Cost Optimization of Construction Projects using Building Information Modelling

Shashank.R.Chandak

Abstract— Building Information Modelling “BIM” is becoming a better known established collaboration process in the construction industry. Many Construction firms are now investing in “BIM” technologies during Bidding, Preconstruction, Construction and Post Construction. The goal of this research is to understand the benefit of Fifth Dimension (5D) BIM in lowering the costs of structure during preconstruction phase i.e. planning stage & while construction phase i.e. execution phase. A 3D Model of a Residential Project including Luxurious Apartment and High class Amenities is developed in 3D Modelling software i.e. Autodesk Revit Architecture 2015, Database of Cost estimates and Schedule are prepared in Microsoft Project Software available commercially by Microsoft and further linked to the 3D Model of the project using Autodesk Navisworks software, Clash detection between objects is an another part shown in Navisworks which omits the design errors in the 3D Model for better accuracy in the estimation. Thus any change in the Building design can ultimately be reflected in the overall budget of the project.

Key words: Fifth Dimension (5D) Building Information Modelling (BIM), Module Take-off Manager, Clash Detection, Module Timeliner, Conflict Interference, Tracking Gantt Chart

I. INTRODUCTION

5D in Building Information Modelling (BIM) is a concept that refers to the linking of 3D BIM with Time and Cost related information. 5D BIM incorporates the cost estimation ability to the BIM model in such a way that any change in the design gets reflected in the budget immediately. In other words, the 5D model enables architects, contractors, and engineers to work on a live model, which ensures that cost calculations are changed automatically whenever any change is brought to the structure and design of the project.

With easy access to detailed information, about costs and schedules, 5D BIM takes the efficiency of a construction team to the next level. With the effective use of 5D in BIM, owners, contractors, engineers, and all other members associated with the project can work collaboratively achieve timely delivery, cost efficiency, and quality.

Here, a detailed case study of a 22 acre live project of Luxury Villas and apartments with all high class amenities, naming Marvel Selva ridge estate, bavdhan pune is studied. To get a better knowledge about 5D BIM a 3D model of the project is made in commercially available software called Autodesk Revit and further this model is linked to 5D modelling (Cost estimation) in commercially available software Microsoft project.

II. 5D BIM WORKFLOW

This Research represents time and cost planning in construction projects using BIM approach. The BIM Technique can be incorporated into the time and cost planning process through several step,

Step 1: A 3D model of the construction site is developed using Autodesk Revit 2015 so that the format of the file is supported by Navisworks. A 2D file of the available architectural drawings of the project are imported in Cad format and further traced to develop a 3D model.

Step 2: When the 3D model of the project is formed, the project and cost planning can be executed employing the BIM approach through work steps demonstrated in the flowchart below.

![Flowchart of 5D BIM Structure](image)

Step 3: The module takeoff manager is applied to determine the geometrical properties of the 3D model. The takeoff items are created automatically and can be rearranged in different group of building elements in navisworks. The geometrical properties of takeoff items are then employed as source quantities for further time and cost planning of the project.

Step 4: The project costs is then estimated within the module cost planner using Microsoft project 2016 software on the basis of defined quantities of required material and resources consumptions, production rates and unit costs. Hence, the source quantities from previous step are used to calculate the appropriate components or subcomponents of project costs as function of geometrical properties.

Step 5: The project activities are then defined and linked to the construction elements of the 3D model employing the model navisworks. The quantities that were defined in the estimation process are linked to the construction project activities. A care has to be taken that duration of activities are calculated and they are treated as input data, that means a calculation of quantities per location divided by the productivity rate of the work crew.

Step 6: During the process of project scheduling the construction activities are mutually connected together into the project network plan by taking into account relevant precedence relationship. Further the defined links between construction activities enables to obtain Tracking Gantt chart of planned vs actual schedule.
The resources and the crew sizes are allocated to the construction project activities, later the durations of construction activities are calculated and the project duration is automatically determined from the generated network plan.

Step 7: In the final step, the BIM model of the construction object is completed by upgrading the 3D model with defined scheduling and cost data. At the end of the step, the project time and cost planning process is completed and the 5D BIM model is developed.

III. RESEARCH METHOD

Detailed Illustration of how BIM is adopted for the purpose of cost saving and optimisation is shown below,

A. Site Selection

Marvel Selva ridge is a site located at bavdhan, pune consisting of 4 midrise apartments, 16 villas and high class amenities like Clubhouse, reflecting pool, Lap pool, children's playground, spa, gymnasium, meditation and yoga center, Lounge area, BBO area, etc. A detailed coverage of all the interior and exterior of buildings along with surrounding activities can be shown in the 3D model using Revit. Any changes in the design or type of any interior part of buildings or other amenities if done, can easily be shown in the overall budget, and the cost can be optimized. A part of site i.e. a 4.5 BHK residential apartment with basic amenities like swimming pool, garden, internal roads, etc. is taken as a part of study to shorten the scope of the research.

1) Details of Site selected

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<th>Sr. No.</th>
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<th>Name</th>
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<tr>
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<td>Location</td>
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</tr>
<tr>
<td>6</td>
<td>Project end date</td>
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</tr>
</tbody>
</table>

Table 1: Site Details

B. Data Collection

1) Site Photographs

Fig. 2: Google Image of Project Site
(Source: http://www.marvelrealtors.com/residential-properties/selva-ridge-estate)

Fig. 3: Photo of 3.5 & 4.5 BHK Residential Apartment
(Source: http://www.marvelrealtors.com/residential-properties/selva-ridge-estate)

2) CAD Drawings

Auto CAD drawings of all Floor plans, Sectional plans, RCC plans, MEP drawings, Interior detailed drawings, Specification drawings and Amenity drawings are collected from the site. For example,

Fig. 4: 2D Architectural plan
(Source: CAD Drawing from Site)

Fig. 5: Building Elevation
(Source: CAD Drawing from Site)

3) Collection of Software’s

Autodesk Revit Architecture 2015: Revit Software is specifically built for Building Information Modelling (BIM), empowering design and construction professionals to bring ideas from concept to construction with a coordinated and consistent model-based approach. It includes the functionality of all of the Revit disciplines (architecture, MEP, and structure) in one unified interface.
Autodesk Navisworks Manage 2016: Navisworks Manage project review software helps you holistically review integrated models and data with stakeholders to gain better control over project outcomes. Integration, analysis, and communication tools help teams coordinate disciplines, resolve conflicts, and plan projects before construction or renovation begins.

Microsoft project 2016: Microsoft Project is a project management software program, developed and sold by Microsoft that is designed to assist a project manager in developing a plan, assigning resources to tasks, tracking progress, managing the budget, and analysing workloads. Project creates budgets based on assignment work and resource rates. As resources are assigned to tasks and assignment work estimated, the program calculates the cost, equal to the work times the rate, which rolls up to the task level and then to any summary tasks and finally to the project level. Schedules can be resource levelled, and chains are visualized in a Gantt chart.

4) Site Visit
Currently Site is under construction work, RCC work of all four apartments is completed, RCC of four out of sixteen villas completed. Work undergoing are Masonry, Internal & External plastering, Excavation for villas and clubhouse, Flooring, Excavation for Internal access roads.

Six visits of Construction site was carried out, data collected from site are detailed drawings, specification charts, work scheduled report generated from WBS, Daily progress, Report of 4.5BHK apartment and site photographs.

5) Software Application
Project model can be directly designed in the Autodesk Revit. However If 2D drawing is available it can be directly linked to Autodesk Revit, by link cad option and later tracing of elements on the CAD drawing is done to generate a 3D Model. A Schedule is prepared in MS Project 2016 software to get the Actual vs planned dates and cost difference. This future is linked to the 3D model to get the 5D BIM model including cost and time Simulation.

a) Creation of 3D Model
Step 1: Open Autodesk Revit Architectural Software. Select new file then in the dialogue box choose architectural template and click ok.

Fig. 6: RCC work of apartment
Fig. 7: RCC & Block work of apartment

Last visit was done on 25th march 2016, where flooring work was undergoing. Few pictures were also collected.

Fig. 8: Flooring work

Fig. 9: Revit 2105 Architectural Homepage

Step 2: Add floor levels as specified in the drawing available and then to each level, add floor plans using link CAD option to each level.
**Fig. 10: Floor levels footing bottom to LMR Level**

**Fig. 11: Link CAD file to floor levels**

Step 3: Tracing of elements as per size like columns, beam, slab, staircase, walls, door, windows, flooring, etc. on the various floor plans added to the levels.

**Fig. 12: Tracing of elements**

b) **Clash Detection**

Clash detection in navisworks enable to perform interference checking and anticipate and manage potential problems before construction, minimizing expensive delays and rework.

There are two types of clashes found in BIM-based clash detection: hard clashes and soft clashes. A” hard clash” is the overlapping of members of the BIM Model in a space. A “soft clash” is a design error that is a failure to secure sufficient space for other parts, including access, insulation and safety. In the construction document phase, a BIM model is built for construction, structure MEP (machine/fire-resistance/electricity) and then it is determined whether or not there is any “hard clashes” between construction structure/construction MEP/structure MEP using clash detection software (including naviswork of Autodesk).

**Fig. 13: Clashing of beam and shear wall**

The above figure illustrates clashing of object like the red indication for shear wall needs to be corrected in the BIM model. The wall top should match the bottom of the beam.

Dashboard of tests is created, add a test and name it. For example Column first floor to slab and beam 1st floor. Now use the selection tools to compare two different model elements together, that can be done by selection tree. Expand on each file and pick the objects for comparing for clash detection. Types of clash can be selected i.e. hard clash, soft clash, run through a clearance or duplication clash and set the tolerance level. Run the tests and see the results.

**Fig. 14: Dialogue box for conducting tests between levels**
c) As shown in the above figure, Clashes between any level can be determined as shown in section A and Section B levels are selected, for eg. Hard Clash between Level 1 and Level 2 has to be determined. Then choose those levels from the section and set the tolerance level finally run the test. Likewise do for different levels. After these clashes are determined in the Navisworks software they are needed to be rectified in the 3D BIM Model, consequently change the status of clashes after rectification is done. (Active, Reviewed, Approved or Resolved).

d) Accurate Quantity Calculation
Rectify the clashes in Autodesk Revit to get error free design model for accurate quantity calculation.

e) Schedule Of Activities And Cost Calculation
Developed a Schedule of activities, planned vs actual duration, and Cost calculation using MS Project 2016 software and link the file to Navisworks for Time and cost Simulation using timeliner option available in Navisworks.

IV. RESULTS

A. Generated 3D model in Revit 2015
Using default 3D view option available in Revit software, click on the button as shown in the figure below, to generate a 3D model.

B. Clash detection output in Navisworks 2016
Total of 2104 hard clashes are found after the tests is run, which need to be rectified in the 3D model software. 21 duplication errors are found. The figure below shows test1 which is done for hard clash, test 2 for duplication errors.

C. Time and Cost simulation (4D and 5D BIM)
Within naviswork there’s a tool called timeliner, which collects information from external project files (import files) or can be built inside the current project model. Each activity is assign a task called construct, thus after assigning each task, simulation is run. Thus building construction activity planned date wise is Shown at the top left corner of the window screen.
V. CONCLUSIONS

By using BIM method 80% reduction in time to generate estimates 10% saving on construction cost through clash detection. 20% saving through construction cost simulation.

REFERENCES


