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Application of Building Information Modeling in Construction Projects – A Critical Review

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Abstract : Building Information modeling (BIM) is a valuable tool which provides extensive information about the nature & magnitude of work, documentation, specification, design, planning and scheduling construction resources, workmanship, quality, safety, energy analysis, life cycle costing etc. In the past few decades, there have been growing interests of the construction sector using BIM due to many benefits & effective utilization of resources during design, planning & construction of new buildings. The BIM is mainly focused on developing different models by adding time, cost and energy analysis in existing 3D model. It has potential to increase efficiency of the project, minimize waste and increase sustainability across construction projects. Although, studies in the past reported the application of BIM mostly in building construction; however, limited studies have been reported in infrastructure. Present study provides a comparative analysis of the impacts & benefits of BIM on the horizontal industry such as Roads, Bridges. Findings of this research provide a critical review of various studies reported on BIM & also suggests the potential area of research. The application of BIM in infrastructure sector has many challenges such as structural & design complexities, lack of skilled personnel, the type of infrastructure, expansion joints etc. throughout the life cycle of the projects which needs to be addressed in future studies. Also, application of BIM to the existing buildings faces many challenges such as automation of data capture, BIM creation, updating information etc. which yet to be studied and can be considered as potential area of future research.

Keywords: Building Information Mo0064eling, CAD, Crisis Management, Infrastructure.

I. Introduction

A. Construction industry

The construction Industry is the backbone of any nation's economy. It is essential for the correct progress of the country and it is consider as a unit to measure the economic growth of the country by measurement of the development of the infrastructure and construction sector. The construction industry is very complex industry which involves various parties in different processes and stages of project which work
together to achieve the target success of any project. The construction Sector is widely affected by many problems like Cost overrun, Time overrun and also the Quality of end product which is not achieved due to various problems during the Constructions stage of the project. The cost overrun for any project has been persistent problem and it has affected economy of different countries in the past. The Problems have not only cause significant effect on the project but also has caused several negatives effect on the main parties involved in the project like clients, Contractors, stakeholders, design team etc. It not only causes a significant decrease in the productivity of the project but also distrust and litigation among the parties, apart from the problems like cost and time overrun.

The need for the more cost effective, better quality and environmental friendlier construction has grown over the years, this factors are the main influence for the technology to be developed in the construction Industry. Building Information Modeling is one of the technologies resulted because of the constant development and has been creating a buzz in construction industry over past few years.

Building Information modeling has gained a significant acceptance in the present day in construction industry (Suermann and Issa, 2009). It is an upcoming technique gaining popularity in the construction Industry over last few decades. Suermann and Issa (2009) states Building Information Model as "A digital representation of physical and functional characteristics of a facility". The use of BIM has not only gained a measure of acceptance from Architects and engineer but also from the clients and stake holders.

Hardin (2009) states BIM has been an revolutionary Technology and process which has transferred the way that a building are being designed, analyzed constructed and managed. BIM has not only taken the construction industry to the new era of technology but has also speeded up the process of construction industry by reducing the risk and uncertainty of the any construction project. The UK government has implemented the use of BIM on UK government construction project of £ 5 million or over starting from 2016.This has been a major step proving the usefulness of BIM in Construction Industry and its Reliability. Although the use of BIM has not been used to its full advantages but the growth is been steady and slow.

B. Problems in construction

The relationship between the construction Industry has been mainly adversarial, which has caused the sad picture of construction industry which is overcoming its challenges over last few decades. The results of the fragmentation have caused haphazard implementation and uncontrolled quality in the construction projects, there has been significant increase in cost as well and the execution time of the project due to failure to communicate internally (Barlow, 2000). These problems affect

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the project success mainly due to various factors such as time, cost and quality which are generally interrelated to each other. The presence of cost overruns and time overruns are generally considered to be the main problems in any project along with the other attributes like the ineffective identification of the project output, the client needs and poor management of project. There is need for the main parties involving the project, not just to identify the problems in the project but suggest remedial measures to prevent them. The problem can be identified right at very beginning of the projects through effective planning and BIM can play a significant role in avoiding these problems (Baloi and Price, 2003). The construction Industry is still using its traditional ways of communications like exchange of drawing, documentations etc., that result in the need for adoption of BIM in the modern projects rather than completing it in old fashioned way. It has been well documented that the adoption of BIM in Construction Industry has significantly improved the project performance and become a key area in the construction sector (Vogt, 2010).

II. Material and Methodology

A. Defining Building Information Model

Many researchers have defined BIM but the main problem arises when the most of the definitions stated by the several authors fail to express the use of BIM on the time, cost and quality concept of any construction project (Vanlandea et al., 2008). The National BIM Standard (2007) defined BIM as: "A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability".

The basic theory Of Building Information Modeling was well termed by Thompson and Miner (2007) describes the relevant data required to the project is stored in one single online system and this data could be first executed in a virtual environment to identify any problem in the projects, when time and cost are added to this virtual project it almost instantaneously enables the cost time benefit analysis of the various different options available with the project. This enables the user to identify the amount of cost or time overrun that could happen in a project without even initiating anything in reality. Nick Nisbett (2007) is the one of the very earliest user of BIM in UK and who is also a key contributor to BS 1192:2007 Standard for managing BIM/CAD defined BIM as, "A digital model of a building in which information about a Project is stored. BIM can be 3D, 4D (integrating time) or even 5D (including cost) – right up to 'nD' (a term that covers any other information) (Nisbett and Dinesen, 2010).

There have been several other definitions given by Software Company like AEC info systems, Archicad, Autodesk which were described by authors like Eastman et al (2008) and Vogt (2010) in their research papers. But none of this definition were successful to include time cost and quality concept in the defining BIM. International Alliance for interoperability (IAI) and Associated General Contractors (AGC) are mainly the two bodies which have been very active in recommending the use of BIM in the construction Industry (Hamil, 2010). It is worth to mention that there is significant distinction between Buildings information Modeling and Building information model (NIBS-NBIMS Project Committee, 2006). Building Information Modeling refers to process by which models are generated; while Building information Model refers to representation of the building at a specific time in any given time. There has been lots of argument over BIM is tool or is it a process.

B. BIM as a management tool/process

Understanding the BIM is a complex phenomenon due to its nature. There are some researchers consider BIM as a tool (Suermann and Issa, 2009 and McCuen, 2008) while some of them refers it as a process (Eastman et al., 2008 and Beesley.P., et al., 2006). Camps (2008) stated that BIM is not a mere tool for construction Industry but it is a process, where BIM acts as an agent to improve the collaboration between the Project team for any construction projects. However, Cook et al (2007) considered that BIM is not more than a tool for the construction Industry. Fong et al (2009) devised an equation expressing the value of BIM is a summation of BIM as tool and BIM as a process.

Value of BIM=Tools +Process

In order to understand BIM more Clearly National Institute of Building Science (2007) has given a clear understanding of BIM by dividing it into three main categories; BIM as product, BIM as Process and BIM as life cycle management tool.

- BIM as a Product-Building Information Model
- BIM as a Process-Building Information Modeling
- BIM as a Management Tool-Building Information Modeling.

1. BIM as a product

BIM is a product which represents the model of a digital representation of data about the project (NIBS, 2007). In order for software to qualify as intelligent it should not just be 3D representation of project, but it should possess properties and information beyond the graphical representation (CRC Construction innovation, 2009).

2. BIM as a process

The view for BIM to be considered as a process of developing a BIM Model and using the process to reach the most suitable project productivity (WPS group, 2011).

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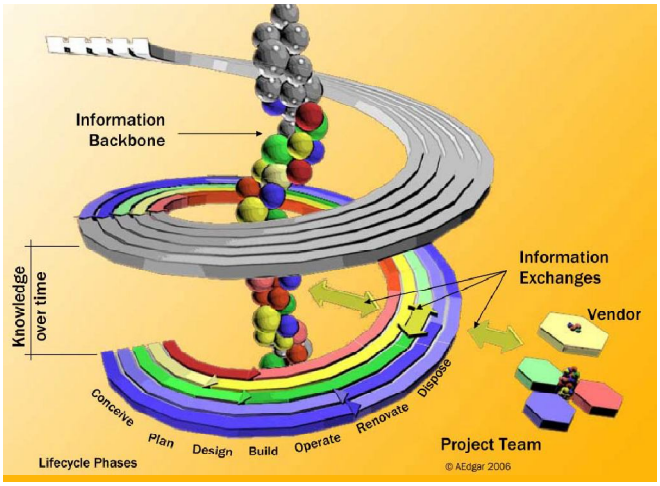

Figure: 1 Relationship of BIM to all the facts of AEC industry: Source NBIMS

3. BIM as management tool

Building information models are files (often but not always in proprietary formats and containing proprietary data) which can be exchanged or networked to support decision-making about a place. Current BIM software is used by individuals, businesses and government agencies who plan, design, construct, operate and maintain diverse physical infrastructures, such as water, wastewater, electricity, gas, refuse and communication utilities, roads, bridges and ports, houses, apartments, schools and shops, offices, factories, warehouses and prisons. Hence improving the efficiency of planning and scheduling any project which in return improves the project management.

C. Need of BIM in construction industry

The construction industry is often criticized for its traditional methods and it had been one of the major problem of the construction industry for sticking it with its traditional methods of construction and that's has been one of the main effect for causing various delay cost overrun as well as time overrun. So there has been a need to have a paradigm shift in the construction sector with lean production, Offsite construction as well as BIM acting as an agent for the change in the construction sector. Henderson and Jordan (2009) defined "The BIM paradigm" as the preference of companies in the construction sector to use newer methods of construction over the traditional methods to achieve the delivery time, reduced the cost of projects and also to provide higher quality to the client. Covey (2004) described paradigm as an single phase frame of mind during resolving the problem and similar thing is happing with construction industry as well so there should be new solution to old ones in order to resolve the various problems, a new way of thinking; a process which is thought outside the confine box of traditional methods can be term as Paradigm shift (Covey, 2004).

The main reasons for considering BIM as an agent of paradigm shift are studied by various authors and all have different thinking regarding the BIM by the construction firms. Henderson (2009) states the shift is from analog system to the digital system, Yan and Damian (2008) states that the move is more from pure visualization approach to the simulation of the actual project. Aranda-Mena et al (2008) has a slightly different approach in term of the change his study focuses more on the entire lifecycle of the project right from procurement to the final stage of the construction.

The new methods of the working has been very much necessary for the successful implementation the BIM the in the construction Industry there have been many new methods like offsite construction, prefabrication etc., but one of the method that has been caught the main attention of the clients and stakeholders is "LEAN production". It is a waste eliminating production method which has been adopted by Toyota for manufacturing cars and also in recent years in manufacturing Toyota homes which are currently very new for the construction sector. Davis (2007) compares BIM and LEAN Production and states that lean production refers to the manufacturing industry while BIM is to the Construction Industry. Also it has been suggested that Architecture, Engineering and construction (AEC) Industry should become more collaborative and willing to the change in the working methods in construction project which will necessarily accompany the fully adopting of the BIM in the Project lifecycle. Salmon (2009) has a different view on BIM and LEAN production he states that the Lean concept is not exclusive Of BIM. He has distinguished BIM, Lean and Integrated Project Delivery where each of them plays a crucial and important role in serving the whole project life cycle. BIM is one of the agents which are driver for the project success; this implies that BIM alone is not sufficient to address all the problems of the construction industry so it should not be implemented like other process such as LEAN Production or IPD.

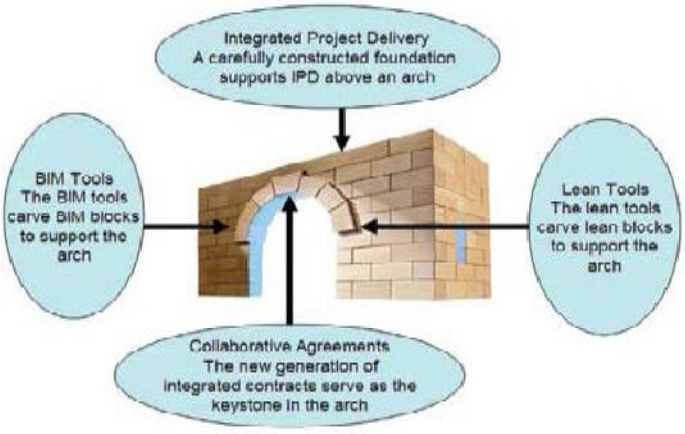

Figure 2: BIM, IPD and LEAN Source (Salmon, 2009)

Camps (2008) states BIM will require professional in industry to do more in the very limited time; it should be implemented in students who will be handling it future given a strong educational background. A study carried out by Azar et al., (2010) reported the use of BIM for educational reports amount

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the student's gains a greater understanding among the student for understanding the construction divisions especially in mechanical, plumbing and electrical arrangement because of ability of BIM to detect clashes and its ability to produce visual details. Currently around 50% of industry is using BIM and companies which are Using BIM require student who are capable and comfortable in BIM process, they don't require software expertise but understanding of BIM as a process. The Inclusion of BIM in the Contraction industry will very beneficial for the preparation of the future employees for the construction industry (McGraw Hill, 2009). The Implantation of BIM in the education curriculum will provide a strong background for students who will be using it in the future.

III. Results and discussion

A. Comparison between BIM and CAD

Is BIM just 3D visualization of BIM or more than that? It has been topic of discussion among all the professional since BIM has been used in the construction Industry. BIM is clearly considered much more different and advanced from CAD it's been supported by authors like (Dimyadi, 2007 and Eastman et al, 2008). Cook et al (2007) describes as the transformation from manual drafting to CAD drawing was evolutionary, but the transition from CAD to BIM can cause and revolution in the construction Industry

BIM is one of the great Visualization tool it not only provides three dimensional representation of building but it also provides rendering , walkthroughs and sequencing of model to the construction manager during the bidding phase of the project. It takes away the process of thought of bringing different 2d drawing views together to come out with a 3D view in detail. The virtual presentation helps to communicate better with the project and also with one who collaborate among the project participants. Virtual mockup of any drawing is more cost efficient in BIM it helps to understand the planning of aspects of the drawing such as where the curtain wall will or where the duct will pass through. Although virtual Mock up is less expensive than the physical mock-up but there is still a need for a physical mock up in order to go thought the series of physical test.

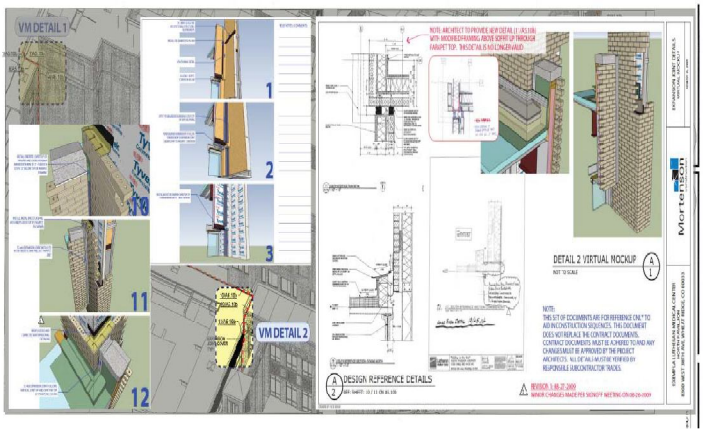

Figure 3: Exterior envelops Virtual mock up Source (Khemlani, 2011)

Dimyadi (2007) distinguish BIM in the term of the design process not only in the visualization of the 3d output he considers BIM process for design is much more different from that of the CAD and both have complete different aspect for the design aspect. Eastmal et al (2008) considered the distinction of BIM vs CAD more holistically by showing the various merits of the BIM that can be over the BIM in real project.

The conventional method of the drawing regards to the drawing of 2d sketches as shown in the Fig.4 & Fig.5, CAD generated has provided a great help for AEC Industry but they can also lead to great deal of confusion and misunderstanding if more person are involved in the drawing it also causes a major problem while drawing a complex projects considering many utilities The process changes more while transforming the 2D drawing into 3D drawing. As stated by Architectural standards (2008) Cad consist of following problems which have been associated with the Manual drafting.

- Its time consuming and complex and it requires to create separate plans and section, elevations and details even it's for the same building.
- If there is any change or update it should be made manually and it should be updated manually in all drawing and reports.
- To coordinate the work between the various professional of this drawing is very difficult.
- The error occurring on the construction stage are way more and expensive to fix.

CAD simply replicates the manual drafting on the digital scale hence doesn't help in reducing the inefficiencies, wastage due to errors or any unwanted cost that are common during the design process. The main challenge arises when there is need to maintain the consistency between the large and extremely complex drawing even with the help of computerized drafting and data control system it becomes at greater risk due to various inconsistencies between the various information of the CAD drawing and hence making it less reliable for information retrieval.

Figure 4: CAD Drawing 2D-1

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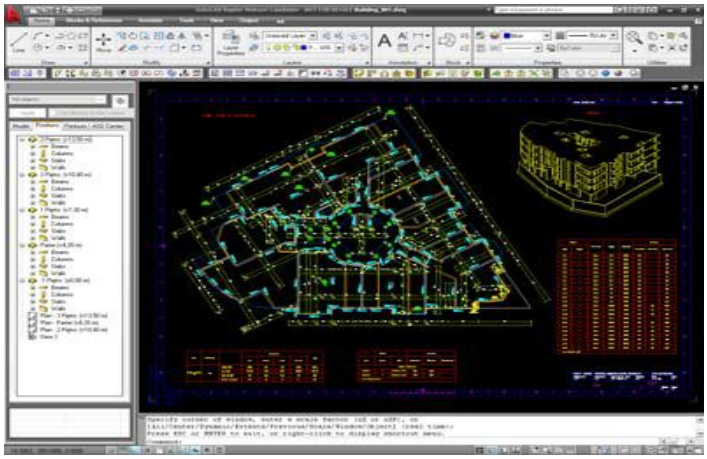

Figure 5: CAD Drawing 2D-2

The main advantage of BIM over CAD comes during the design process where BIM acts as an information repository for the stakeholder and client to understand the project with clearer perspective view (Dimyadi, 2007). Fong et al. (2009) describes perception of the monitoring process in the BIM which user can access which is clearly absent in the CAD System. The monitoring process is one that captures the time element of the BIM and makes better available for the user to manage the better project time using BIM as compared to that they do on CAD.

BIM and CAD can be majorly and distinguished in the term of Cost. The BIM is cost saving in terms of model creation, It will reduce the cost at the design stage and will also reflect the all the phases of the project including the construction phase of the project (Teran, 2008). But on another note Butler (2009) states rather than distinguishing them it is advisable for the industry to determine the strengths and standards and moving forward by using benefits of CAD and BIM.

B. BIM in infrastructure

Now that BIM has conquered the building industry and is here to stay, the question arises to whether it can be applied to a larger scale, going beyond a building, to a street, a neighborhood, a city, and so on. Since the application of BIM from building to infrastructure is difficult due to its components, variation in WBS, physical environment and level of operation Therefore, the application of BIM to infrastructure represented by intelligent data-rich 3D models that carry information about themselves and relationship among different components will help to improve the efficiency of project management. Also, to support the crisis management activities in large scale infrastructure projects BIM can be very useful. Facility management professionals face challenges resulting in cost and time related productivity, efficiency and effectiveness losses. Building information modeling, that seeks to integrate the structure lifecycle, can provide improvements and help to overcome those challenges. Just as the ultimate scenario with BIM for buildings is to have a single model that is used for design, construction, and ongoing facilities management, imagine the ultimate scenario of applying the same concept to infrastructure—a live intelligent 3D model of every city that represents all its transportation networks, utilities, zones, open spaces, buildings, and any other infrastructure components, all physically located within a geographical map and related to each other. For instance, to select any street in the city, it is very easy finding out where it is located, what are the overhead and underground utilities that run through it, which are the streets that connect to it, which are the buildings and/or spaces that are located on either side of it, and any other information you might want to know. Imagine the power of having such a model, not only in facilitating the myriad city planning tasks that need to be done on an ongoing basis, but also in disaster forecasting and planning—we could run analytics on the model and determine what the impact would be in an earthquake or a hurricane, for instance, so that we are better prepared to deal with them.

C. Limitations of BIM

Although, BIM is considered as a collaborative tool but in reality most of firms are not multidisciplinary and in fact relatively small in nature.The size and complexity of the files that BIM systems create for complex projects, the scalability and manageability of a fully loaded central BIM project database represents a major challenge. BIM reveals limitations in the information collecting process in existing or age old buildings. Due to lack of information in existing buildings using BIM can be a difficult task. As the details of existing structure will be hard to get due to unavailability of structural data, the creation of model will not be possible in such cases. Also, due to multiple components in infrastructures, usage of BIM can be a tedious job. Architects major interests lies in providing means of representing the final form of the design while designers also need a continual stream of abstractions, advice and information to facilitate in the move from information to the distillation of knowledge (Coates et al., 2010). Apart from these limitations, implementing BIM in Indian construction industry can be difficult job due to lack of knowledge about it. Most of the companies who do not use BIM believe that BIM training would cost their companies too much time and human resource.

IV Conclusion

The findings of this study suggest that there is strong perception that BIM is process for enhancing the productivity of the project rather than just serving as a tool unlike CAD. Most of the studies reveal that BIM can address interdisciplinary inefficiencies in the construction industry. Also, it can serve as future of the project management which can be really beneficial for the construction Industry. BIM can play a significant role to change the scenario of construction Industry which suffers due to several problems. As there is need for more greener projects in construction industry within few years, BIM can execute more greener and more sustainable projects to the construction sector, hence directing construction Industry to more Environmental friendly Industry. The implementation of BIM in the Project can reduce the cost as well the time for completion of project, also the communication for the project can be improved and hence increasing the overall productivity of the project However, further studies are required to investigate success of BIM in feedback and customer feedback technologies, tailoring issued information to meet the needs and capabilities of the recipient and integrating with contextual information and GIS systems..

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