IJARESM
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING, SCIENCE & MANAGEMENT

REVIEW ON BUILDING INFORMATION MODELING (BIM)

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***Abstract:** The rapid development of Information Technologies in Architecture, Engineering and Construction Industry (AEC), as well as in Architecture, Engineering, Construction and Owner/Operator (AECO), are consistently changing the definition of Building Information Modeling (BIM). BIM technology takes new meanings, highlighting the generic concepts of this universal determination for product deliverables build on usage of building intellectual 3D virtual model associated with this processes like project inception, design, evaluation, construction, operation and demolition. In his article, the authors review the trends of BIM concept development, benefits, as well as obstacles and problems of practical BIM.*

***Keywords:** Building Information Modeling, Benefits, Obstacles, and Flow of information*

I. INTRODUCTION

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.

Traditional building design was largely reliant upon two-dimensional technical drawings (plans, elevations, sections, etc.). Building information modeling extends this beyond 3D, augmenting the three primary spatial dimensions (width, height and depth) with time as the fourth dimension (4D) and cost as the fifth (5D). BIM therefore covers more than just geometry. It also covers spatial relationships, light analysis, geographic information, and quantities and properties of building components (for example, manufacturers' details).

BIM involves representing a design as combinations of "objects" – vague and undefined, generic or product-specific, solid shapes or void-space oriented (like the shape of a room), that carry their geometry, relations and attributes. BIM design tools allow extraction of different views from a building model for drawing production and other uses. These different views are automatically consistent, being based on a single definition of each object instance. BIM software also defines objects parametrically; that is, the objects are defined as parameters and relations to other objects, so that if a related object is amended, dependent ones will automatically also change. Each model element can carry attributes for selecting and ordering them automatically, providing cost estimates as well as material tracking and ordering.

For the professionals involved in a project, BIM enables a virtual information model to be handed from the design team (architects, landscape, surveyors, civil, structural and building services engineers, etc.) to the main contractor and subcontractors and then on to the owner/operator; each professional adds discipline-specific data to the single shared model. This reduces information losses that traditionally occurred when a new team takes 'ownership' of the project, and provides more extensive information to owners of complex structures.

II. HISTORY

The term 'building model' (in the sense of BIM as used today) was first used in a 1986 paper by Robert Aishthen at GMW Computers Ltd, developer of RUCAPS software - referring to the software's use at London's Heathrow Airport. The term 'Building Information Model' first appeared in a 1992 paper by G.A. van Nederveen and F. P. Tolman.

However, the terms 'Building Information Model' and 'Building Information Modeling' (including the acronym "BIM") did not become popularly used until some 10 years later. In 2002, Autodesk released a white paper entitled "Building Information Modeling and other software vendors also started to assert their involvement in the field. By hosting contributions from Autodesk, Bentley Systems and Graphisoft, plus other industry observers, in 2003, Jerry Laiserin helped popularize and standardize the term as a common name for the digital representation of the building process. Facilitating exchange and interoperability of information in digital format had previously been offered under differing terminology by Graphisoft as "Virtual Building", Bentley Systems as "Integrated Project Models", and by Autodesk or Vectorworks as "Building Information Modeling".

As Graphisoft had been developing such solutions for longer than its competitors, Laiserin regarded its Archicad as then "one of the most mature BIM solutions on the market but also highlighted the pioneering role of applications such RUCAPS, Sonata and Reflex. Following its launch in 1987, ArchiCAD became regarded by some as the first implementation of BIM, as it was the first CAD product on a personal computer able to create both 2D and 3D geometry, as well as the first commercial BIM product for personal computers.

To those familiar with the construction industry it may appear as though BIM appeared virtually overnight. In a traditionally slow moving field, the percentage of companies using BIM has jumped precipitously from 28% in 2007, to 49% in 2009, and to 71% in 2012. As of 2014 it can be assumed this number is edging ever higher. However, this recent proliferation of this technology belies a long iterative software development process of over 40 years.

As with most new technologies, the underlying concepts of BIM were first developed by academics before being adopted by industry, and can be traced back to basic 2D and 3D computer-aided design (CAD) research of the 1970s.

As personal computers became more powerful, the usefulness of these tools to architects and engineers became increasingly evident. In 1984, the first commercial version of ArchiCAD was released for the Apple Lisa personal computer, the oldest continuously marketed BIM architectural design tool today.

The next early leap for BIM occurred with the introduction of the 4^{th} dimension, 4D, or “time”. In 1986, the concept of temporal phasing was used for the first time during the phased construction of Heathrow’s Terminal 3.

The dimensions of BIM were further developed to a 5th, or 5D, in 2000. The release of AutoDesk Revit allowed cost to be associated with individual components, thus allowing contractors to generate not only construction schedules, but also cost estimates. One of the first projects to use AutoDesk Revit was the Freedom Tower in New York, which was completed in a series of separate but linked BIM files.

III. LITERATURE REVIEW- BIM IMPLEMENTATION TRENDS

- **United States of America**

The Associated General Contractors of America and U.S. contracting firms have developed various working definitions of BIM that describe it generally as: an object-oriented building development tool that utilizes 5-D modeling concepts, information technology and software interoperability to design, construct and operate a building project, as well as communicate its details.

Although the concept of BIM and relevant processes are being explored by contractors, architects and developers alike, the term itself has been questioned and debate with alternatives including Virtual Building Environment (VBE) and virtual design and construction (VDC) also considered.

BIM is seen to be closely related to Integrated Project Delivery (IPD) where the primary motive is to bring the teams together early on in the project. A full implementation of BIM also requires the project teams to collaborate from the inception stage and formulate model sharing and ownership contract documents.

The American Institute of Architects has defined BIM as "a model-based technology linked with a database of project information", and this reflects the general reliance on database technology as the foundation. In the future, structured text documents such as specifications may be able to be searched and linked to regional, national, and international standards.

- **United Kingdom**

In the UK, the Construction Project Information Committee (CPIC), responsible for providing best practice guidance on construction production information and formed by representatives of major UK industry institutions, produced (c.2008) a similar definition to that produced by the US National BIM Standard Project Committee. This was proposed to ensure an agreed starting point, as different interpretations of the term were hampering adoption.

In May 2011 UK Government Chief Construction Adviser Paul Morrell called for BIM adoption on UK government construction projects of £5million and over. Morrell also told construction professionals to adopt BIM or be "Betamaxed out". In June 2011 the UK government published its BIM strategy, announcing its intention to require collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on its projects by 2016. Initially, compliance will require building data to be delivered in a vendor-neutral 'COBie' format, thus overcoming the limited interoperability of BIM software suites available on the market. The UK Government BIM Task Group is leading the government's BIM programme and requirements, including a free-to-use set of UK standards and tools that define 'level 2 BIM'.

National Building Specification (NBS), owned by the Royal Institute of British Architects (RIBA), publishes research into BIM adoption in the UK. There have now been five annual surveys. The April 2015 survey of 1,000 UK construction professionals revealed that BIM adoption had increased from 13% in 2010 to 48% in 2014.

Several UK-based websites host BIM objects, including those of many construction product manufacturers.

- **Singapore**

The Building and Construction Authority (BCA) has announced that BIM would be introduced for architectural submission (by 2013), structural and M&E submissions (by 2014) and eventually for plan submissions of all projects with gross floor area of more than 5,000 square meters by 2015. The BCA Academy is training students in BIM.

- **South Korea**

Small BIM-related seminars and independent BIM effort existed in South Korea even in the 1990s. However, it was not until the late 2000s that the Korean industry paid attention to BIM. The first industry-level BIM conference was held in April, 2008, after which, BIM has been spread very rapidly. Since 2010, the Korean government has been gradually increasing the scope of BIM-mandated projects. McGraw Hill published a detailed report in 2012 on the status of BIM adoption and implementation in South Korea.

- **Canada**

Several organizations support BIM adoption and implementation in Canada: the Canada BIM Council (CANBIM), the Institute for BIM in Canada and buildingSMART Canada.

Founded in December 2008, CANBIM is a consensus- and committee-driven organization for BIM in Canada developed by business leaders to standardize the use of models in architecture, engineering and construction. Can BIM has close to 100 architectural, engineering, contracting and trade firms, and is managed by industry volunteers, hosting events across Canada. Members fund and direct the priorities and activities through eight discipline focused committees.

The mission of the IBC is: "to lead and facilitate the coordinated use of Building Information Modeling (BIM) in the design, construction and management of the Canadian built environment." Its founding partner organizations represent specific industry sectors with keen interest in seeing BIM implemented in a way, and at a pace, that enables the primary stakeholders to understand their roles and responsibilities and to assess their capacity to participate in this process.

buildingSMART Canada, the Canadian chapter of buildingSMART International, works in partnership with all Canadian AECOO community stakeholders including Canadian associations of architects, engineers, specification writers, contractors as well as public and private owners, government and industry. It creates standards and supports programmes and tools to ensure that Canada will be successful in its movement towards a better built environment supported through open and internationally compatible standards for BIM.

- **New Zealand**

In 2015, many projects in the rebuilding of Christchurch were being assembled in detail on a computer using BIM well before workers set foot on the site. The New Zealand government started a BIM acceleration committee, as part of a productivity partnership with the goal of 20 per cent more efficiency in the construction industry by 2020.

- **Switzerland**

In Switzerland, ETH Zurich University has taught CAD and digital architecture since 1992 through Prof. Dr. Schmitt. Since 2009 through the initiative of buildingSMART Switzerland, then 2013, BIM awareness among a broader community of engineers and architects was raised due to the open competition for Basel's Felix Platter Hospital where a BIM coordinator was sought. BIM has also been a subject of events by the Swiss Society for Engineers and Architects, SIA.

- **Netherland**

On 1 November 2011, agency within the Dutch Ministry of Housing, Spatial Planning and the Environment that manages government buildings, introduced the RGD BIMnorm, which it updated on 1 July 2012.

- **Spain**

A July 2015 meeting at Spain's Ministry of Infrastructure launched the country's national BIM strategy, making BIM a mandatory requirement on public sector projects with a possible starting date of 2018.

- **India**

In India BIM is also known as VDC: virtual design and construction. India is an emerging market with an expanding construction market and huge potential for large scale residential and commercial development (because of population and economic growth). It has many qualified, trained and experienced BIM professionals who are implementing this technology in Indian construction projects and also assisting teams in the USA, Australia, UK, middle east, Singapore and North Africa to design and deliver construction projects using BIM. In spite of this, and India's vibrant building sector, BIM usage was reported by only 22% of respondents to a 2014 survey.

IV. IMPLICATIONS ON THE FLOW OF INFORMATION

As noted earlier, the implementation of BIM changes the traditional flow of information in the AEC industry. For the sake of simplicity, let us consider the interaction within only the core design team, with only architect, structural engineer, and the mechanical engineer. In Figure 1(A) below, which depicts the traditional flow of information within the design team, all information goes through the architect. When a mechanical engineer has a structural-related question, he/she passes it along to the architect, who passes it to the structural engineer, who reports back to the architect, who in turns replies back to the mechanical engineer who initiated the question. Whereas in a project where BIM is implemented, all relevant parties work on their specific aspect of the building information model with all other disciplines' models linked into theirs for reference while the discipline-specific models are being developed. This model of communication, as depicted in Figure 1(B), encourages more direct interactions among different disciplines of the same design team and keeps all the parties informed on design changes as everyone's model is kept up-to-date with the live linking of models from all other parties.

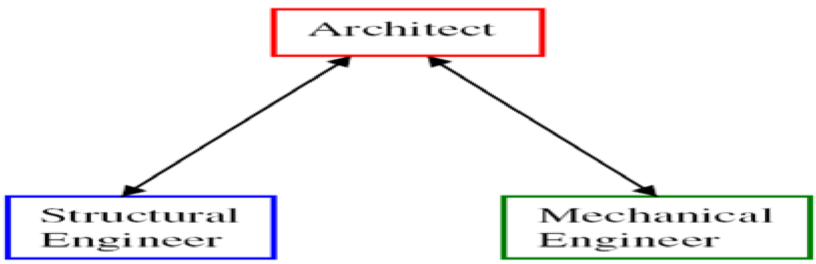

FIGURE 2(A)

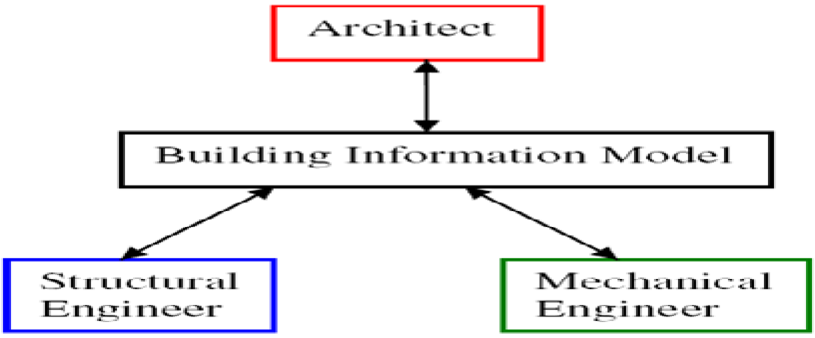

FIGURE 2(B)

FIGURE 2 – Flow of information in the design team a) in the traditional process; and b) with implementation of BIM. Source: Derrick Roorda (2008)

V. DIFFERENCES BETWEEN 3D CAD AND BIM

Having been to various conferences and discussed "BIM" with engineers of different generations, it appears that there is widespread misunderstanding of what BIM is and what it is not. Most people, especially those not familiar with 3D graphic programs such as 3D AutoCAD and Rhinoceros, often confuse 3D CAD and BIM. While there are overlaps between the two, there are significant distinctions that make the idea of BIM a great one in the AEC industry. A simplistic, yet effective explanation of the differences between the two vastly different concepts is that 3D CAD, while capturing three-dimensional information, is mere geometry. A W8x10 steel beam representation in 3D CAD is nothing more than a solid or a collection of surfaces in the geometry of a familiar rolled steel shape. To create a beam in 3D CAD, the user needs to first define a line that is the length of the beam. A polyline in the geometry of the cross section of the beam is then introduced, place appropriately in relation to the length of the beam and its orientation about its centroid, and then finally extruded to make the graphic representation of a steel beam. There is no intelligence inherent in this representation; no other information aside from geometry is created.

In a building information model, however, a W8x10 steel beam "knows" that it is a steel beam with certain pertinent information, such as length, level association, to which columns does it frame into, section properties, etc. The promise by BIM is to be more readily realized when changes are made in the model. In building information model, when one of the beam's supporting columns is moved, the location of the beam will be automatically adjusted to follow the new location of its support. Most listeners are impressed with this explanation, which in all its right is only a tiny part of the potential of BIM, due to the fact that in 3D CAD, to make the above-mentioned change is a tedious process: after one of the column is moved, the user needs to manually delete the extrusion that was the representation of the beam, recreate the new line that defines the new location of the beam, reintroduce the cross section that represents the said shape of the beam, rotate it to be perpendicular to the new line of the beam and its intended orientation (which is not always trivial in 3D), and then extrude the section again to recreate the beam representation.

Also, unlike traditional 2D drawings, a building information model contains pertinent information such as three dimensional geometric relationships, as well as a fully parametric relationship between various views of the model. For instance, in traditional practice, when one beam size is changed, this change needs to be manually updated not just on plan, but also on relevant sections, details and schedules. In a building information model, however, the change of beam size can be done in any view, and this change will automatically be updated in any and all views containing this beam in question. All schedule and quantity takeoff will also be updated without user intervention. It is obvious that the use of BIM holds much promise in the increase of efficiency in the AEC industry, and is highly regarded as the way of the future.

VI. BENEFITS OF BIM

- **Capture Reality:**

The wealth of information that's easily accessible about project sites has expanded greatly with better mapping tools and images of Earth.

- **Maintain Control:**

The digital model-based workflow involves such aids as auto-save and connections to project history so that users can be certain they've captured their time spent working on the model.

- **Improve Collaboration:**

Sharing and collaborating with models is easier than with drawing sets, as there are a lot of functions that are possible only through a digital workflow.

- **Simulate and Visualize:**

There are an increasing number of simulation tools that allow designers to visualize such things as the sunlight during different seasons or to quantify or the calculation of building energy performance.

- **Resolve Conflict:**

The BIM toolset helps automate clash detection of elements such as electrical conduit or ductwork that run into a beam. By modeling all of these things first, clashes are discovered early, and costly on-site clashes can be reduced. The model also ensures a perfect fit of elements that are manufactured off-site, allowing these components to be easily bolted into place rather than created on-site.

- **Sequence Your Steps:**

With a model and an accurate set of sub-models for each phase during construction, the next step is a coordinated sequencing of steps, materials, and crews for a more efficient construction process.

- **Dive into Detail:**

The model is a great end point for a lot of knowledge transfer, but there's also a need to share a traditional plan, section, and elevation, as well as other reports with your project team. Using automation and customization features, these added sheets can save valuable drafting time.

- **Present Perfectly:**

With all of the design completed on a capture and alteration of existing reality, the model is the ultimate communication tool to convey the project scope, steps, and outcome.

- **Take It With You:**

With the added benefit of a model that's tied to a database, you have a great deal of intelligence at your fingertips. Combining this capability with the cloud, as with Autodesk's BIM 360 Field software, means that you have access to the model and project details from anywhere, on any device.

VII. OBSTACLES TO BIM

- **Cost of Software and Hardware**

Every organization currently utilizing 2D or 3D CAD drafting software can attribute a cost element against purchasing, maintaining and upgrading software licenses to keep a competitive market advantage. Current trends show that the cost of BIM software packages tends to be more expensive than CAD software packages available on the market. With the introduction of BIM software, the requirements on hardware have increased significantly. Currently, CAD software can be operated (with limitations) on a vast majority of professional laptops. Yet with the introduction of BIM software, dedicated high-specification workstations, equivalent to those required by advanced modeling and rendering software, are required.

- **Cost of Training**

With new software, there is a great demand to train staff quickly so that the investment can be justified. It is not realistic to assume professionals with CAD proficiency will be able to learn new BIM software quickly or without specialized training. Given the fundamental differences between BIM and CAD, training should be considered a requirement for all professionals involved with designing and producing documentation.

- **Transition from Drafting to Modeling**

When moving from a CAD-based drafting environment to a BIM-based modeling environment, a change in the workflow will surround what used to be simple drafting tasks such as copying markups or picking up redlines. These tasks now require a higher-level skilled design drafter who has an understanding of the project and the materials used. The costs associated with training and maintaining a skilled design modeler are higher than a draftsman with no knowledge of the trade. Some companies may even be compelled to stay out of the BIM world altogether due to the time- and knowledge-intensive nature of BIM.

- **Compatibility Between Software Platforms**

One of the biggest issues with early adaptors of BIM is the issue of inter-product compatibility. Due to the relatively new nature of the market, every software manufacturer is doing something different with its software. This interoperability challenge can make it difficult for projects to function if different team members own different software packages.

- **Innovation**

Since a goal of BIM is to assign constraints and parameters to intelligent objects to improve efficiency, there is a potential to inhibit innovation which would possibly otherwise occur without the automated processes and shared knowledge that BIM now provides. Those firms implementing BIM should view the parameters and metadata constraints as a global database that allows designers to save time associated with updating and configuring product-specific data repetitively on different projects, hence increasing the amount of time spent on system design and innovation.

VIII. CONCLUSION

Building Information Modeling (BIM) is the use of computer generated model to simulate the planning, design, construction and operation of a facility; a technology that allows users to create visual simulation of a project with a digital prototype of a building prior to construction. The deployment of BIM in construction can make the industry more efficient, effective, flexible, and innovative. The BIM technology and tools are developing rapidly (based on basic BIM methodology), but their effective and fast use in the practice are constrained by existing contractual arrangements and traditional organization in the projects directed by stronger party with atmosphere of fights for individual benefits instead for search better project delivery solutions and alternatives, which can make participation in the project delivery beneficial for all involved.

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 ISSN : 2394-1766