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Contribution Of Building Information Modeling (BIM) To Solve Problems In Architecture, Engineering and Construction (AEC) Industry and Addressing Barriers to Implementation of BIM

Vinay Kushwaha
Assistant Professor, Civil Engineering Department, SSITM, Chhattisgarh, kushvinay161@gmail.com

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Abstract – In 21st century, Building Information Modelling (BIM) is one of the most eminent advancement that has taken place in architecture, engineering and construction (AEC) industry. BIM provides a digital platform for managing the functional and physical characteristics of a building throughout its lifecycle. It offers a collaborative approach for design, planning, construction and operation of the facility. BIM has served to satisfy the objectives of AEC industry to improve productivity and quality of project delivered, curtail the project delivery time and cost. BIM enables architects and engineers to visualize any design, construction, managerial or operational barrier which may arise during the actual construction activities. Also, BIM finds the application of cloud computing which enables all the stakeholders to access data related to construction project. As the visualization and hardware technology is improving, the framework approach is moving from "client based" to "host based" which is referred to as Cloud Computing. This paper aims at evaluating the extent to which BIM has contributed to soothe the plight of AEC industry and the various hurdles which were faced during implementation of BIM and are still contemporary.

Key Words: *Building Information Modelling, BIM, AEC Industry*

1. INTRODUCTION

1.1 What is Building Information Modelling?

In simple terms, BIM is a tool to collaboratively design various elements of a structure in 3-D format and provides a better means to visualize and analyze these structures. In actual, a BIM design is equivalent to virtually designing a structure which shows virtual elements of actual building parts and pieces used to build a building. These virtual elements are digital prototype of physical building elements that allows us to simulate the building and understand its behavior in a computer environment way before actual construction starts. BIM provides a much better means of communication and distribution of information between clients, construction and architecture firms and legal authorities involved in project.

Fig-1 *Virtual designing using BIM and it's comparison with actual construction of same BIM design.*

1.2 What Special Does BIM Offer?

Apart from designing BIM serves a wide variety of purpose in Construction Project Management. What makes BIM unique is its collaborative effort to solve problems related to Construction Engineering. The collaborative feature it offers can be appreciated very well by its application in almost all construction related activities. BIM serves an essential purpose in all aspects of construction and project management including design, scheduling and estimating, resource allocation, supply chain management, account of deliverables during the course of construction, structural health monitoring, Data Management and Structural Management. Looking at these aspects it can rightly be said that instead of implementing BIM as a technology it is rather implemented as a process which starts even before actual construction and is serves useful purpose throughout the service period of structure.

1.2(A) Improved 3-D Visualization.

The 3-D visualization provided by the BIM is more densely packed with information about the various elements of structure, hence it provides a more comprehensive prior analysis of possible problems that are faced during actual construction which ensures timely completion of projects and prevents overshooting of budget arising due to uncertainties which pop up during actual construction. The visualization also helps to keep track of the construction and if any changes are required in designing during the course of construction then it can be analyzed and made readily using BIM. The accuracy which BIM 3-D visualization models provides through animation diminishes the possibility of risk at which the engineers

and architects are at when it comes to successful delivery of projects.

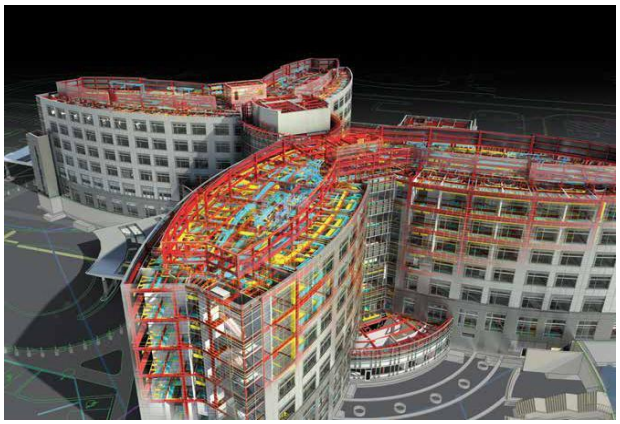


Fig-2 *A 3-D model design of a building using BIM.*

1.2 (B) Unique "D" Feature of BIM.

In addition to 3-D visualization which signifies length, breadth and height of structure, BIM offers 4-D, 5-D, 6-D and 7-D features. The 4th, 5th, 6th and 7th dimension pertains to Time (Scheduling), Cost (Estimating), Sustainability and Facility Management.

a) 4TH Dimension—Time (Scheduling).

Prior to BIM many software like MS Project and Primavera were available for scheduling purpose but in these the scheduling can't be collaborated with design but BIM solves this intricacy. With the 3-D visualization the scheduling can be done simultaneously taking time as 4th dimension.

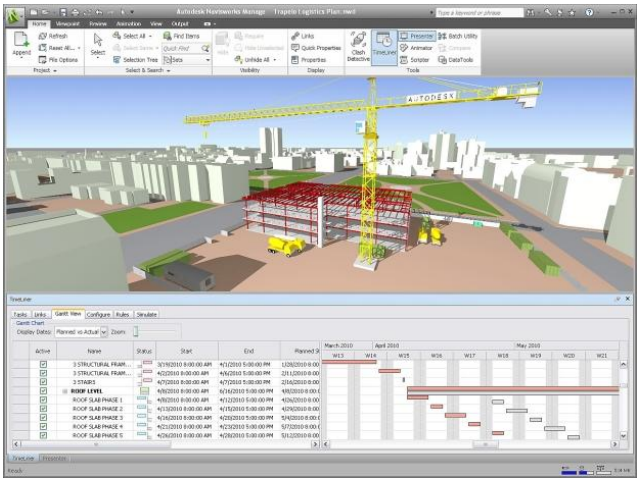


Fig-3 -- *Scheduling timeline is collaborated with 3-D Model of Structure taking time as 4th Dimension*

b) 5TH Dimension—Cost (Estimating).

The 5th dimension is cost which relates to estimating purpose. Estimating involves precise quantification of modeled material and generates cost estimates at a faster rate. BIM provide forehand cost information to the owner which makes decision making process more effective. It allows BIM experts to concentrate more on value adding activities in estimation such as construction assembly identification, generating price and factoring risks which are very much useful for high quality estimation. When synchronized with the construction schedule, a BIM cost estimate can help track budget throughout the construction phase.

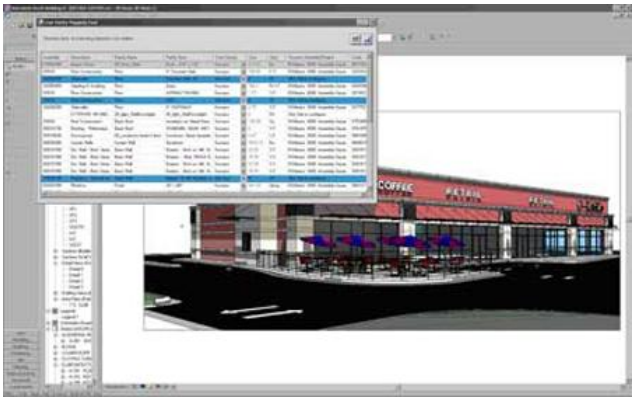


Fig4 – *An intermediate step in BIM for cost estimation using Autodesk Revit.*

c) 6th Dimension – Sustainability.

A 5-D BIM model limit itself and fail to consider the environmental impact because of its negligence to consider two important aspects of Sustainability: the economic and the social aspect. These aspects are complex to analyze and adds to the cost of project and therefore are of limited value while comparing design options. To make BIM environment friendly, a new concept called "Green BIM" has been introduced which involves collaboration of Green Building and BIM to keep check on adverse effects of construction on environment.

Fig 5 -- *Zero-energy, and carbon neutral community in USA. BIM was used to create sun studies which helped shape the roofs.*

d) 7TH Dimension-- Facility and Asset Management

Building assets database can be linked to BIM record model and is utilized to reinforce the planning and decision making relevant to facility management issues. The impact of enhancing or altering the building assets can be reflected explicitly using BIM further quantity takeoffs of the assets can also be developed for cost estimation and financial reporting. Facility managers are responsible for operating and maintaining the structures throughout their service period which span a period of 30 years or even more. BIM provides two essential features which are used in Facility Management: Geometry of building and related assets, and bill of the materials. BIM system doesn't only produce a model of building but also provides an action plan for logistics, facility management and real-time collaboration.

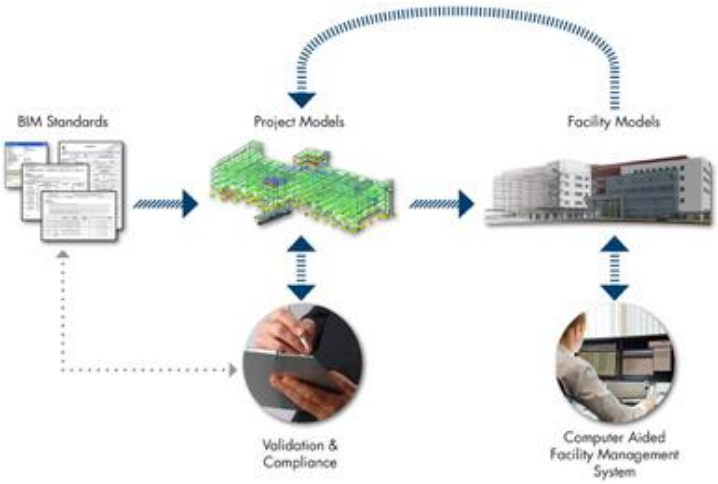


Fig-6 *BIM modelling making it useful through every step of Facility Management.*

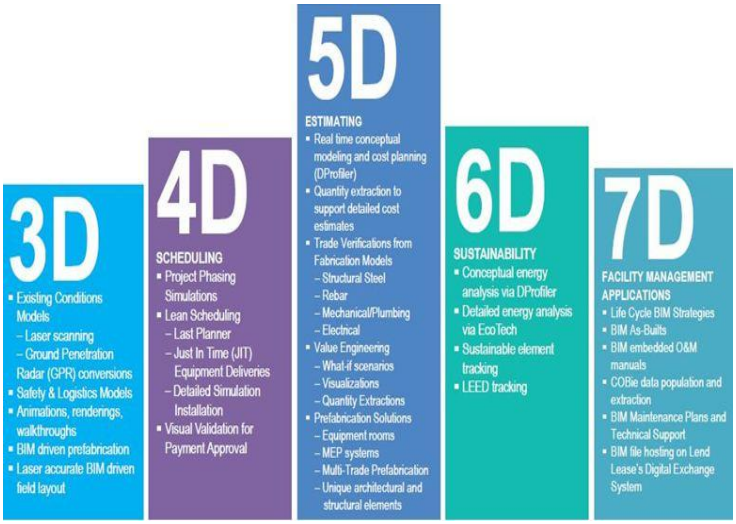


Fig-7 *Different dimensions of Building Information Modelling.*

2. *APPLICATION OF BIM TO SOLVE PROBLEMS IN AEC INDUSTRY.*

Proper implementation of BIM can solve the excruciating problems related to construction, project management and facility management.

- **Visualization:**
  The 3-D visuals of BIM contains precise geometry and present amazingly accurate and detailed building model**.** Simulation based visuals obtained from BIM expands the visual context of a design concept for more effective validation. This accurate and precise visualization facilitates the prior understanding of any anomaly which may arise during the actual construction activities.
- **Parametric Objects**:
  A Building Information Model is designed using parametric objects such as ventilators, windows, steel bars, concrete slabs, water supply pipes, electrical fitting lines. These parametric objects are integral part of BIM which allows for exact modelling of the targeted building to be constructed. This way you are constructing a virtual building which is properly defined with intelligent objects.
- **Faster and Better Communication:**
  Similar to Cloud Computing, BIM provides a common platform for all the stakeholders to have access to information. This common platform eliminates the need to apprising every stakeholder when any change is made in project in subsequent time during the project completion period. This saves time, effort and fosters a better communication among the stakeholders.
- **Scheduling and Estimating:**
  Prior to BIM, the scheduling and estimating activities were done in software like Primavera or MS Project and designing was done separately in CAD. These two endeavor took plenty of time, but after designing in BIM it takes much lesser time to schedule and do the cost estimates.
- **Change Management:**
  The data is placed in a central location in BIM, so any modification made to any element of building design will automatically make the proportionate changes to other elements of design. This serves to the strict quality assurance demands of industry and also makes the documentation faster. In tradition methods if a change is made in position of a beam or wall, then the changes were made accordingly in each and every component affected by this change. But in BIM, if a change is made in one component then it automatically gets reflected in all other components.

- **Conflict Management:**
  Since Building Information Models provides 3D visualization of all elements of a building, any interference arising among different elements of building can be easily detected. For example, if an electric wiring line is intersecting with water supply system then it can be easily detected and can be rectified instantly.
- **6D and 7D Approach to Projects Using BIM:**
  As the advancement in technology is taking place rapidly, a need for sustainable development is equally vital. The 6th dimension of BIM with pertains to Sustainability provide alternate solutions to construction activities without compromising on environment health. In recent developments to sustainability, efforts have been made to collaborate Green Building Concept with BIM to make construction even more ecofriendly. Other dedicated efforts like conceptual energy analysis via DProfiler, detailed energy analysis via Eco tech and LEED tracking makes BIM even more special.
  Facility Management as the 7th dimension enables the Facility Managers for maintenance and renovation operations. BIM can be used effectively in infrastructure health monitoring which continues till service period of structure which is usually 30 years or even more.
- **Waste Minimization:**
  Demand of more profitability has made waste minimization an important criteria to take care of. So far, many efforts have been made for construction waste minimization but a comprehensive approach to all construction related activities including design and pre construction phase was first introduced by BIM. Virtual design before the actual construction ensures a limited waste production and also optimizes energy usage.
- **Controls and Minimizes the Cost of Project:**
  The combined application of lean construction and BIM optimizes the resource utilization and minimize the waste generated in project. A significant amount of funds is saved by the prefabrication and scheduling aspects of BIM. The amalgam of Green construction and BIM also makes the project economical.
- **Fast Delivery of Project:**
  As the technology is growing faster, the need to complete projects shortly is on high demand by clients. Because of collaborative effort made by BIM for precise documentation, instant change management, better communication, improved visualization the projects are delivered well before time and adheres to client satisfaction simultaneously.
- **Prefabrication:**
  The process of BIM was developed presuming prefabrication. BIM development follows the general truth "The more the building is built off site and then onsite, the better the saving, both in labor and material costs". Prior to BIM, the 2D document of the material to be manufactured was designed and then handed over to CAD expert who design in a simulated computerized environment. Whereas BIM, instead of generation a 2D document directly generates 3D design model for prefabricators thus saving time and cost involved in 2D designing and CAD.
- **Acoustic and Lighting Feature**:
  Analysis features available in BIM can allow to analyze the reverberation time for different conditions allowing the designer to test and decide for STC (Sound Transmission Class) rated building especially in a location where noise pollution is a menace. While designing it is an important issue to determine how much light will enter the building and is this level of light sufficient enough the lightning condition to work. Efficient and comfortable lighting is a LEED certification criteria as well.
- **Energy Analysis and LEED Achievement :**
  Leadership in Energy and Environmental Design (LEED) is concerned with sustainability and environmental impact of the projects. 40% of the energy produced worldwide is used by the buildings. So, legal authorities are very much stringent about energy usage of buildings. BIM accompanied with green construction soothes this concern. BIM also provides tools to calculate heat loss or gain by building and modelling performance of the building throughout the year when energy availability vary.
- **Return on Investment:**
  For small scale projects BIM is not beneficial because the initial cost involved with usage of BIM is high. But, if used for large complicated projects BIM incurs heavy chunk of profit because of increased productivity. The qualitative benefits of reduced time overruns and lower change order cost are appreciable.

$$\frac{\left(B-\left(\frac{B}{1+E}\right)\right)\times(12-C)}{A+(B\times C\times D)} = \text{First Year ROI}$$

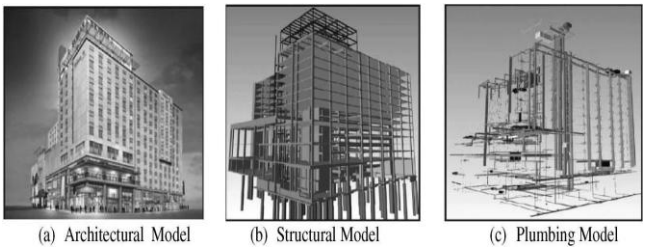
A = cost of hardware and software (dollars)
B = monthly labor cost (dollars)
C = training time (months)
D = productivity lost during training (percentage)
E = productivity gain after training (percentage)

3. *BIM Benefits: Case Studies.*

3.1 Aquarium Hilton Garden Inn, Atlanta, Georgia:

The Aquarium Hilton Garden Inn project comprised a mixed-use hotel, retail shops, and a parking deck.
Brief project details are as follows:

- Project scope: $46 million, 484,000-square-foot hotel and parking structure
- Delivery method: Construction manager at-risk (CM at-risk)
- Contract type: Guaranteed maximum price
- BIM scope: Design coordination, clash detection and work sequencing.
- BIM cost to project: $90,000, or 0.2% of project budget ($40,000 paid by owner)
- Cost benefit: Over $200,000 attributed to elimination of clashes
- Schedule benefit: 1,143 hours saved.



(a) Architectural Model (b) Structural Model (c) Plumbing Model

Fig 8 *Building Information Models of Aquarium Hilton Garden Hill.*

More than 590 clashes were detected before the actual construction began and the overall cost saving pertaining to this was $801,565. For the purpose of calculating net cost saving it was assumed that 75% of the collision can be detected by traditional practices. So, the net cost saving by implementation of BIM was estimated to be $200,392.

3.2 Savannah State University, Georgia, USA

- Project: Higher education facility, Savannah State University, Savannah, Georgia
- Cost: $12 million
- Delivery method: CM at-risk, guaranteed maximum price
- BIM scope: Planning, value analysis
- BIM cost to project: $5,000
- Cost benefit: $1,995,000

For this project three different building information models were prepared and BIM based cost estimate was also calculated. The entire process took around 2 weeks to finalize the design and the client saved $1,995,000 at the predesign stage by selecting the most economical design. This was possible only because of proper implementation of BIM to project.

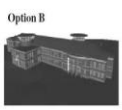
Option/Aspect	Specifications	Option A	Option B	Option C
Front Elevation				
Plan				
Stories	Not specified	2	2	3
Construction Funding	$11,000,000			
Max. Cost/GSF	$147.74			
Area (GSF)	74,459	87,296	83,018	73,852
Net Area	46,537	49,125	50,612	43,338
Net to Gross Ratio	63%	56%	61%	59%
Cost Scenarios				
Budget: $147.74/sf	$11,000,000	$12,897,111	$12,270,919	$10,910,894
Mid-Range: $175.00/sf	$13,030,325	$15,276,800	$14,535,140	$12,924,100
High-Range: $200.00/sf	$14,891,800	$17,459,200	$16,611,600	$14,770,400
Building Skin				
Primary Materials	Brick/Precast/Glass	Brick/Precast/Glass	Brick/Precast/Glass	Brick/Precast/Glass
Skin Articulation	Articulated, Trim	Articulated, Trim	Articulated, Trim	Articulated, Trim
Floor to Floor Height	n/a	14' @1; 14'@ Upper	14' @1; 14'@ Upper	14' @1; 14'@2; 12' @ Upper
Skin to Floor Ratio	n/a	58%	50%	39%
% Glass, % Brick	n/a	20% Glass, 80% Brick	28% Glass, 72% Brick	36% Glass, 64% Brick

Fig 9 *Scope and Budget options for Savannah State University.*

4. *Barriers to Effective Implementation of BIM:*

- **Hesitancy to Adopt New Technology:**
  The stakeholders are with a stiff mindset and are not comfortable enough to adopt new technology as it would to change the whole approach in the way they manage projects which require lot of efforts.
- **Lack of BIM Experts:**
  Since BIM is relatively a new technology in AEC industry and because of lack of BIM education in professional and academic institutes there are not much available BIM experts in market. This makes the AEC industry even more vulnerable to stick to traditional methods of project delivery.
- **Unavailability of BIM Specific Clients:**
  Due to concrete mindset of clients to adhere to tradition approaches of project delivery, there is not much demand for BIM specific projects. The awareness about the benefits of BIM is not sufficient enough to motivate the clients to demand for BIM driven projects.

- **Return on Investment:**
  BIM is not suitable for small scale projects. The cost incurred in BIM implementation may exceed the proposed funds for project if the project is small scale. Hence, in these type of projects the return of investment generally results in overshooting of project budget.
- **Lack of BIM Education:**
  Even though there are short term courses available in market to learn BIM, but these courses are not equipped to facilitate an appreciable level of BIM learning. The lack of proper curriculum and insufficient training make these courses superfluous.
- **High Initial Cost:**
  The economic benefits of BIM can be realized only at the end of projects. BIM implementation requires huge initial investment which demotivates the clients and firms to implement the use of BIM. This is the reason why BIM is not used in small scale projects.
- **Little Efforts from Government to Adopt BIM:**
  In every country a major number of projects are handled by Government institutes or public sector projects are handed over to private firms. But, the government also doesn't show enthusiasm to implement BIM. It's difficult to change mindset of private clients because their main motive is profit, but if the government takes an initiative adopt BIM in more number of projects then this would serve as an motivation and lesson to other private firms to implement BIM.
- **Software and Training:**
  Implementation of BIM requires purchasing of software and training the staff to operate it. The may impact the financial condition of organizations. Software packages are costly and need regular updates which adds to the financial concerns of the organization. Also, providing training to staff from experts needs an appreciable chunk of funds.
- **Lack of Supply Chain buy-in:**
  To ensure the effective implementation of BIM all the stake holders i.e. clients, contractors, sub-contractors and pre-fabricators must have knowledge of BIM. Adoption of BIM involves a collaborative effort from all the stakeholders, otherwise a conflict may rise.

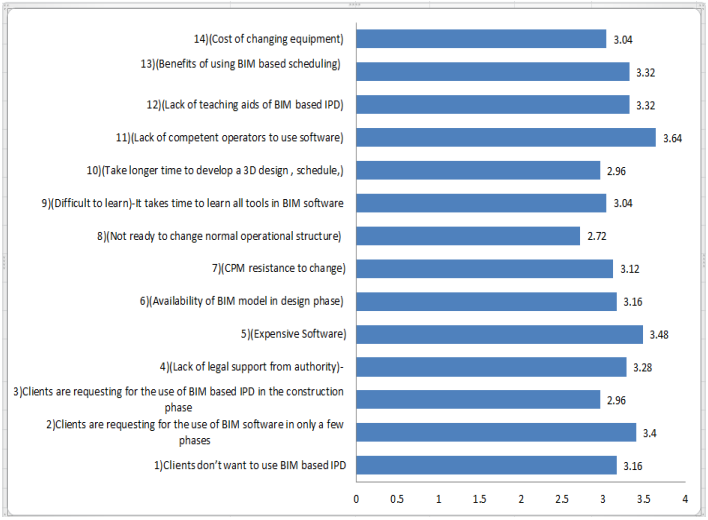


Fig 10- *Barriers to Building Information Modelling*

5. CONCLUSION

Without any doubt Building Information Modelling has brought a revolution in the AEC industry, but the rate of implementation of BIM in the industry is low because of various barriers addressed here. The lack of initiative from government organizations and educational institutes is the major factor which is responsible for very limited awareness and implementation of BIM. Transforming from traditional approaches to BIM is not an easy task, it requires collaborative efforts from government agencies and private organizations. To make the industry aware of benefits of BIM various seminars should be organized throughout the AEC industry which makes use of case study approach to enumerate the usefulness of BIM adoption. The government and education institutes must take an initiative to ensure that the advantage offered by the BIM is properly explored.

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