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Application of BIM in Construction Industry using 5D Methodology

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Abstract— The three main factors driving the construction industry in India are Time, Cost and Quality of work in any construction project. Building Information Modeling (BIM) comes with multiple dimensions to facilitate the construction process and monitor the above three factors in timely and collaborative manner. 5D BIM is another such advancement which right from the initial stage until the final stage and has the potential to monitor the time and cost aspect of construction work going on in the project. The traditional construction methodology has quite moderate effectiveness while huge waste is generated in the process, which have critically affected the construction industry in terms of environmental impact and sustainability. This too can be effectively manager by using Building Information Modeling. By using 5D BIM, the above-mentioned factors can be carefully managed and optimised in the planning and design phase itself, even before the actual construction process starts. The main aim for this paper is study the implementation of BIM on a commercial building (Storage Facility) and its design procedure. The 5D BIM model consist of the 3D aspects of the buildings while the 4th dimension is Time and 5th being Cost of the construction project. The 4D model is use for preparing the activity schedule and work break down structure for the construction project as well as to monitor the progress work on field and compare the same to planned work. This helps to prevent delays and avoid loss of time. The 5D model helps prepare the cost estimate for the planned construction work and budget the finances of the project as required, thus managing the financial aspect of the construction project.

Keywords— Building Information Modeling (BIM), 5D Model, Autodesk Revit, Autodesk Navisworks, Oracle Primavera, Virtual Simulation

I. INTRODUCTION

Building Information Modeling proved to be a catalyst in shifting Indian traditional 2D drawing based construction industry into 3D object-based BIM modeling industry. The transformation changes the primitive documentation process and manual labour required to do so into an automated process. This building design and planning process includes the time and cost aspect of the building as well in from of 5D BIM model. The 5D BIM model also helps the client and the stakeholders to conceptualize the project and have a better understanding of the on-going progress and finances of the project. The BIM process strives to optimise the construction process, increase the effectivity of construction activities, reduce material waste, minimize the total cost and build effective collaboration between the stakeholders involved in the project. The 5D BIM model makes use of various tools in the design and planning process, in this paper Autodesk AutoCAD, Autodesk Revit, Autodesk Navisworks and Oracle Primavera P6 are employed for creation of 5D BIM model. These tools can be used by multiple discipline for time scheduling, cost estimating, visualization and understanding complexities of an activity.

A. Scope of this Paper

The scope of this paper is to use the concept of BIM to develop a 5D model by integrating 3D model with time and cost parameters. To assess the potential of BIM as management system for project scheduling and monitoring using a case study of G+2 storage facility.

B. Problem statement

The Indian construction sector is currently facing many challenges, especially it is marred by unnecessary delays, cost overruns, quality issues, reworks and other inefficiencies in the delivery process. Much of this can be attributed to current work practices, inefficient processes and lack of information sharing among industry stakeholders. Given the volume of construction India has to undertake, it cannot be done by traditional business practices as usual. 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.

C. Objectives of this Paper

1. To understand fundamental concept of Building Information Modeling;
2. To prepare 3D model in Autodesk Revit 2018 for a case study i.e. storage facility;
3. Also, to prepare activity scheduling and cost estimation in Oracle Primavera P6 for selected case study;
4. To prepare a 5D model in Autodesk Navisworks Manage 2018 for case study by using time as 4th and cost as 5th dimension and finally;
5. Run 5D Simulation for the model in Navisworks Manage 2018.

II. BUILDING INFORMATION MODELING

Building Information Modelling is a building design and documentation process. It enables stakeholders to create and manage information about a building project, using the information about the building project which is stored in a 3D model. More importantly, the intelligent data inherent in the building model allows to experience the design before it is real, simulate and visualize design alternatives, analyse performance, and make better informed design decisions earlier in the process.

A. 4D Building Information Modeling

4D BIM, an acronym for 4-dimensional Building Information Modeling, is a term used in the CAD and construction industries, refers to the intelligent linking of individual 3D CAD components or assemblies with time or schedule related information. The use of the term 4D is intended to refer to the fourth dimension: time, i.e. 4D is 3D plus schedule (time). The construction of the 4D models enables the various participants (from architects, designers, contractors to clients) of a construction project, to visualize the entire duration of a series of events and display the progress of construction activities through the lifetime of the project. This BIM-centric approach towards project management technique has a very high potential to improve the project management and delivery of construction project, of any size or complexity.

B. 5D Building Information Modeling

5D BIM, an acronym for 5-dimensional Building Information Modeling, is a term used in the CAD and construction industries and refers to the intelligent linking of individual 3D CAD components or assemblies with schedule (time - 4D BIM) constraints and then with cost-related information. The creation of 5D models enables the various participants (from architects, designers, contractors to owners) of a construction project to visualize the progress of construction activities and its related costs over time. This BIM-centric project management technique has potential to improve management and delivery of projects of any size or complexity.

C. Characteristics of Building Information Modeling

The characteristics of the BIM software i.e. Autodesk Revit, Autodesk Navisworks and Oracle Primavera are discussed in the following paragraph.

1) Characteristics of Autodesk Revit 2018 and Navisworks Manage 2018:

Characteristics of Revit and Navisworks for Building Information Modelling work the way architects and designers think about buildings;

- Enjoy a more intuitive process with software that mirrors the real world.
- The building information model contains essential information about a project, so as you design, Revit software automatically creates accurate floor plans, elevations, sections, and 3D views, as well as area calculations, schedules, and quantity take-offs.
- Gain better design insight through in-process visualization and analysis.

Capture early design thinking to better support design, documentation, and construction;

- Enhance conceptual building design efforts to gain better design insight earlier in the process.
- Support smarter, more sustainable design through the analysis of materials, quantities, sun position, and solar effects. Exchange building information with partner applications to perform energy analysis and better predict building performance.
- Provide essential BIM data for use in clash detection, construction analysis, and fabrication.

Improve your business through better-coordinated, higher-quality project work;

- Accelerate decision making and shorten production time.
- Minimize coordination mistakes and rework with fully parametric change management.
- Gain a competitive advantage with increased client satisfaction and greater profitability through more efficient project delivery.

2) Characteristics of Oracle Primavera P6:

Primavera P6 is a cloud enabled integrated solution for globally prioritizing projects, planning and managing activities executing projects and enriching company's portfolios. It optimizes performance so as to improve role specific functions and respond to each team members responsibilities and skills precisely. The important characteristics of Oracle Primavera P6 are as follows;

- Presenting users with the right strategic method in terms of planning, scheduling and managing a construction project.
- Helps in making informed project, resource allocation and cost management decision.
- Improves collaboration within the construction team as well provides framework for workflow to increase productivity.
- Maximize each stakeholder's skill and delegates responsibility without putting one single person at most risk.
- Effective tracking of progress and optimizes capacity to render maximum profit for the firm.
- Helps deliver construction project in time and within given budget.
- Effective data sharing in between executive offices, onsite offices and enterprise resource division for smoother collaboration and maximum productivity.

III. METHODOLOGY

The methodology adopted to attain the project objective are divided into various steps in order to create a work flow and for easy understanding of the modeling process. The preliminary step is to collect the required information and drawings of the case study and filter for un-necessary noises and redundant data. The second step is to create a 3D model in Autodesk Revit (Fig. 1) by using the component and object information. This 3D model has all the required details including the site layout, structural details as well as architectural details.

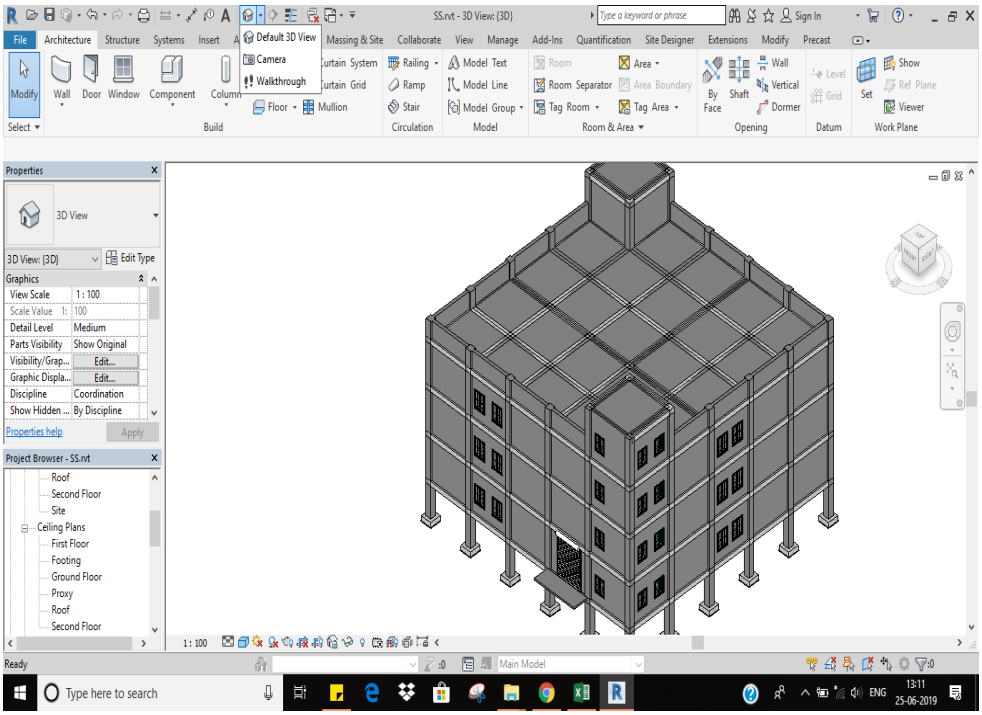

Figure 1: 3D Representation of model in Autodesk Revit 2018

The third step is to export the material take-offs from the 3D model, to assist in the activity scheduling and quantity estimating process in Primavera P6. Number of quantity take-offs can be extracted from single Revit model such as for structural frame work, doors and windows as well as the floor and wall finishing. Following figure 2 shows one example for material take-offs for wall components of the building extracted from Revit 2018.

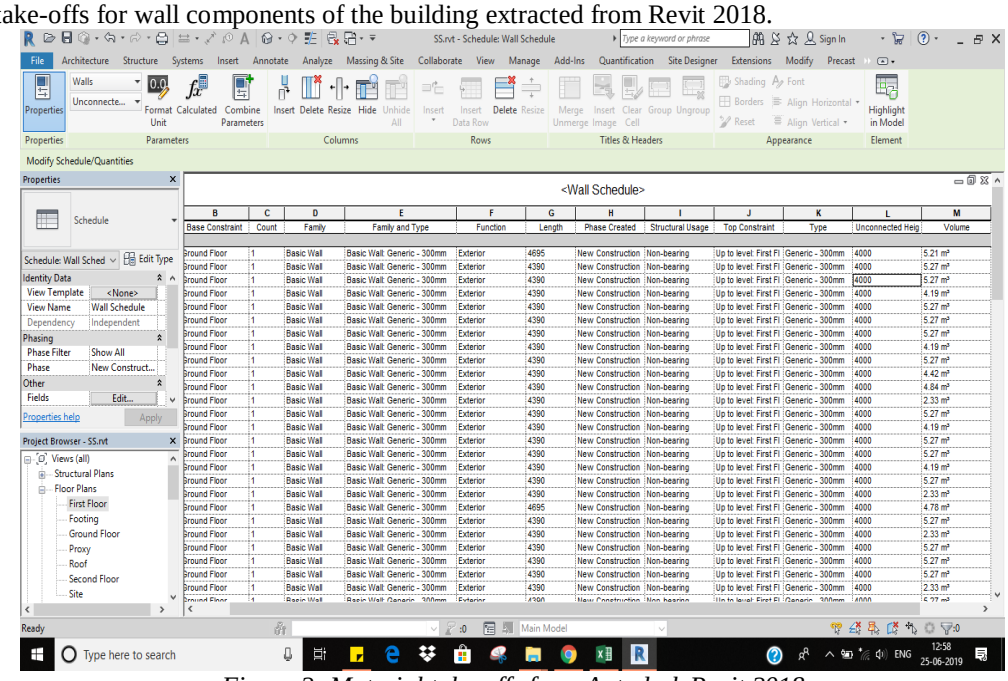

Figure 2: Material take-offs from Autodesk Revit 2018

Referring to the material take-offs and quantity schedule, the activity schedule and work breakdown structure is prepared. This WBS (Fig. 3) and activity schedule (Fig. 4) helps in scheduling the procurement of materials and machinery on site. Because material take-offs are used for scheduling purposes, wastage of material is minimised as well as delay in transportation of materials is also avoided.

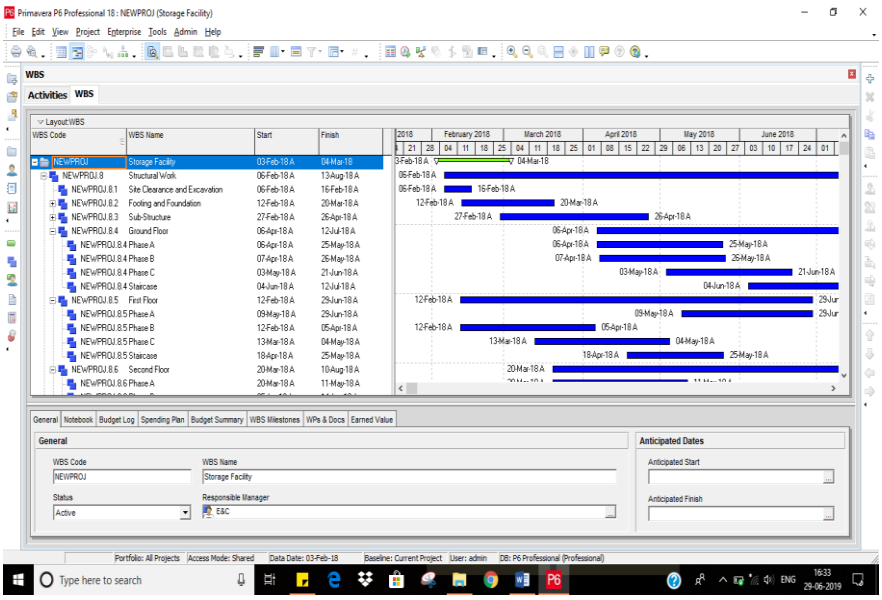

Figure 3: Work Breakdown Structure (WBS) and time scale in Primavera P6

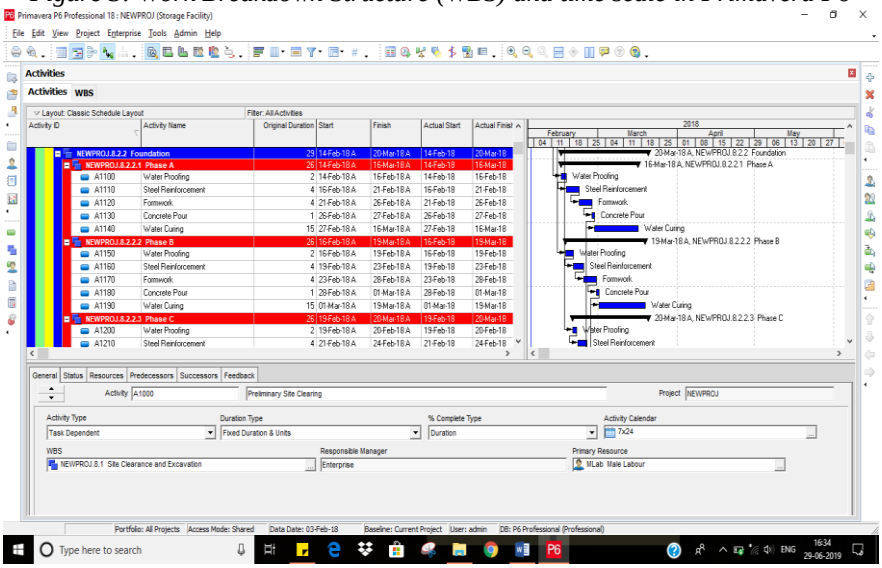

Figure 4: Activity schedule and time scale in Primavera P6

Also, using Primavera P6 resources are allocated to these activities as deemed required, and the cost of unit materials are allocated to the same. Since the material take-offs are readily available, the cost estimates for the activities are prepared accurately. The resources are divided into labour, non-labour (machinery) and material resources in Primavera. For example, resources allocated in the month of February, 2018 for activity block wall is shown in figure 5.

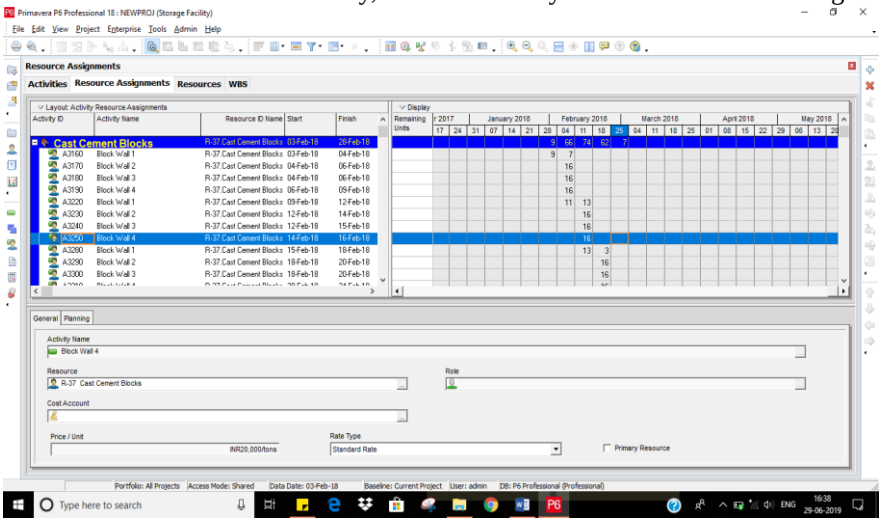

Figure 5: Resource allocation to individual activities in Primavera P6

The data file from Revit and Primavera P6 are then exported to Navisworks Manage 2018 for final simulation. The time-liner and clash detection tool are of prime importance for preparing a 5D model. The 3D model from Revit is appended

in Navisworks and saved in '.ncw' format as shown in figure 6. The time-liner tool is used to import activity schedule and cost of resources into Navisworks file containing 3D model.

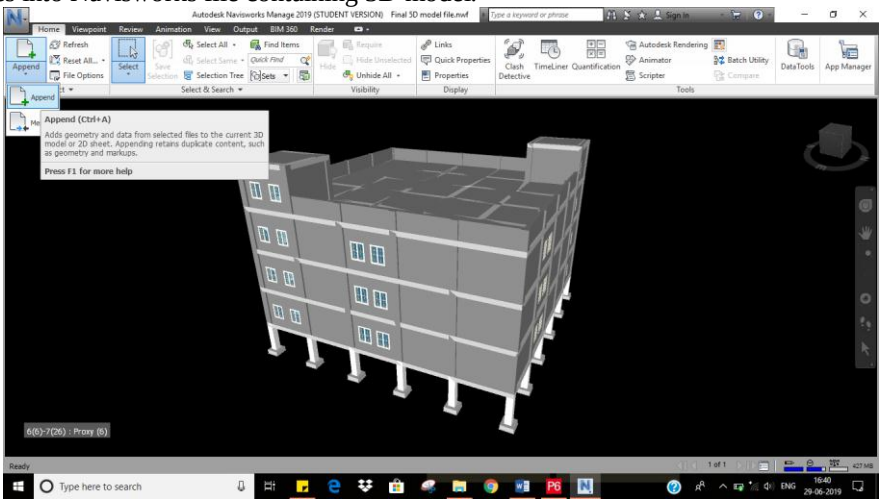

Figure 6: Appending 3D Revit file and Primavera P6 file in Navisworks Manage 2018

The selection tree is created in Navisworks for the 3D model as per the layers and floors of the model. These selection tree can also be created as per the structural work, architectural work, MEP model and interior work of the model. Then as per the activity schedule, sets of specific components are created as per the activities. Then these sets are attached to the schedule in time-liner tool. The interface for this process is shown in figure 7 below.

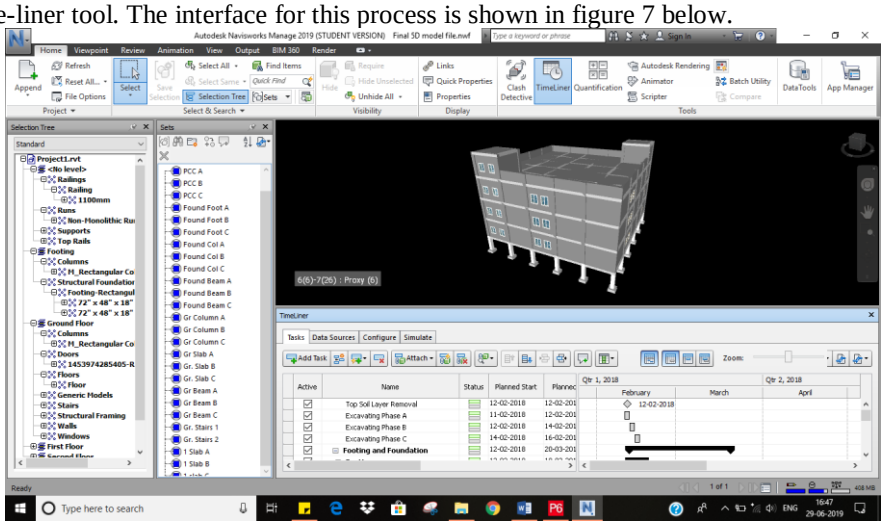

Figure 7: Selection Tree and Set creation as per activity schedule from time-liner

Clash detection is used to identify interferences in between overlapping and interfering components in the model as well as in the activity schedule. The clash detection helps identify possible collusions of components, hence can be avoided using the tool. One such example is for the clash between the void in the wall for window and the window framework itself as seen in figure 8. This clash is interpreted before-hand and proper solution is provided before actual construction process even begins.

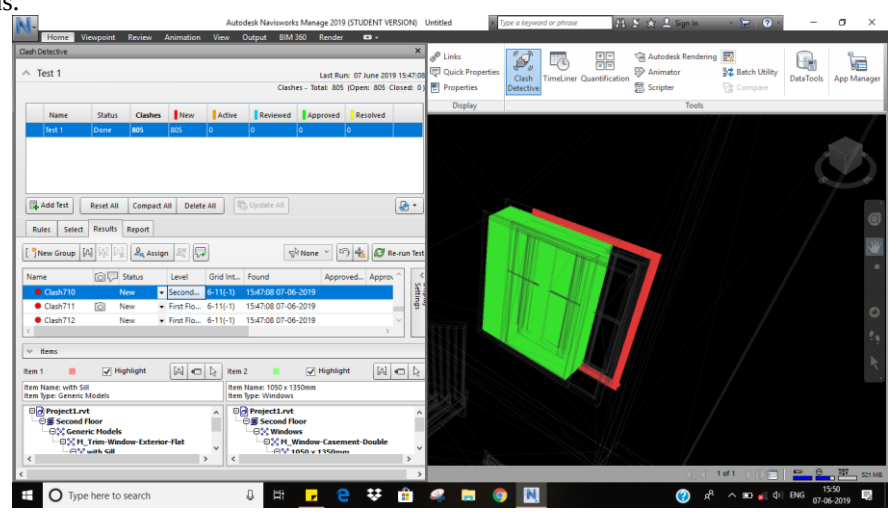

Figure 8: Example of Clash Detection tool and highlighted interference in objects

Finally, using the animator tool, the simulation of 5D model is carried out. This provides a visual presentation of the construction process and resources consumed in doing so (Fig. 9). This helps in improving client conceptualisation of the construction process as well help to monitor and track the progress of the on-site construction work compared to planned work.

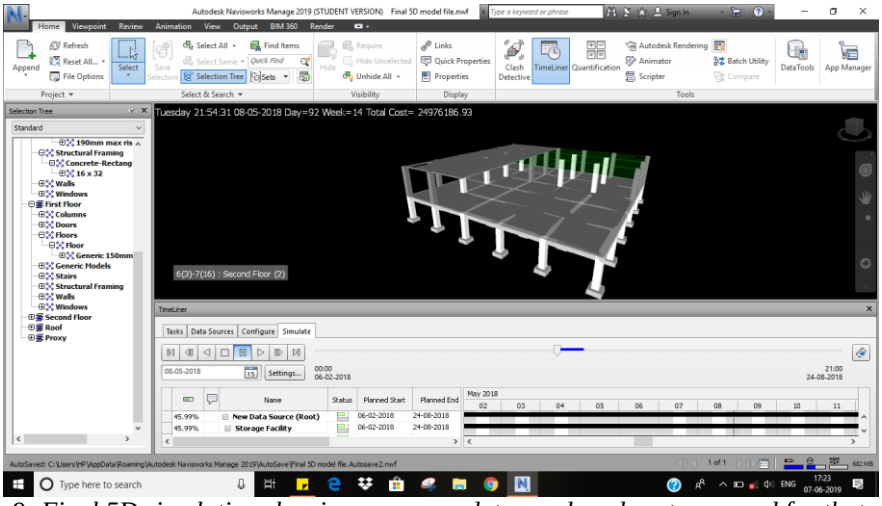

Figure 9: Final 5D simulation showing progress, date, week and cost occurred for that activity

IV. CONCLUSIONS

The 5D Building Information Model consist of integration of 3D model, Time and Cost of construction project into a single file. 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. Also, 5D visualisation helps in better conceptualization of the construction project for clients and other stakeholders involved in the project. Proper finance and resource distribution is possible before hand by referring to 5D BIM model. And finally, 5D BIM model can be used for facility management until the very life cycle of the building.

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