Multidimensional BIM to Build Infrastructure Fast and Efficient – An Overview

[1]Mayuri S. Sethia
[1]Assistant Professor
[1]Jawaharlal Darda Institute of Engineering & Technology, Yavatmal, Maharashtra,India

***Abstract* - According to the UN, by 2050 the world's population will be 9.7 billion. The global AEC industry must look to smarter, more efficient ways to design and build not just as a means to keep up with global demand but to help create spaces that are smarter and more resilient too. Also, India is expected to have a population of 1.4 billion by 2025.This will call for more food, housing and public transport. Apart from building new infrastructure, the existing ones need to be refurbished and buildings, bridges, railways need to be constructed to last long. Thus to cater to the growing number of people striving for better living, there is a need to adopt Building information Modeling (BIM) process for efficient and faster execution of projects in the lines of several developed countries. This paper deals with the details of multidimensional (2D, 3D,4D, 5D, 6D and 7D) BIM so that knowledge of this will help architects, engineers, and constructors to get a fuller understanding of the construction project - how it will be delivered, what it will cost and how it should be maintained etc. This will also visualize what is to be built in a simulated environment to identify any potential design, construction and operational issues if any. In this 5D BIM Implementation in Nagpur Metro Project is carried out as a case study.**

***keywords* - BIM, AEC**

I. INTRODUCTION

India is expected to have a population of 1.4 billion by 2025, surpassing China. This will call for more food, housing and public transport. Apart from building new infrastructure, the existing ones need to be refurbished and buildings, bridges, railways need to be constructed to last long. Also Project management has always been a challenge in India which is evident with delaying of numerous mega projects of the country in the past coupled with overwhelming quality and safety issues. Furthermore, these challenges spill over to the operation and maintenance wings of the projects, shrinking their efficiency and ROIs considerably. For centuries, we have used symbols on paper (i.e. drawings and specifications) as the primary means to represent and communicate design intent for client approval, bidding, procurement, fabrication, construction and installation. These abstractions have no native intelligence in them and require human interpretation (i.e., reading) and manipulation (e.g. take-offs, redlines) to provide meaning and value. All other major capital- and knowledge-intensive industries (e.g. manufacturing and finance) have long since transitioned to data-rich environments that enable virtual and automated design, analysis, fabrication and communication. They have reaped the rewards of higher productivity, accuracy, and quality and worker safety. The growing worldwide adoption and implementation of BIM for its powerful digital data-based modeling, visualization, analysis and simulation capabilities represents the start of a transition to an integrated information infrastructure that will ultimately revolutionize almost all aspects of the construction industry.

BIM is a transition from 2D CAD based design to 3D model based workflows. But BIM is not just about 3D models. The additional dimensions that of time (4D BIM) and cost (5D BIM) help take the project to the next level. Not only can BIM be used as a visual planning tool but the entire project management and cost control can be undertaken with the use of a BIM model. While the 4th and 5th dimensions are crucial during the construction phase, the as-built information and facility data can be incorporated into the model to make it a 6D one. The BIM can therefore act as a single source of truth for the project, delivering value throughout the entire life cycle.

II. BIM

Building Information Modelling (BIM) is the process of creating information models containing both graphical and non-graphical information in a Common Data Environment (CDE) (a shared repository for digital project information). The information that is created becomes ever more detailed as a project progresses with the complete dataset then handed to a client at completion to use in the building's In Use phase and potentially on into a decommissioning phase.

III. THE PROCESS OF BIM

The process of BIM supports the creation of intelligent data that can be used throughout the lifecycle of a building or infrastructure project.

- **Plan:** Inform project planning by combining reality capture and real-world data to generate context models of the existing built and natural environment.
- **Design:** During this phase, conceptual design, analysis, detailing and documentation are performed. The preconstruction process begins using BIM data to inform scheduling and logistics.
- **Build:** During this phase, fabrication begins using BIM specifications. Project construction logistics are shared with trades and contractors to ensure optimum timing and efficiency.

- **Operate:** BIM data carries over to operations and maintenance of finished assets. BIM data can be used down the road for cost-effective renovation or efficient deconstruction too.

IV. MULTIDIMENSIONAL BIM

- **2D (CAD):**2D for drafting of statutory approval documentation and Production Information. CAD standards are managed to BS 1192:2007, and electronic sharing of data is carried out from a common data environment (CDE), often managed by the contractor.
- **3D (The shared information model):** 3D BIM is perhaps the BIM we are most familiar with - the process of creating graphical and non-graphical information and sharing this information in a Common Data Environment (CDE).As the project lifecycle progresses this information becomes ever more rich in detail until the point at which the project data is handed over to a client at completion. 3D represents the three geographical dimensions (x, y, z) of a building structure. The geographical capabilities help stakeholders to visualize a building's structure in 3 dimensions even before the project is started. 3D BIM enables all the stakeholders to collaborate effectively for modeling and solving typical structural problems. Also, as everything is stored at a central location i.e. the BIM model, it becomes easier to resolve issues at a future stage.

  Benefits of 3D BIM
  - Enhanced 3D visualization of the entire project
  - Streamlined communication and sharing of design expectations
  - Easy collaboration between multiple teams irrespective of their area of expertise
  - Reduced instances of rework and revisions due to complete transparency from the beginning
- **4D (Construction sequencing)*:*** 4D Construction sequencing is a great tool for on-site construction. This process helps in understanding the time line and schedule of construction phase wise. With the help of BIM Modelling, we can actually link the construction elements across Architectural, Structural and MEP discipline to create a complete sequence of building construction. We can create a 4D simulation that represents the time line and schedule of completion. Based on this we can determine the entire process of on-site construction, check the areas causing delays etc. It is an extremely creative way of presenting the building design and details in a simulation form which helps in design presentation, collaboration meetings, on-site contractors etc.

  The main functionality of 4D construction sequencing is to synchronize 3D geometry, Building data and the scheduling of materials together to create a project's phase wise construction simulation. This feature has the capacity to cut costs by 20 to 30% overall. Parties involved in the construction process can suggest on site changes based on the simulation and helps on site construction through a data rich virtual model. Visuals of the work progress makes it convenient to monitor the overall progress.

  Depending on the time line schedule and the virtual components, it becomes easy to monitor the live construction. With an accurate sequencing, we can identify potential construction issues, clashes or interferences, shortage of materials or any kind of break that can hamper the execution or installation of components. Based on this we can change the processes, designs and manage the schedule in a way that the contractor does not suffer due to lack of drawings, materials etc. All the critical stages are evaluated and issues are resolved prior to construction with the help of 4D BIM Modeling. .

  There have been instances where the site work is completed and building is handed over to the owners before schedule. The productivity is maximized with on-time completion of the project and reduced cost. 4D BIM modeling can also be presented in .avi or video format that can be retained for as built modeling too. 4D construction Sequencing is a great tool for large scale projects provided we make complete use of the model.

  Benefits of 4D BIM
  - Improved site planning and scheduling optimization
  - Seamless coordination among architects, contractors, and on-site teams
  - Better preparedness in terms of next steps during every construction stage
  - Enhanced information sharing related to timeline expectations helping to avoid costly delays
  - Enhanced safety and efficiency due to documentation of an entire plan with specific timelines

- **5D (Cost Estimation, Analysis, and Budgetary Tracking):** Drawing on the components of the information model being able to extract accurate cost information is what's at the heart of 5D BIM. Considerations might include capital costs (the costs of purchasing and installing a component), its associated running costs and the cost of renewal/replacement down the line. These calculations can be made on the basis of the data and associated information linked to particular components within the graphical model. This information allows cost managers to easily extrapolate the quantities of a given component on a project, applying rates to those quantities, thereby reaching an overall cost for the development.

  An information model is likely to contain three types of quantity. Quantities based on actual model components (with visible details) which you can explore through the model are the most obvious. Quantities may also be derived from model components (such as mouldings around windows) that aren't always visible. The third kind of quantity is non-modelled quantities (these include temporary works, construction joints etc.). Unless the construction phase is modelled then the design model will show, graphically, design quantities but not the construction quantities. A cost manager is likely to be skilled in picking up the quantities that aren't solely based on model components.

  One of the advantages of extrapolating cost from the information model is the fact that the data can be queried at any

time during a project and the information that feeds cost reports is regularly updated. This 'living' cost plan helps teams design to budget and because cost managers are engaged from the start of a project this allows for faster, more accurate reporting of costs at the early stages of a project. Compare this to a traditional approach where a cost manager's report may be updated a few times during the early stages of a project with completed designs only fully costed at the end of the project team's design process. The cost manager may have to get used to working earlier and more iteratively than in a traditional process but has just as important a role to play in overall project delivery.

Benefits of 5D BIM

- Real-time cost visualization with notification on changes in costs
- Automatic count for components/system/equipment associated with a project
- Simplified cost analysis and budgetary analysis with predicted and actual spends over time
- Minimization of budgetary offshoot due to regular cost reporting and budgeting

- **6D (Project lifecycle information):** 6D building information modeling helps to analyze the energy consumption of a building and come out with energy estimates at initial design stages. Accounting for various life stages of a structure, 6D BIM ensures accurate prediction of energy consumption requirements. 6D BIM technology takes the industry a step beyond the conventional approach that just focuses on the upfront costs associated with a project. This approach helps in getting an idea of the entire cost of an asset and how the money should be spent on achieving sustainability and cost-efficiency.

  6D BIM involves the inclusion of information to support facilities management and operation to drive better business outcomes. This data might include information on the manufacturer of a component, its installation date, required maintenance and details of how the item should be configured and operated for optimal performance, energy performance, along with lifespan and decommissioning data.

  Benefits of 6D BIM

- Reduced energy consumption in the long run
- Faster and more accurate decision making related to component installation during the design process
- Detailed analysis and impact of a decision on economic and operational aspects over the entire lifecycle
- Better operational management of the building or structure after handover

- **7D (Holistic Facility Management Information for Entire Lifecycle)*:*** 7D BIM is all about operations and facility management by building managers and owners. The dimension is used to track important asset data such as its status, maintenance/operation manuals, warranty information, technical specifications, etc. to be used at a future stage.

  7D BIM is a unique approach where everything related to the facility management process is collated at a single place within the building information model. Such a tactic helps in improving the quality of service delivery during the entire lifecycle of a project. Using 7D BIM ensures that everything in a project stays in its best shape from day 1 to the day of demolition of a structure.

  Benefits of 7D BIM

- Optimized asset and facility management from design stage to demolition
- Simplified and easy replacement of parts and repairs anytime during the entire life of a building
- Streamlined maintenance process for contractors and subcontractors

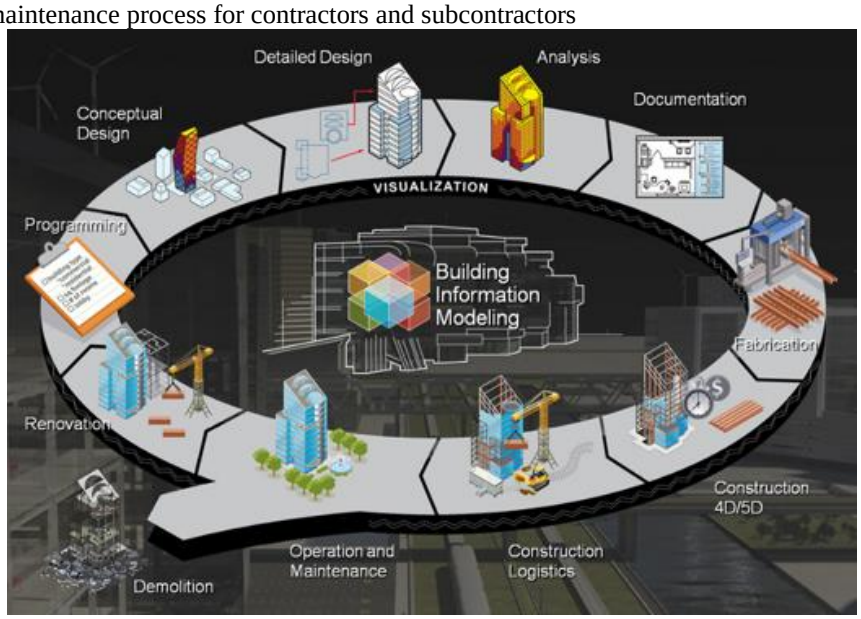

Fig.(i) Multidimensional BIM

V. SOFTWARES:

The use of software leads to the development of multidimensional BIM system.

- **AutoCAD** is computer-aided design (CAD) software that architects, engineers, and construction professionals rely on to create precise 2D and 3D drawings.

- Draft, annotate, and design 2D geometry and 3D models with solids, surfaces, and mesh objects
- Automate tasks such as comparing drawings, adding blocks, creating schedules, and more
- Customize with add-on apps and APIs

- **Autodesk Civil 3D** civil engineering design software supports BIM (Building Information Modeling) with integrated features to improve drafting, design, and construction documentation.

- **Infraworks** infrastructure design software supports BIM processed. Conceptualize, optimize and visualize infrastructure projects- all in the context of the built and natural environment.

- **Navisworks** project review software to improve BIM (Building Information Modeling) coordination. 4D simulation can be developed using Navisworks or any time liner tool compatible with a BIM software.
  - Combine design and construction data into a single model.
  - Identify and resolve clash and interference problems before construction.
- **Revit software** to drive efficiency and accuracy across the project lifecycle, from conceptual design, visualization, and analysis to fabrication and construction.
  - Begin modeling in 3D with accuracy and precision.
  - Automatically update floor plans, elevations, and sections as your model develops.
  - Let Revit handle routine and repetitive tasks with automation so you can focus on higher-value work.

VI. CASE STUDY:

5D BIM Implementation in Nagpur Metro Project: The ongoing Nagpur Metro project spans across 38 Km covering two corridors including North-South and East-West respectively. The mega project also boasts of 36 stations spread across key locations of the city

The Nagpur Metro project, however, is set to stand apart as a differentiator in this regard with the implementation of 5D BIM digital project management platform. The platform integrates the benefits of an ERP software like SAP with construction design software and project management software from other tech giants, thus allowing a 5-Dimensional view of the project in near-time. The combined ability of these multiple technology products integrated into a single 5-Dimensional Digital Project Management Platform has played a decisive role in ensuring project delivery

Fig. (ii) Nagpur metro construction

timelines and cutting upfront expenditures.

The Nagpur Metro 5D BIM system encompasses of 3D models and the related data nestled in a common data environment termed as Electronic Data Management System (EDMS). The 5DBIM Digital Project Management platform also offers significant benefits in post commissioning operation and maintenance by way of easy, visual access to vendor contracts and asset warranties with suitable alerts.

The digital platform will capacitate Nagpur Metro to achieve enhanced construction quality, curtailing of construction-related expenditures, comprehensive understanding of the project design and optimized operational efficiencies. The entire ecosystem of Maha Metro including GC, DDC's and Contractors are using this digital platform.

VII. CONCLUSION

Building information modeling is emerging as an innovative way to virtually design and manage projects. Predictability of building performance and operation is greatly improved by adopting BIM. As the use of BIM accelerates, collaboration within project teams should increase, which will lead to improved profitability reduced costs, better time management, and improved customer–client relationships.

BIM represents a new paradigm within AEC, one that encourages integration of the roles of all stakeholders on a project. This integration has the potential to bring about greater efficiency and harmony among players who all too often in the past saw themselves as adversaries.

Use of software leads to multidimensional BIM i.e., Design and deliver better civil infrastructure with BIM, Aggregate data from multiple trades to better control outcomes , Reimagine infrastructure design with Infraworks, , Create coordinated, consistent, and complete model-based designs.

REFERENCES

[1] J. Vinoth Kumar and Mahua Mukherjee, "Scope of Building Information Modeling (BIM) in India," Journal of Engineering Science and Technology Review 2 (1) (200)9,pp. 165-169
[2] Rafael Sacks , Lauri Koskela , Bhargav A. Dave and Robert Owen," The Interaction of Lean and Building Information Modeling in Construction," the Journal of Construction Engineering and Management.
[3] Salman Azhar, Ph.D., A.M.Asce," Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry," Leadership and Management in Engineering (July2011)pp.241-252
[4] Ghang Lee, Rafael Sacks, Charles M. Eastman," Specifying parametric building object behavior (BOB) for a building information modeling system," Automation in Construction 15 (2006) pp. 758 – 776
[5] Atul Porwal, Kasun N. Hewage," Building Information Modeling (BIM) partnering framework for public construction projects," Automation in Construction 31 (2013) pp. 204–214