

Study of 5D Building Information Modeling in Architecture, Engineering and Construction Industry

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Abstract - Any given construction and engineering project have three most important factors that is the quality, time and cost depending on the decision-maker and the decision-making process involved in the project. An emerging trend in construction industry is five-dimensional Building Information Model (5D BIM), that integrates all three factors. There are various drawbacks in conventional method used for planning, estimating cost, scheduling and monitoring projects in architecture, engineering, and construction industry. The traditional CPM schedule does not provide any information pertaining to the spatial aspects or context and complexities of the various components of a construction project. Different project members and teams involved may develop inconsistent interpretations of the activity when viewing only the CPM schedule and usually leads to ineffective communications. Also, the traditional cost estimation method and resource monitoring techniques fail to respond efficiently with the changes and modification in the project. Application of Building Information Modeling (BIM) for project scheduling and monitoring by combining it with the currently used tool like Oracle Primavera help in linking of the activities in a critical path method schedule with the corresponding elements of a three-dimensional 3D model, from Autodesk Revit, thus making the project sequence easier to interpret. BIM provides the user with a real time representation of the project which may improve and speed up the construction planning as well as ensure data integrity and accuracy.

Key Words: Building Information Modeling (BIM), 5-Dimensional Modeling, Autodesk Revit, Autodesk Navisworks, Oracle Primavera, Construction Industry.

1. INTRODUCTION

The construction and engineering industry has long sought techniques to reduce project delivery time, decrease project cost and increase productivity and quality. Building Information Modeling (BIM) has the potential to accomplish these. BIM simulates the construction project in a virtual environment. With BIM technology, an accurate virtual model of a building, known as a building information model, is digitally constructed. When completed, the building information model contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realize the building. After completion, this model can be used for operations and maintenance purposes. BIM can be described as a virtual

platform that accommodates all aspects, disciplines, and systems of a project in a single file, virtual model, allowing all design team members (owners, architects, engineers, contractors, sub-contractors, and suppliers) to collaborate more accurately and efficiently than using traditional processes.

2. BUILDING INFORMATION MODELING

Building information modelling is a building design and documentation process. Building information modelling software captures information about a building and then presents that information as 2D and 3D views, schedules, cost or in other required formats. Architects and engineers can use digital design information to analyse and understand how their projects will perform before they are built. Developing and evaluating multiple scenarios simultaneously enables well defined comparison between alternatives and informs better and sustainable design decisions and procedures.

Eastman et al. defined BIM as a 'modeling technology and associated set of processes to produce, communicate, and analyse building models.' They also identified that 'BIM is one of the most promising developments in the architecture, engineering and construction (AEC) industries.' The major difference between BIM tools and conventional ones is that the BIM tools focus on the data of the model rather than the drawings and 3D images. In other words, the BIM tool provides more information on what it can support than what it contains.

4-Dimensional BIM: Scheduling denotes BIM 3D model extended with one extra variable i.e. time. Tedious scheduling is replaced by parametric modelling, in which every element is assigned in a sequence of assembly. BIM 4D provides new opportunities for BIM, by creating division of project into phases, visualization of phases in real time view, simulation of schedule of works for clash detection, accurate planning for procurement of products and materials required for the activity.

5-Dimensional BIM: Estimating is BIM 4D extended with another variable i.e. the cost of labour and delivery for each item. BIM 5D provides with fast estimation of cost for structural and architectural designs and any other cost estimations. With help of 5-dimensional BIM construction managers can compare execution time (ETA) and total costs of various alternatives in terms of materials and technology, what can promote the optimization of the total cost of the investment.

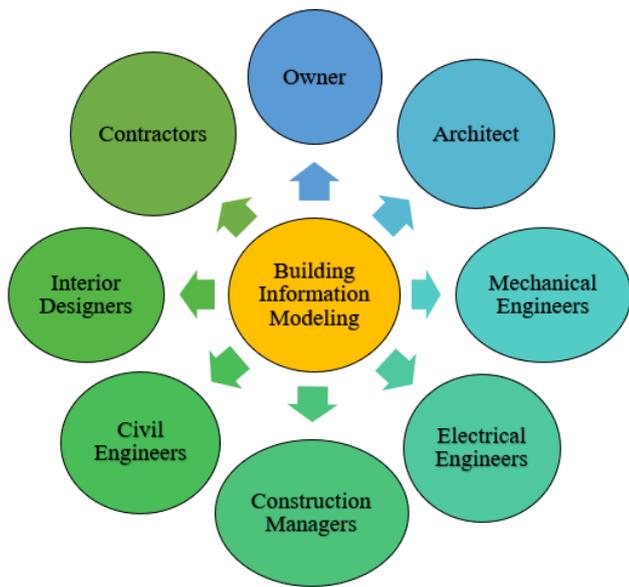


Fig-1 Correlation chart for stakeholders involved in project

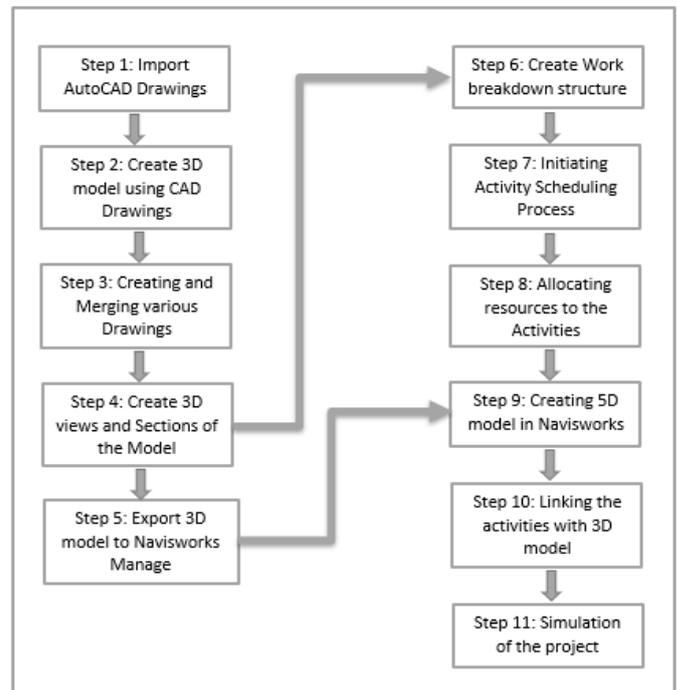


Fig-2 Information flow among various applications in the 5D system

3. METHODOLOGY

A detailed methodology is explained in this paper as to create a 5D model and various other benefits that can be extracted from the model. This methodology comprises of three most important steps to prepare a 5D model. In first step, a 3D model is prepared in Autodesk Revit 2018, then as second step, a construction schedule and cost estimates are prepared in Oracle Primavera P6 (Version 18) and finally a 5D model is generated in Autodesk Navisworks 2018. Thus, the work covers the literature review of various articles related to traditional methods of scheduling projects to current available tools. With the help of currently available modeling and scheduling tools a 5D model is prepared. This study provides methodology for creating a 5D model which act as a platform for future projects.

In an attempt to integrate time and cost into planning research efforts have been emerged to provide project planners and managers with computer based advisory tools to visualize the construction plan in a 5-dimensional (5D) environment. The greater advantage is that the construction manager and the client can use the BIM visualization technique to gauge the scope of work, monitor activities and the impending cash flow. BIM improves the construction planning and design efficiency by integrating the 3D model with schedule and cost of the project at one platform.

3.1 Procedure for Project Scheduling and Monitoring system using BIM

Step 1 — Importing Architectural Design:

The design of the construction project is created using AutoCAD, a widely used software package in architectural design practice.

Step 2 — Creating 3D model:

Project model can be directly designed in the Autodesk Revit. However, if the architect is using AutoCAD for designing the architectural drawing than 2D CAD drawing can be imported to the Revit using link CAD option and later model is created.

Step 3 — Creating or merging various drawings:

Autodesk Revit facilitates merging of various components like HVAC, Mechanical, plumbing & piping, electrical etc. under one platform. If drawings are made separately than they are imported in the Revit using insert option. Revit plays a vital role in detecting clashes between various components of the project, which in turn helps in managing, planning & getting forecast of project at planning stage.

Step 4 — Creation of 3D view:

An orthographic 3D view is created by pressing a home shape button in the view tab. different 3D views can be viewed by rotating the cube. 3D view shows the various components attached with the project. This enables the user to view the project in real virtually.

Step 5 — Export 3D model for Autodesk Navisworks Manage:

After creating the 3D model in the Autodesk Revit, it is exported for the Autodesk Navisworks Manage for preparation of 5D model. Model is exported while 3D view is open in Revit.

Step 6 — Creating Work Breakdown Structure:

This helps to make the entire construction project control effective and manageable. It defines and groups a project's discrete work elements in a way that helps organize and define the total work scope of the project.

Step 7 — Initiating Activity Scheduling Process:

Primavera Project Planner (P6) is used as the scheduling tool. The project is scheduled based on the activities identified in the work breakdown structure. Primavera is used to schedule the project, showing the start and completion dates, locating the critical paths and float times of activities, and also showing the sequence and interrelationships between the activities.

Step 8 — Allocating resources to the Activities:

Primavera Project Planner (P6) is used as resource allocation tool. The resource allocation is calculated based on the activities identified in the work breakdown structure. Primavera is used to resource levelling, man power planning and equipment management.

Step 9 — Creation of 5D model:

In Autodesk Navisworks Manage 2018 is the platform for making the 5D model. 3D model and Primavera schedule are imported. When 3D file is imported into the Navisworks, the program automatically aligns rotation and origin of models, and rescales the units in each file to match display units. If the rotation, origin, or file units are incorrect for the scene, we can manually adjust them for each of the opened files.

Step 10 — Linking the activities with 3D model:

In Autodesk Navisworks Manage, project schedule is imported through data source in time-liner tab. For creation of 5D model, activities from the Primavera schedule is linked with model elements.

Step 11 — Simulation of the project:

The 5D visualization of project is seen through the starting the simulation. The amount of work done on the various work packages could be seen in the 3D view. The project is updated as progress information becomes available from corresponding Primavera schedule. 5D model helps in visualization of the project, predicting the future impediments, planning, managing etc.

4. DISCUSSIONS

4.1 Planned Schedule vs. Actual Work Done

Using the simulation in Navisworks, planned and actual work done can be compared by using just the visual elements. The tool enables us to represent the work in green if the activity is going as per the schedule, while in red when it is lagging behind the schedule.

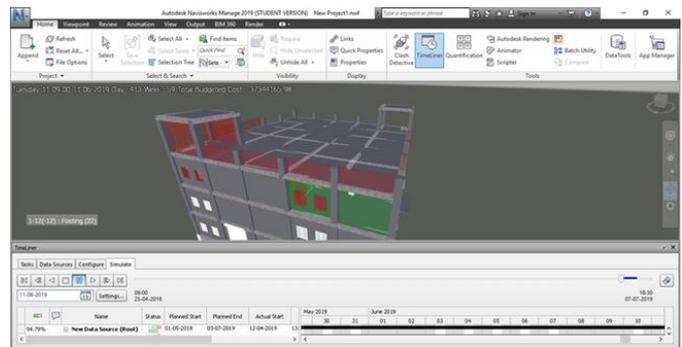


Fig-3 Planned Schedule vs. Actual Work Done Example from the project

4.2 Clash Detection Test

Clash detection tools in Navisworks Manage 2018 enables user to detect overlapping, intersecting or unconnected object in the 3D Revit model. For the given model 5054 clashes were detected with most of them being architectural components colliding with structural components. Among those cases 576 cases were resolved within the given duration of this project work.

Example of Clash Detection test and its Solution:

Location of clash: Grid Interaction 5 – 7 (foundation level). Clashes in between structural component (concrete column) and structural component (concrete beam) as seen in figure 4 is one of the many clashes found and rectified in the project.

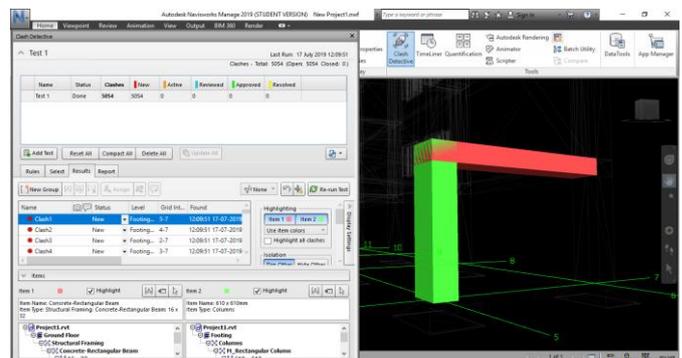


Fig-4 Clash Detection presented as an example

Solution: One possible solution would be coping the beam into the column, thus retaining its original length. Much easier solution is to shorten the length of beam and providing proper connection at intersection as highlighted in figure 5.

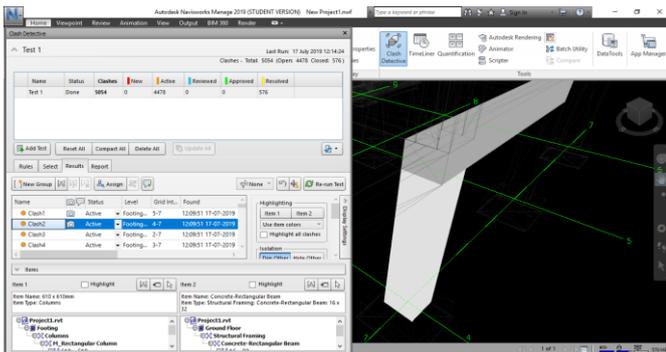


Fig-5 Solution for Clash detected as an example

5. CONCLUSIONS

Conclusions from the study clearly indicate that practical application of BIM is possible by the integration of 3D model, Time and Cost of construction project into a single platform enabled better project model understanding and also enabled the decision-making process much easier as compared to a 2D CAD schedule. The software used for this process are Autodesk Revit, Autodesk Navisworks and Oracle Primavera P6, which are all compatible in the BIM format hence feasible for collaboration in between various disciplines of construction industry.

By using the quantity take-offs, time and labour for creating separate report for quantity of material is saved, also accuracy of the project is increased. The time-liner and clash detection tool help in avoiding interferences and collusion in building components and object in BIM model. This avoids labour and re-works on actual construction site. 5D BIM provides project managers to monitor and track daily progress on site by comparing planned work versus the actual work completed till date.

However, it is also observed that difficulties may arise for the stakeholders not familiar with the primary concept of BIM or CAD in general. The visual representation of construction project should also help the client to have a better understanding of the project beyond the technical barriers. This help to fill gap in between the client and the stakeholders, as client is able to anticipate the project outcome and satisfactorily gauge the difference between initial prediction and actual project outcome.

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