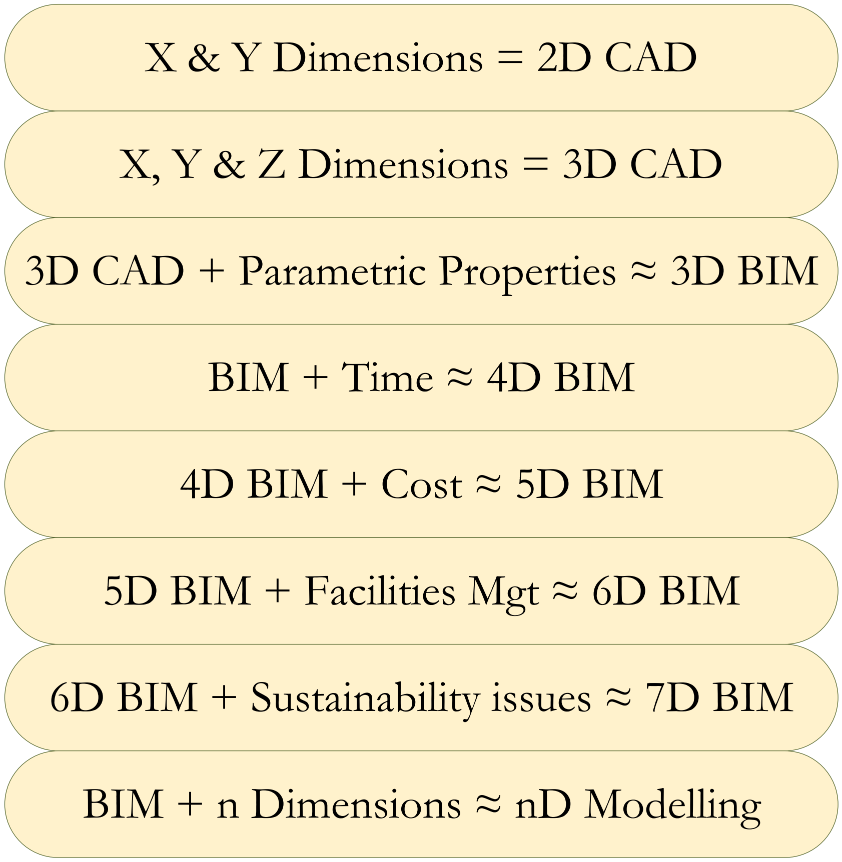

Figure 2: BIM Dimensions (RICS, 2014)

- **3D BIM:** This is a highly rich three-dimensional model (X, Y and Z) made up of intelligent/smart parametric objects.
- **4D BIM:** 3D model with time dimension assigned to its objects. Each component or object of the model can be assigned a schedule indicating its start and finish time
- **5D BIM:** 4D model with cost parameter added to it. A 5D model facilitates cost management function such as cost analysis and planning, and cash flow management.
- **6D BIM:** This constitutes a 5D model with facilities management related information embedded to it
- **7D BIM:** A 6D Model with sustainability issues

- **nD Model:** is an extension of a Building Information Model that incorporates all design information required at each stage of the lifecycle of a building facility. It was first developed at the University of Salford by Aouad et al. (2006).

3.0 BIM Technologies

There are basically two major technologies that drive the implementation of the concept of BIM. These technologies are:

1. Object oriented CAD
2. Parametric Modelling

3.1 Object oriented CAD Technology:

There are two forms of CAD technologies; the entity-based CAD, and the 'Object-oriented CAD'. The entity-based CAD is a CAD technology that uses vector graphics such as dots, lines, arcs and circles to create designs (Aouad et al., 2014). For example, series of lines can be used to form a wall. The entity-based CAD has the capability of creating 2D and 3D 'dumb' CAD using geometric entities in a way similar to real world objects. Traditional CAD software such as AutoCAD, internally represent design information using geometric entities. However, the fundamental drawback of this approach as observed earlier is that, while the system can accurately describe geometry in any domain, it cannot capture non-geometric domain-specific information about objects (e.g. properties of a column, hosting of a door or window in a wall, location of the pipe rack etc.).

On the other hand, the object-oriented CAD technology utilises complete parametric objects to form a design (Aouad et al., 2014). Building elements or components such as walls, columns and floors are created using pre-defined parametric objects that have sufficient information regarding the properties and attributes of the object embedded into them. Object oriented CAD is one of the technologies behind BIM that addresses the weaknesses of the 'dumb' 3D CAD by providing domain specific data of every object, capturing both geometric and non-geometric information. BIM objects used in most BIM software nowadays are stored in the objects' libraries and contain customised objects created and commercialised by manufacturers and suppliers.

3.2 Parametric Modelling:

The objects created and used in BIM environment become intelligent only if they are enhanced using defined parameters in the form of attributes, properties and other parametric characteristics. The parametric characteristics of BIM objects allow some degree of automation in the modelling process that makes the objects intelligent and sensitive to changes made to other related objects in a model. For example, defining a parameter that captures the design intent that the location of a window is midway between its horizontal edges. When a modeller uses this window in the model and defines the size of the window, the location of the window is automatically set using the parametric characteristic of the object, thus allowing the window in a BIM environment to update itself as its context changes (Eastman et al., 2011).

The Parametric object modelling provides a powerful way to create and edit geometry. Without it, model generation and design would be extremely cumbersome and error-prone. Designing a building that contains a hundred thousand or more objects would be impractical without a system that allows for effective low-level automatic design editing. The concept of parametric objects is central to understanding BIM and its differentiation from traditional 3D objects. Eastman et al. (2011) defined Parametric BIM objects as follows:

- Consist of geometric definitions and associated data and rules.
- Geometry is integrated non-redundantly, and allows for no inconsistencies. When an object is shown in 3D, the shape cannot be represented internally

redundantly, for example, as multiple 2D views. A plan and elevation of a given object must always be consistent. Dimensions cannot be "fudged."

- Parametric rules for objects automatically modify associated geometries when inserted into a building model or when changes are made to associated objects. For example, a door will fit automatically into a wall, a light switch will automatically locate next to the proper side of the door, a wall will automatically resize itself to butt to a ceiling or roof, and so forth. Objects can be defined at different levels of aggregation, so a wall can be defined as well as its related components. Objects can be defined and managed at any number of hierarchy levels. For example, if the weight of a wall subcomponent changes, the weight of the wall should also change. Objects' rules can identify when a particular change violates object feasibility regarding size, manufacturability, and so forth.

In parametric design, instead of designing an instance of a building element like a particular wall or door, a designer first defines an element class or family which defines some mixture of fixed and parametric geometry, a set of relations and rules to control the parameters by which element instances can be generated. The shape from a model family will vary according to its context. Objects and their faces can be defined using relations involving distances, angles, and rules like attached to, parallel to, *and* offset from. These relations allow each instance of an element class to vary according to its own parameter settings and the contextual conditions of related objects (such as the walls a given element butts into). Alternatively, the rules can be defined as requirements that the design must satisfy, such as the minimum thickness of a wall or concrete covering of rebar, allowing the designer to make changes while the rules check and update details to keep the design element satisfying the rules and warning the user if the rules cannot be met. Object-based parametric modelling supports both interpretations

3.3 BIM Applications

BIM has potential applications to different stakeholders and across the project lifecycle. For stakeholders, the applications vary as shown on Table 1.

Table 1: Applications of BIM to project stakeholders

	Owners	Designers	Constructors	Facility Managers
Visualisation	X	X	X	X
Options Analysis	X	X	X	
Sustainability Analyses	X	X		
Quantity Surveying and Cost Estimating	X	X	X	
Site Logistics	X		X	
Phasing and 4D Scheduling		X	X	
Constructability Analyses		X	X	
Building Performance Analyses	X	X	X	X
Building Management	X			X

BIM can be applied at any stage of the lifecycle of a facility. This section presents a brief highlight of the various applications of BIM at various project phases; project programming, design, preconstruction, construction, and post-construction (operations and maintenance)(Aranda-Mena et al., 2008; Ashcroft & Shelden, 2008; Eastman et al., 2011; Kymmell, 2008).

BIM and Project Programming

BIM can be used in the project programming phase to analyse space and understand the complexity of space standards and land regulations. This significantly saves time and provide the project team with opportunity of doing more value-added activities that help towards achieving project goals and objectives. For example, researchers have investigated the integration of BIM with GIS (Geographical Information Systems) and have found BIM to aid project planners in selecting appropriate site and conducting project feasibility and marketing studies. BIM with GIS can be used to determine if potential sites meet the required criteria according to project requirements, technical and financial factors, etc.

BIM and Project Design

BIM can be used by designers, particularly the Architects and Engineers at different stages of project design for schematic design, detailed design and construction detailing.

For Schematic design:

At the planning stage, BIM can be used to carry out options analysis which involves the comparison of multiple design options in order to select the most optimum, economical and workable design. Also, Photo Montage can be done to integrate photo realistic images of project with its existing conditions

Detailed design:

BIM can be used to develop detailed designs in the form of 3D exterior and interior models with Walk-through and fly-through animations that visualise the entire facility in a real life virtual form. Detailed analysis such Building performance analyses (e.g. energy modelling), and structural analysis and design could also be undertaken using BIM

Construction Detailing

BIM can be used for to provide construction specific details such as 4D phasing and scheduling; building systems analysis (e.g. clash detections), and the generation of shop or fabrication drawings

BIM in the Preconstruction Phase

At the preconstruction stage, BIM can be applied in the following activities:

- Estimating: More realistic and accurate estimate can be prepared by Quantity Surveyors from building information models. Contractors can perform fairly accurate quantity surveying and prepare detailed estimates from quantities directly extracted form BIM.

- Site coordination: Contractors can use 3D or 4D site coordination models to plan for site logistics, develop traffic layouts, and identify potential hazards at the jobsite which can aid in preparing a more realistic site safety plan.
- Constructability analysis: Using BIM models, the project team can perform detailed constructability analysis to plan sequence of operations at the jobsite.

BIM in the Construction Phase

During the construction phase, the project team can use BIM for the following activities:

- Project progress monitoring using 4D phasing plans
- For trade coordination meetings
- Integrating RFIs, change orders and punch list information in the BIM models.
- The advances in smartphone and tablets technology have allowed contractors and subcontractors to frequently use BIM models at the jobsite for information extraction and coordination.

3.4 BIM Benefits

The followings are the benefits of BIM at the various stages of the lifecycle of a facility(Aranda-Mena et al., 2008; Bernstein & Pittman, 2004; Eastman et al., 2011; Pittard & Sell, 2016; RICS, 2014a):

3.4.1 Preconstruction Benefits to Owner

3.4.1.1 Concept, feasibility, and design benefits

Owners/clients of facilities are always interested in determining whether a building of a given size, quality level, and desired program requirements can be built within a given cost and time budget. BIM model built into and linked to a cost database can provide owners with accurate and reliable information that guides decision on whether to proceed with a project or not.

3.4.1.2 *Increased building performance and quality*

Schematic models developed prior to constructing detailed building model allow for a more careful evaluation of the proposed scheme to determine whether it meets the building's functional and sustainable requirements. Early evaluation of design alternatives using BIM analysis/simulation tools improves the general quality of the building.

3.4.1.3 Improved collaboration using integrated project delivery

Where Integrated Project Delivery (IPD) is the adopted project procurement approach, BIM can be used by the project team from the commencement of the design to improve their understanding of project requirements and to extract cost estimates as the design is developed (Eastman et al., 2011). This allows design and cost to be better understood and also helps in avoiding the use of paper exchange and its associated delays and other complications.

3.4.2 Design Benefits

3.4.2.1 Earlier and more accurate visualisations of a design:

3D models can be used to visualize the design at any stage of the process with the expectation that it will be dimensionally consistent in every view.

3.4.2.2 Automatic low-level corrections when changes are made to designs:

The parametric nature of BIM makes objects used in the design to be controlled by parametric rules that ensure proper alignment, hence making the 3D model free of geometry, alignment, and spatial coordination errors which ensures automatic adjustments to changes made at later stages.

3.4.2.3 Generation of Accurate and consistent 2D drawings at any stage of the design:

Through a BIM model, 2D designs can be extracted for any set of objects or specified view of the project. This significantly reduces the amount of time and number of errors associated with generating construction drawings for all design disciplines.

3.4.2.4 Earlier collaboration of multiple design discipline:

BIM technology facilitates simultaneous work by multiple design disciplines which consequently shortens the design time; significantly reduces design errors and omissions, and ultimately gives earlier insight into design problems and presents opportunities for a design to be continuously improved.

3.4.2.5 Easy verification of consistency to the design intent:

BIM provides earlier 3D visualisations in such a way that both design intent and client requirements are evaluated. For technical buildings (labs, hospitals, and the like), the design intent is often defined quantitatively, and this allows a building model to be used to check for these requirements. For qualitative requirements (this space should be near another), the 3D model can also support automatic evaluations.

3.4.2.6 Extraction of cost estimates during the design stage:

At any stage of the design, BIM technology can extract accurate quantities and specifications that can be used for cost estimation

3.4.2.7 Improvement of Energy Efficiency and Sustainability

Linking the building model to energy analysis tools allows evaluation of energy use during the early design phases. The capability to link the building model to various types of analysis tools provides many opportunities to improve building quality.

3.4.3 Construction and Fabrication Benefits

3.4.3.1 Use of design model as basis for fabricated components

BIM models are used in steel, sheet metal work, precast components, fenestration, and glass fabrication. These offsite fabrications help in drastically reducing cost and construction time. BIM also allows larger components of the design to be accurately fabricated offsite than would be done using 2D designs.

3.4.3.2 Quick reaction to design changes

Changes introduced during design can be automatically evaluated and updates made automatically based on the established parametric rules. Design changes can be resolved more quickly in a BIM system because modifications can be shared, visualized, estimated, and resolved without the use of time-consuming paper transactions. Updating in this manner is extremely error-prone in paper-based systems.

3.4.3.3 Discovery of design errors and omissions before construction

Because the virtual 3D building model is the source for all 2D and 3D drawings, design errors caused by inconsistent 2D drawings are eliminated. In addition, because models from all disciplines can be brought together and compared, multisystem interfaces are easily checked both systematically (for clash detection) and visually (for other kinds of errors).

3.4.3.4 Synchronization of design and construction planning

With a BIM model, construction planning using 4D CAD can be done by linking a construction plan to the 3D objects in a design, so that it is possible to simulate the construction process and show what the building and site would look like at any point in time. This type of analysis cannot be undertaken using paper bid documents or dumb 3D CAD(Eastman et al., 2011).

3.4.3.5 Better implementation of lean construction techniques

Lean construction techniques require careful coordination between the general contractor and all other subcontractors to ensure that work can be performed when the appropriate resources are available onsite. This minimizes wasted effort and reduces the need for onsite material inventories. Because BIM provides an accurate model of the design and the material resources required for each segment of the work, it provides the basis for improved planning and scheduling of subcontractors and helps to ensure just-in-time arrival of people, equipment, and materials. This reduces cost and allows for better collaboration at the jobsite. The model can also be used with wireless hand-held computers to facilitate material tracking, installation progress, and automated positioning in the field.

3.4.3.6 Synchronization of procurement with design and construction

BIM model provides accurate quantity information and specifications that can be used to procure materials from product vendors and subcontractors directly using the models. Currently, concerted efforts are underway to provide adequate object definitions for many manufactured products which is expected to make this capability a complete reality.

3.4.4 Post Construction Benefits

3.4.4.1 Improved commissioning and handover of facility information

During the construction process the general contractor and MEP contractors collect information about installed materials and maintenance information for the systems in the building. This information can be linked to the object in the building model and thus be available for handover to the owner for use in their facility management systems. It also can be used to check that all the systems are working as designed before the building is accepted by the owner.

3.4.4.1 Better management and operation of facilities

BIM provides a source of information (graphics and specifications) for all systems used in a building. Previous analyses used to determine mechanical equipment, control systems, and other purchases can be provided to the owner, as a means for verifying the design decisions once the building is in use. This information can be used to check that all systems work properly after the building is completed.

3.4.4.1 Integration with Facility Operation and Management Systems

A building model that has been updated with all changes made during construction provides an accurate source of information about the as-built spaces and systems. This provides a useful starting point for managing and operating the building. A building Information Model supports monitoring of real-time control systems, provides a natural interface for sensors, and remote operating management of facilities. Many of these capabilities have not yet been developed, but BIM provides an ideal platform for their deployment.

4.0 BIM Implementation

4.1. Implementation Levels

There are various approaches to implementing BIM. Ahmad, Demian, and Price (2012) reported that BIM can be implemented using Top-down; Bottom-up; slow and drawn out methods; or by using a selected team; using multiple teams; and implementing on specific projects, all projects or the entire organisation. According to Jung and Joo (2011), the implementation of BIM can be done at three levels; Industry, Organisational and Project levels. However, Implementation at the industry level tends to be faster and easier because BIM standards are successfully developed. For example, the US NBIMS serves as a major actor in the successes recorded in BIM implementation in the United States. Meanwhile, at organisational and project level, standards differ due to their formats, details and purpose, and are also related to managerial corporate strategy issues, and this makes implementation quite slower and difficult.

Ashcroft and Shelden (2008) Observed that BIM adoption is divided into three groups of activities covering different scopes.

- For example, to implement BIM within an office, activities such as selecting software; addressing IT issues; and training of personnel have to be tackled comprehensively.
- To implement across the design team: activities such as selecting software; addressing IT issues: and also legal and contractual issues are critical.
- Across the project delivery team: Procedural scope (design, coordination, estimating, scheduling, submittal review, fabrication, agency review and facility management); and also legal and contractual issues are worth consideration

4.2 BIM Environment, Platform and Tools

There are generally three levels of BIM application. BIM could be adopted as a tool, as a platform, and as an environment. It is important to note that no one application will be ideal for all types of projects and therefore, an organisation would have several platforms that it supports and moves between for specific projects. Some BIM tools uniquely support communication between different applications; others may support collaboration with a particular fabricator or consultant. However, the need for multiple platforms depends on the nature of services offered by an organisation. For example, fabricators are less likely to need multiple platforms while a consortium firm housing various professionals may need to install different BIM platforms that suit the various services they offer. In planning and developing BIM within an organisation, it is useful to think of it in system Architecture terms. BIM, in most organisations, will involve multiple applications, for different uses. How are the different applications to be conceptualised and organised? Large firms will typically support and in some sense integrate 10 to 50 different applications for their employees' use.

4.2.1 BIM tool:

A BIM tool is a task-specific application that produces a specific outcome (Eastman et al., 2011); For example tools for model generation, drawing production, specification writing, cost estimation, clash and error detection, energy analysis, rendering, scheduling, and visualisation. The outputs of these tools are usually standalone in form of reports and drawings and sometimes are exported to other tool applications, such as quantity take-offs to cost estimation, and structural reactions fed to a connection-detailing application.

4.2.2 BIM platform:

A BIM platform is a design application that generates data for multiple uses. It provides a primary data model that hosts the information on the platform and provides interfaces to multiple other tools with varied levels of integration. These interfaces internally incorporate other tool functionalities such as drawing production and clash detection.

4.2.3 BIM Environment:

This is a setting that involves the data management of one or more information pipelines that integrate the applications (tools and platforms) within an organisation. A BIM environment facilitates the automatic generation and management of multiple BIM tool datasets in such a way that policies and practices of information within the organisation is supported. It is usually required where multiple platforms are used, and thus multiple data models generated. These address tracking and coordinating communication between people as well as multiple platforms. BIM environments provide the opportunity to carry much wider forms of information than model data alone, such as video, images, audio records, emails, and many other forms of information used in managing a project (Eastman et al., 2011; Succar, 2009).

4.2.4 BIM Software

The choice of the most appropriate software to use is informed by several factors ranging from production practices, interoperability, and to some degree, the functional capabilities of a design organisation to do particular types of projects. Decisions about applications involve understanding new technologies, the new organisational skills needed, and then learning and managing those skills. These challenges will reduce over time, as the learning curve and practices surrounding BIM use become more rooted in practice. However, due to the rapid improvement in the functionality of BIM applications, BIM implementers need to keep track of new releases made by software vendors. Reviews of the current versions of BIM applications can be found in *AECBytes, Catalyst,* or other AEC CAD journals and collaboration sites such as LinkedIn. As there isn't one single BIM application that does everything, various categories of BIM tools exist such as the design authoring tools, BIM analysis tools, Scheduling and construction management tools, Shop drawings and fabrication tools; Quantity take-off tools, file sharing and collaboration tools. Table 2 below provides a highlight of some of the BIM software available in the market.

Table 2: BIM software

Product Name	Vendor	BIM use	Primary Focus
Design Authoring Tools			
Revit Architecture suite	Autodesk	Architecture and site design, Structural and MEP modelling	Modelling and parametric design.
Bentley BIM Suite -	Bentley Systems	Multi-discipline	Architectural, Structural, Mechanical, Electrical and Generative Components - all within the 3D modelling environment
Digital Project	Gehry Technologies	Multi-discipline	High- performance 3D modelling tool for architectural design, engineering, and construction.

ArchiCAD	Graphisoft	Architecture, MEP and site design	Architectural Modelling and parametric design.
Vectorworks	Nemetschek	Architecture	Structural Modelling and parametric
RISA	RISA	Structural	MEP Design
Tekla Structures	Tekla	Structural	3D Architectural and Structural
BIM Analysis Tools			
Robot	Autodesk	Structural Analysis	Bi-directional link with Autodesk Revit
Green Building Studio	Autodesk	Energy Analysis	Measure energy use and carbon footprint
Solibri Model Checker	Solibri	Model Checking & Validation	Rules-based checking for compliance and validation of all objects in the model
Carrier E20-II	Carrier	MEP Analysis	HVAC system analysis
Shop drawings and Fabrications			
CAD-Duct	Micro Application Packages Ltd.	Fabrication	Use AutoCAD geometry, for fabrication
PipeDesigner 3D & Duct Designer 3D	QuickPen International	Fabrication	Use AutoCAD geometry, for fabrication
Tekla Structures	Tekla	Shop Drawing	Structure-centric fabrication
Construction Management			
Navisworks Manage	Autodesk	Clash Detection	Model-based Clash Detection between trades
ProjectWise Navigator	Bentley	Clash Detection	Coordination between models and disciplines
Synchro Professional	Synchro Ltd.	Planning & Scheduling	Schedule-driven site coordination
BIM-based Scheduling tools			
Navisworks Simulate	Autodesk	Scheduling	Linking 3D model to popular project schedule applications (e.g. MS Project or Primavera)
ProjectWise Navigator	Bentley	Scheduling	Linking 3D model to popular project schedule applications (e.g. MS Project or Primavera)
Visual Simulation	Innovaya	Scheduling	Linking 3D model to popular project schedule applications (e.g. MS Project or Primavera)
Quantity Take-off			
AQTO	Autodesk	Quantity Take-offs	Generating take-offs from multiple environments both 2D & 3D
DProfiler	Beck Technology	Conceptual Estimates	Conceptual 3D modelling with cost estimating and life cycle operational costs forecasting
Visual Applications	Innovaya	Estimating	Extracting quantities and building estimates from ADT & Revit files
Vico Takeoff Manager	Vico Software	Quantity Take-offs	Quantity Take-offs, feeding into
File Sharing and Collaboaration			

Buzzsaw	Autodesk	File Sharing	A repository for all project related documents and files.
Constructware	Autodesk	Collaboration	Web-based suite of management tools for construction projects
ProjectDox	Avolve	File Sharing	electronic plan submission, review, tracking and archiving

4.2 Status of BIM Implementation Globally

BIM is currently becoming widespread around the globe, affecting the construction industries of many nations at various levels. The construction industry in the developed world is rushing to embrace BIM as a catalyst for gaining operational efficiencies, and tremendous rise in adoption in the last three to five years has been recorded. Annual surveys are frequently being conducted to document the state of affairs, and national-level initiatives are in place to produce BIM standards and guidelines by various public and non-governmental institutions.

High rate of BIM adoption is globally more visible in the developed economies where research activity focusing on BIM has also increased. Studies on the status of BIM implementation as reported in both academic literature and industry publications, generally focused on few selected countries, from the developed world. A typical example is the famous McGraw Hill BIM report (McGraw-Hill Construction, 2014). The story in the developing countries is quite opposite. This is despite the volume of construction going on which is logically expected to leverage the gains that can be achieved from using BIM which are quite enormous.

Recent report by McGraw-Hill Construction (2014) summarises the status of BIM adoption over the last three to five years around the globe and identified Canada, France, Germany, the UK and the USA as mature markets for BIM technology with new under explored market in countries such as; Australia, Brazil, Japan, New Zealand, South Korea, China and India.

On a general note, the report depicts the rapid and robust BIM uptake globally, especially in the US and Scandinavian regions where BIM adoption is at its peak level. Significant successes have also been reported in the UK, Australia and other maturing countries in the Middle East (McGraw-Hill Construction, 2014).

Table *3* and Table 4 show the global status of BIM adoption by contractors as at 2014. According to the report, construction companies have reported a positive return on investment with more savings expected in the future; the volume of construction companies' work using BIM will increase by 50 per cent in the year 2016, leading to increased investment in BIM is expected.

Table 3: Status of BIM Adoption Globally (McGraw-Hill, 2014)

Country	Status of Adoption
United States	71%
Europe	46%
UK	54%
Middle East	25%
China	**15%**
India	**10-18%**
Australia	40%

Table 4: BIM Implementation by Contractors

Over 40% | 30% to 40% | 15% to 29% | Under 15%

Building Projects	UK	France	Germany	US	Canada	Brazil	Japan	South Korea	Aus/NZ
Commercial (Offices, Retail, Hotels)	69%	68%	59%	66%	54%	53%	63%	48%	70%
Institutional (Education, Healthcare, Religious)	61%	32%	31%	77%	41%	31%	23%	35%	39%
Government/Publicly Owned (Courthouses, Embassies, Civic/Sports and Convention)	54%	10%	22%	68%	44%	12%	0%	51%	37%
Multifamily Residential	33%	35%	44%	18%	26%	19%	23%	20%	26%
Single family Residential	17%	19%	22%	1%	10%	16%	0%	1%	4%
Non-Building Projects									
	UK	France	Germany	US	Canada	Brazil	Japan	South Korea	Aus/NZ
Infrastructure (Roads, Bridges, Tunnels, Dams, Water/Wastewater	33%	19%	16%	14%	31%	28%	13%	24%	25%
Industrial/Manufacturing	26%	23%	19%	35%	36%	31%	47%	24%	34%
Industrial/Energy (Primary Power Generation, Oil/Gas facilities)	20%	13%	3%	18%	28%	12%	0%	21%	16%
Mining/Natural Resources	6%	0%	0%	4%	18%	6%	0%	1%	11%

Source: McGraw-Hill BIM Implementation Survey, 2014.

4.3 Challenges to BIM Adoption

Several barriers to BIM implementation have been identified. The following are some of the major ones outlined by researchers (Abubakar, Ibrahim, & Bala, 2013; Aranda-Mena et al., 2008; Ashcroft & Shelden, 2008; Bernstein & Pittman, 2004; Eastman et al., 2011; Hudson, 1978; Usman, 2015):

Challenges with Collaboration and Teaming

While BIM offers new methods for collaboration, it introduces other issues with respect to the development of effective teams. Determining the methods that will be used to permit adequate sharing of model information by members of the project team is a significant issue. For example, if the Architect uses traditional paper- based drawings, then it will be necessary for the contractor (or a third party) to build the model so that it can be used for construction planning, estimating, and coordination.

Legal Changes to Documentation Ownership and Production

Legal concerns are presenting challenges with respect to who owns the multiple design, fabrication, analysis, and construction datasets, who pays for them, and who is responsible for their accuracy. These issues are being addressed by practitioners through BIM use on projects. As owners learn more about the advantages of BIM, they will likely require a building model to support operations, maintenance, and subsequent renovations. Professional groups, such as the American Institute of Architects(AIA) and Associated General Contractors (AGC), are developing guidelines for contractual language to cover issues raised by the use of BIM technology.

Changes in Practice and Use of Information

The use of BIM will also encourage the integration of construction knowledge earlier in the design process. Integrated design-build firms capable of coordinating all phases of the design and incorporating construction knowledge from the outset will benefit the most. IPD contracting arrangements that require and facilitate good collaboration will provide greater advantages to owners when BIM is used. The most significant change that companies face when implementing BIM technology is intensively using a shared building model during design phases and a coordinated set of building models during construction and fabrication, as the basis of all work processes and for collaboration. This transformation will require time and education, as is true of all significant changes in technology and work processes.

Implementation Issues

Replacing a 2D or 3D CAD environment with a building model system involves far more than acquiring software, training, and upgrading hardware. Effective use of BIM requires that changes be made to almost every aspect of a firm's business (not just doing the same things in a new way). It requires some understanding of BIM technology and related processes and a plan for implementation before the conversion can begin. A consultant can be very helpful to plan, monitor, and assist in this process. While the specific changes for each firm will depend on their sector(s) (See Folorunso and Uthman, 2015 for a contractor's perspective) of AEC activity, the general steps that need to be considered are similar and include the following (Ashcroft & Shelden, 2008; Eastman et al., 2011):

- Assign top-level management responsibility for developing a BIM adoption plan that covers all aspects of the firm's business and how the proposed changes will impact both internal departments and outside partners and clients.
- Create an internal team of key managers responsible for implementing the plan, with cost, time, and performance budgets to guide their performance.
- Start using the BIM system on one or two smaller (perhaps already completed) projects in parallel with existing technology and produce traditional documents

from the building model. This will help reveal where there are deficits in the building objects, in output capabilities, in links to analysis programs, and so forth. It will also allow the firm to develop modelling standards and determine the quality of models and level of detail needed for different uses. It will also provide educational opportunities for leadership staff.

- Use initial results to educate and guide continued adoption of BIM software and additional staff training. Keep senior management apprised of progress, problems, insights, and so forth.
- Extend the use of BIM to new projects and begin working with outside members of the project teams in new collaborative approaches that allow early integration and sharing of knowledge using the building model.
- Continue to integrate BIM capabilities into additional aspects of the firm's functions and reflect these new business processes in contractual documents with clients and business partners.
- Periodically re-plan the BIM implementation process to reflect the benefits and problems observed thus far, and set new goals for performance, time, and cost. Continue to extend BIM-facilitated changes to new locations and functions within the firm.

4.3.1 BIM Adoption in the Nigerian Construction Industry

Few researches are available on the level and status of BIM implementation in Nigeria. Studies by Abdullahi, Ibrahim, and Mohammed (2011); Abubakar et al. (2013); Abubakar, Ibrahim, Bala, and Kado (2014);Usman (2015); and Isa (2015) are among the few investigations carried out on issues related to BIM implementation in Nigeria.

Abubakar et al (2013) evaluated the readiness of Nigerian Building Design firms to adopt BIM using four readiness components (management, people, process and technology) and found the firms not fully ready for the adoption. The study reported various readiness levels across the different categories of firms, with some firms fully ready in some components, while critical attention is needed in others for full readiness to be attained. Similarly, although the Nigerian Public Sector (specifically, Federal Ministries and Departments and Parastatals) have demonstrated some level of preparedness for BIM adoption in some readiness components, the Nigerian public sector is also not fully ready for BIM implementation. Usman (2015) assessed the readiness of the Nigeria public sector (Federal Ministries and Departments and Parastatals) to implement BIM in its project delivery process. Results of the study show that the federal ministries of Nigeria have achieved management, process as and technology readiness but need to put in more efforts to improve people's readiness. Similarly, the agencies considered in the study have management and people's readiness but do not have process and technology readiness. Table 5 below shows the readiness status of Nigeria public sector.

Table 5: Readiness of Nigerian Public Sector to Adopt BIM Project Delivery Process

Sectors	Readiness Parameter	Readiness Status
Overall	Management	**Ready**
	Process	**Ready**
	People	**Not ready**
	Technology	**Ready**
Ministries	Management	**Ready**
	Process	**Ready**
	People	**Not ready**
	Technology	**Ready**
Agencies	Management	**Ready**
	Process	**Not ready**
	People	**Ready**
	Technology	**Not ready**

At industry level, factors such as 'the availability of trained professionals to handle BIM tools'; 'software availability and affordability'; 'enabling demands'; 'clients demand'; market demands, competitiveness advantage and growing awareness in BIM were identified as the major drivers influencing the industry's preparedness. However, the industry was assessed to be at BIM level 1 maturity on the Bew-Richards maturity level (Figure 3) due to some barriers hindering adoption (Isa, 2015).

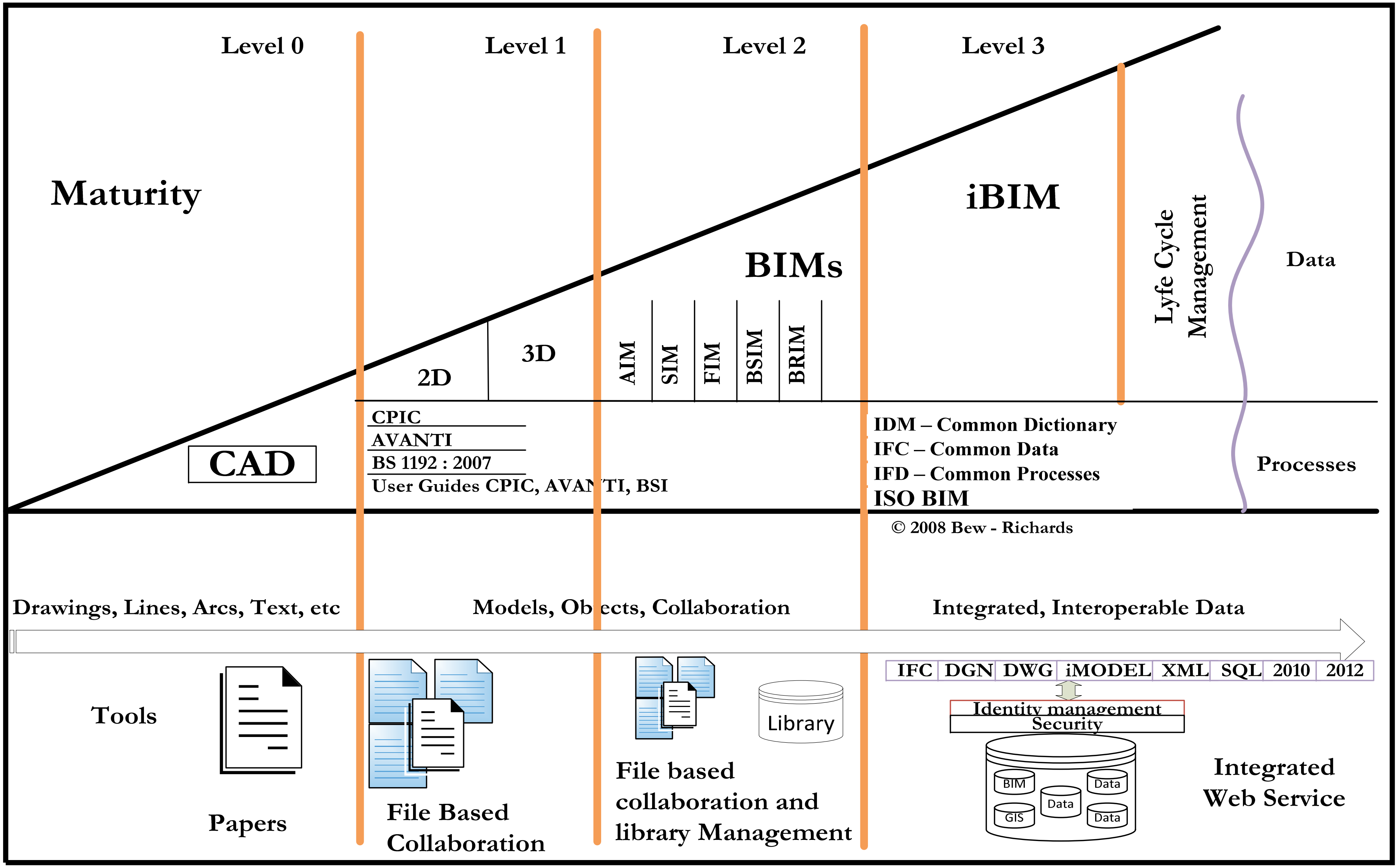

Figure 3: Bew Richards Maturity Model

Several barriers have been identified to be the stumbling blocks hindering successful implementation of BIM in the industry. Abubakar et al. (2014) identified 'lack of client demand'; lack of awareness and understanding of the technology among others. Table 6 below presents some of these barriers as outlined by Abubakar et al. (2014); Isa (2015); and Usman (2015).

Table 6: Barriers to BIM implementation in the Nigeria Construction Industry

Barriers
PROCESS BARRIERS
Lack of Awareness of the technology
Lack of knowledgeable and experienced partners
Lack of Trained Professionals to handle the tools
High Cost of Training
Clients are not requesting the use of BIM on projects
Lack of Enabling Environment (government policies and legislations) to guide implementation
No proof of financial benefits
Legal and Contractual Constraints
Social and Habitual Resistance to change
TECHNOLOGY BARRIERS
Frequent Power Failure
High Cost of Integrated software/Models for all professionals
Lack of Standards to Guide Implementation
Poor Internet Connectivity

To improve the maturity level of BIM implementation reported in Nigeria, Isa (2015) developed strategies for overcoming the barriers for implementation. Isa (2015) developed strategies for overcoming both the process and technology barriers identified. The strategies developed were then mapped to the various barriers and subsequently, a roadmap for BIM implementation was developed mapping analysis was expressed as roadmap for implementation of BIM. The roadmap provides a clear direction to follow for successful BIM implementation in the Nigeria construction industry. **Error! Reference source not found.** and **Error! Reference source not found.** show the barriers/strategies mapping analysis and the BIM implementation Roadmap developed by Isa (2015) respectively.

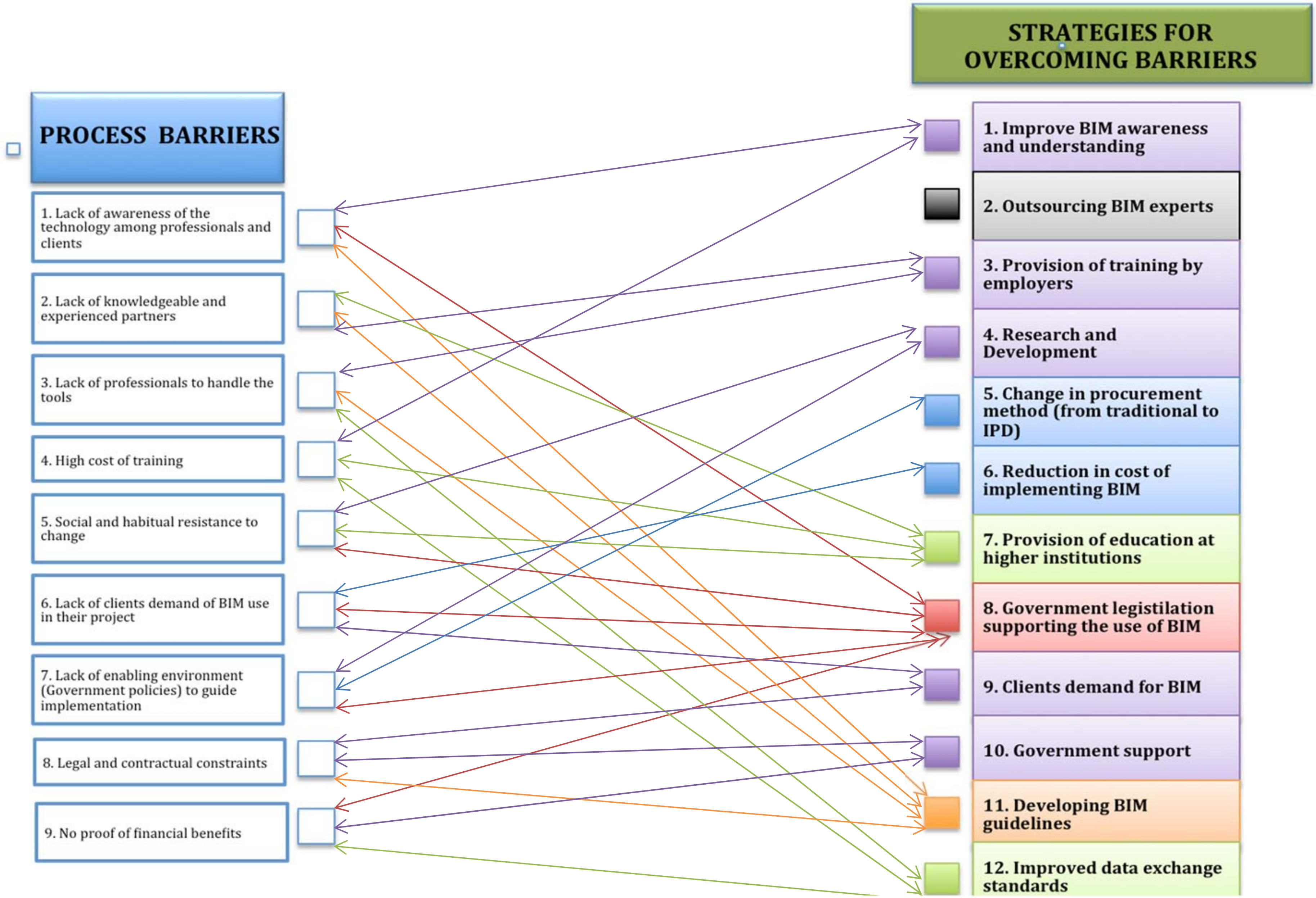

Figure 4: Strategies for overcoming process barriers to BIM adoption Source: Isa (2015)

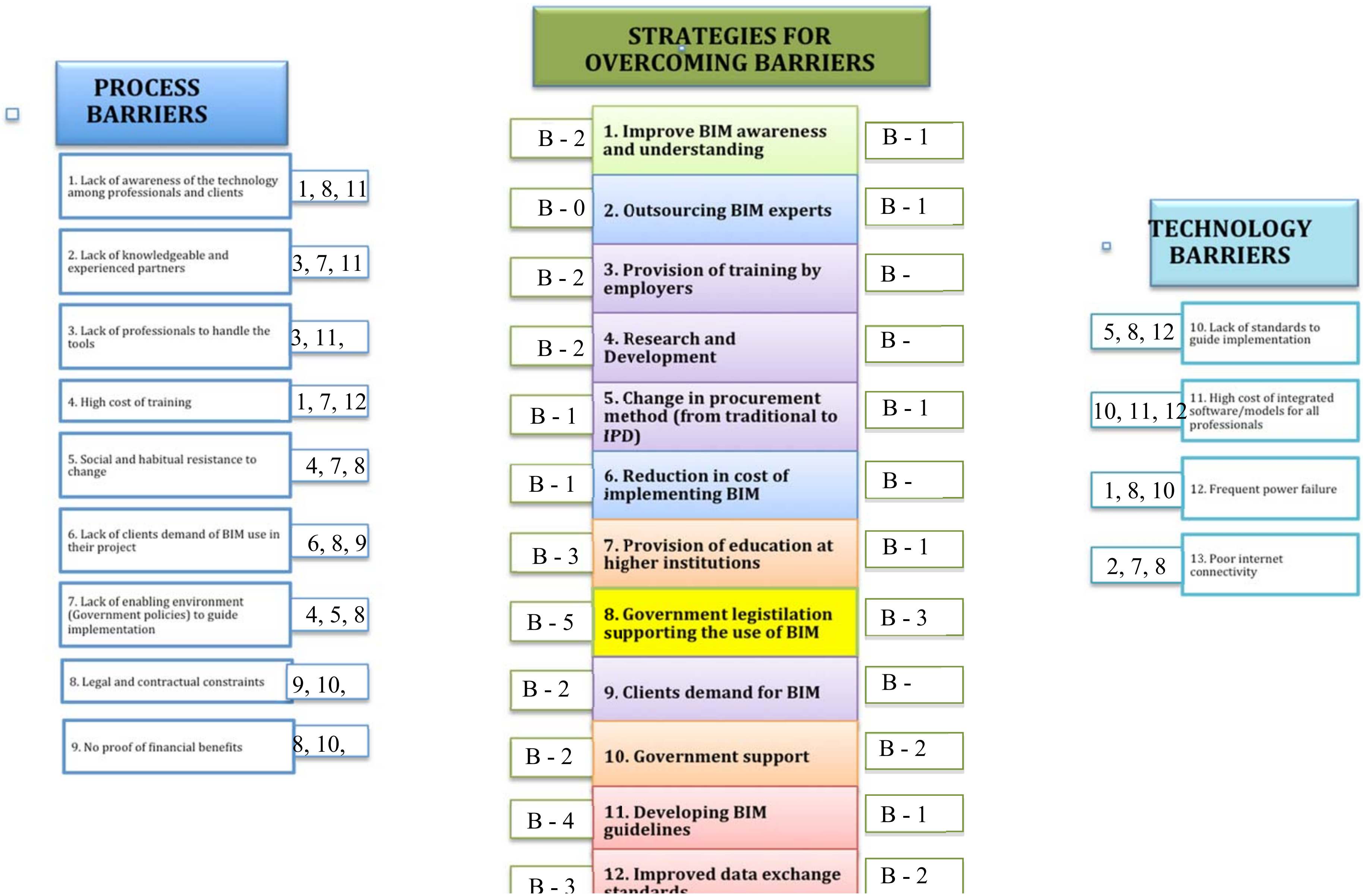

Figure 5: Roadmap for BIM implementation in the Nigeria Construction Industry Source: Isa (2015)

5.0 BIM and the Quantity Surveying Practice

5.1 Changing role of the Quantity Surveyor in the construction industry

According to Ashworth and Hogg (2007), the Quantity Surveyor's traditional roles have been associated to the functions of estimating and cost planning, procurement advice, measurement, preparation of Bills of Quantities and tender documentation, construction cost control, and preparation of valuations, payments, contractual claims and final accounts. However, with the emergence of the newer procurement strategies, the roles and responsibilities of Quantity Surveyors have been evolving and expanding to meet up with the new market demands. Therefore, Quantity Surveyors have embraced other functions such as whole life cycle costing, value management, project and construction management, risk analysis and management, facilities management, and contractual disputes and litigation (Ashworth and Hogg, 2007). With the rapid advancement experienced in construction information and communications lately, Quantity Surveyors are availed with the opportunity of enhancing their role using automated measurement and quantification, environmental and sustainability analysis, facilities management, legal services, investment advice and quality management. BIM can be used efficiently achieve both the traditional and newer functions of the Quantity Surveyors. BIM is largely becoming the mainstream in the global construction industry and as a result, clients expect the QS firms to embrace BIM in order to increase the cost effectiveness and value of construction processes (BCIS, 2011). Therefore, it is important for the Quantity Surveyors to appreciate BIM, understand its potential, and develop and employ effective processes and tools to integrate BIM into their current practices (Cartlidge, 2011).

5.2 Why Quantity Surveyors MUST Adopt BIM in their Practice

Several predictions have been made that the QS profession will become extinct due to the emergence of BIM. This has largely been due to lack of BIM awareness among Quantity Surveyors. However, this prediction is turning out to be wrong as BIM's capability of automating measurements through extraction of quantities directly from the model gives QSs the opportunity to shift more attention on providing knowledge and expertise-intensive advice to the project team. QS Firms are now beginning to embrace BIM in their practices. For example Pittard and Sell (2016) reported wide spread of BIM practice by UK firms in the areas of cost planning; risk management; whole life cycle costing, procurement, contract administration and information management. For example, HC QS; a major QS consultancy in UK engages its junior QSs in developing BIM models of highest level of details for cost planning and estimating using simple BIM authoring tools (Pittard & Sell, 2016).

The following are the set of opportunities that BIM brings to the QS practice based on their value:

1. Accessibility to the model
2. Construction planning and sequencing
3. Clash detection
4. Differing levels of detail
5. Contractor pricing tool
6. Automated quantification in units that relate to industry norms
7. Quality/Completeness checking

5.3 How Quantity Surveyors should apply BIM in their practices

The following are key issues that guide QSs application of BIM:

- QSs work on models developed by other project team members and are expected to perform their tasks using these models. Where the models are of low Level of Details (LODs), the QS improves the models to the required LOD.
- The fact that the models are developed by other project team members, QSs must have to undertake a review of the model for accuracy and information richness. Many instances have been reported where the model does not have

the required information to allow model-based measurements and quantity take-off.

- The QS must ensure that the automatic model-based measurements and quantity take- offs are compliant with locally accepted standard methods of measurements.
- A Standard Classification System is a very critical requirement for BIM-based estimating as it has an impact on the work processes of the QS. Commonly adopted classification systems are RICS' NRM, OmniClass Construction Classification System, ICE CESMM, MasterFormat, UniFormat and Uniclass. In the case of Nigerian QS, a fundamental question of whether the BESMM is a classification system is quite fundamental. Is it BIM-compliant? What improvements must be made to make it so? The QSRBN in collaboration with the NIQS and other professional bodies must develop a unified classification system suitable for application in the industry.
- A clear understanding of model's LOD must be ensured. This is done to ensure that cost planning is carried out in accordance with the level of information that is available in the model.

5.4 Methods of BIM-based Cost Estimating

The ability of BIM platforms to perform automated quantity take-offs does not produce a cost estimate. To prepare estimates, the quantities generated from BIM models are assigned price/rates and descriptions based on a standard format. Therefore, researchers suggest the following three approaches as methods of performing BIM-based cost estimating:

1. Exporting building object quantities to estimating software

In this approach, quantities generated from 3D BIM are exported into spreadsheets where pricing and other estimating activities are carried out. Eastman et al. (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.

2. Bridging the BIM Tool Directly with Estimating Software

This method involves the use of BIM estimating software plug-ins such as Tocoman iLink 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.

3. Using BIM Quantity Take-off Tools

This involves the use of specialised QTO software, e.g. Autodesk QTO, Vico Office, Exactal CostX, 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).

5.5 Requirement for BIM-based Quantity-Take-off and Estimating

Element naming convention and presentation

To effectively perform BIM-based QTO:

a. The project team must ensure that all building elements are modelled in the same style as agreed and documented by the team. It will be problematic when the same element is modelled differently in different parts of the building (RICS, 2014a).
b. A standard naming convention for building elements and their type information should be established. All different building elements should be identifiable through the type information from quantity take-off point of view. It is important to note that different disciplines might view the type information differently. Therefore, an identification system for each element type must be established and documented by the project team.

Quantity information of elements:

The standard method of measurement to be used must be agreed upon by the project team. The SMM defines the measurement rules of the cost estimate/plan in terms of unit of measurement and other requirements for each element. For example, windows can be taken-off by 'count' or by 'area', both of which can be provided by the windows element. The following are the typical units of measurement most commonly used for QTO; Count; Length measure (Length, Perimeter, Height); Area measure (Net area, Gross area); Volume measure (Net volume, Gross volume); and Weight.

5.6 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:

1. *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 LODs. Models of LOD 500 provide adequate information that ensure accurate estimates are prepared. LOD 500 models contain details of size, shape, location, quantity and orientation that have been verified in the field (RICS, 2014b). 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.

2. *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 (Sabol, 2008).

3. *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 requirements in most cases (Ma, Zhenhua, Wu, & Zhe, 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, Uniclass, Omniclass).

Madugu, Abdullahi, and Musa (2016) developed information requirement that supports BIM-based QTO using BESMM 3.

4. *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.

5. *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.

6.0 Conclusions

Currently, BIM had significantly impacted on the way buildings are designed and constructed. BIM is changing the way buildings and other infrastructure look, the way they function, and the ways in which they are built. The BIM process and technology have defined obvious trends that make it mandatory for stakeholders in the construction industry to embrace it wholly as an innovation that has come to stay.

Current trends on the impact of BIM on industry processes manifest in the 'changing roles' of construction professionals as well as the evolution of new roles such as the 'BIM Manager'. As clients and employers are fully realising BIM potentials and are demanding for BIM, construction business processes must be made BIM-based for firms and even professional disciplines to survive (BCIS, 2011). Clients in some parts of the world have developed contract terms and user guidelines that enable full BIM implementation in their business processes. Technologically, BIM concept has revolutionised the industry through the adaption of BIM-based process such as: design, quantity take-off, cost estimating, scheduling, automated checking for code conformance, constructability analysis, etc. BIM vendors are increasingly expanding their scope and providing discipline-specific BIM tools with diverse functionalities that support and facilitate integrated and collaborative project delivery processes. In addition, building product manufacturers are gradually forced to provide parametric 3D catalogues which are directly used in BIM tools. Public sectors, especially in the US and the Scandinavian regions have made significant contributions in fully supporting BIM implementation through standardisations, legislations and funding of pilot projects and researches

However, with the continuous rapid technological developments happening simultaneously with the increased uptake of BIM in the construction industry, the future state of BIM is bright and certain. Researchers are currently leveraging the advantages and capabilities of technologies such as 'cloud computing' and 'Big data' concept to improve on some of the weaknesses associated with BIM-based applications. These technologies help store data, access data and expand organisations' modelling capabilities (especially SMEs). The following are some of the potential future directions and trends of BIM (Eastman et al., 2011):

i. ***Impact on owners: better options, better reliability:*** Owners will experience changes in the quality and nature of services available and an overall increased reliability of the project budget, program compliance, and delivery schedule. Many owners are already experiencing this.
ii. ***Impact on the design professions: shifting services and roles:*** Designers will experience productivity gains at the construction stage and deliver higher quality design services.
iii. ***Impact on construction companies:*** Construction companies, for competitive advantage, will seek to develop BIM capabilities both in the field and in the office. They will use BIM for 4D CAD and for collaboration, clash detection, client reviews, production management, and procurement.
iv. ***Impact on construction contracting: closer collaborations among designers and contractors:*** As design and construction companies gain experience with BIM, recognition of the added-value that can be achieved will

push them to move building procurement from design-bid-build to negotiated contracts, cost-plus, design-build, construction management at risk, and IPD arrangements

v. ***Impact on construction contracting: closer collaborations among designers and contractors:*** As consultants and contractors become more experienced with BIM, newer building procurement methods from design-bid-build to negotiated contracts, cost- plus, design-build, construction management at risk, and IPD arrangements

vi. ***Impact on construction education: integrated education:*** Prominent schools of architecture and civil engineering have already begun teaching BIM to undergraduates in their first year, and that trend is likely to spread in parallel with the adoption of BIM in the design professions.

vii. ***Impact on project documentation: on-demand drawings:*** The relevance and significance of drawings are expected to decline as BIM becomes common on construction sites, even though drawings are unlikely to disappear until digital display technologies are flexible and available for everyday use onsite.

Therefore, construction professionals (Architects, Quantity surveyors and Engineers) and all relevant stakeholders such as development control agencies and statutory authorities in the Nigerian Construction Industry must fully embrace and adopt BIM into their practices and accept the new roles defined by BIM in their service delivery to ensure survival. The public sectors in the country should spearhead the implementation process through funding, development of BIM standards that suits our practices, and legislations among others. The barriers identified as impediments to successful adoption should be effectively overcome and implementation plans and strategies should be developed. Government agencies such as the BPP should impose the use BIM on projects of certain magnitude (large projects) so that large contractors who have adequate resources and capacity take the lead for the implementation. The curriculum for the various built environment programmes in Nigerian Universities should be revised to adequately capture BIM in the training of construction professionals and the respective professional bodies of these professionals should ensure continuous development of their members.

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