International Journal of Emerging Engineering Research and Technology
Volume 3, Issue 4, April 2015, PP 67-74
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Integrating Building Information Modelling (BIM) and Construction Project Scheduling to Result in 4D Planning for a Construction Project with Relevant Illustrations

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ABSTRACT

The present study is to understand about the benefits of 4D Planning to Construction project managers and the Construction industry. Integrating the construction schedule time with 3D modelling components and its parameters will result in 4D planning methodology. Earlier studies on 4D planning have proved to be useful for "On-time delivery" of the project. In turn the Construction manager is exempted from loses caused due to delay in project delivery. Here, the study involves the reanalysis of a project completed in traditional planning method and the same project is demonstrated in 4D planning method. All discrepancies of the executed project are determined and the same can be avoided while following 4D planning technique.

Keywords: 4D Planning, 3D Modelling, Construction Manager, On-time delivery, Project Delivery.

INTRODUCTION

Indian Construction sector is yet to understand the advantages and benefits of 4D planning techniques. Only 10% of the construction projects are planned according to 4D planning methods and techniques. Rest 90% of the projects is still visualized based on 2D design documents with the additional aid of 3D modelling.

This is interpreted as Building Information Modelling (BIM) which is primarily a three dimensional digital representation of a building and its intrinsic characteristics. Since the time schedule defines sequences of activities and allocates resources such as material and labor, it plays an important role in optimizing and managing a construction project.

A 4D model is presented to define the order in which the segments should be constructed or demolished. The result of this step is a sequence which will be used as the process chain for simulation techniques. Then, a probabilistic 4D model is introduced by linking the 3D model of the project with generated probabilistic schedules from suitable scheduling software.

Then a 4D simulation is created in suitable software which lists the sequence of works to be carried out in a date wise manner. The simulation model determines the idleness of resources and locates any potential bottlenecks. To achieve this, the developed simulation model should reflect the real world system.

Live Project Details

- Builder: Sri Jyothi Builders
- Location: Urappakkam, Chennai, Tamil Nadu, India
- Plot Area: 1860 ft² (172.7 m²)
- Total Built-up Area: 4600 ft² (427 m²)

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- Project Status: Completed
- Total Project Value: 1.1 Cr
- Planned Project Duration: 1 year
- Planned Start: Sept 2012
- Planned Finish: Sept 2013
- Actual Finish: Dec 2013
- Planned Construction cost: 60 Lakhs
- Actual Construction cost: 68 Lakhs

4D PLANNING AND SIMULATION PROCESS

Based on the fundamental attributes required by 4D models the software selection may vary depending on construction project planning practice. As per the requirements of the research on 4D planning, the conventional 2D drawings are prepared in Autocad 2010. The 2D drawings are converted into 3D model in Revit Architecture 2014 and the Time Scheduling is done in Microsoft Office project 2007. Both the 3D model and the scheduling are integrated in Naviswork Manage 2014 for creating the 4D simulation. Further the features in Naviswork Manage 2014 enable us to do Material Management and Elemental Clash Detection of the project effectively. The figure1 shows the process of 4D simulation in a schematic representation.

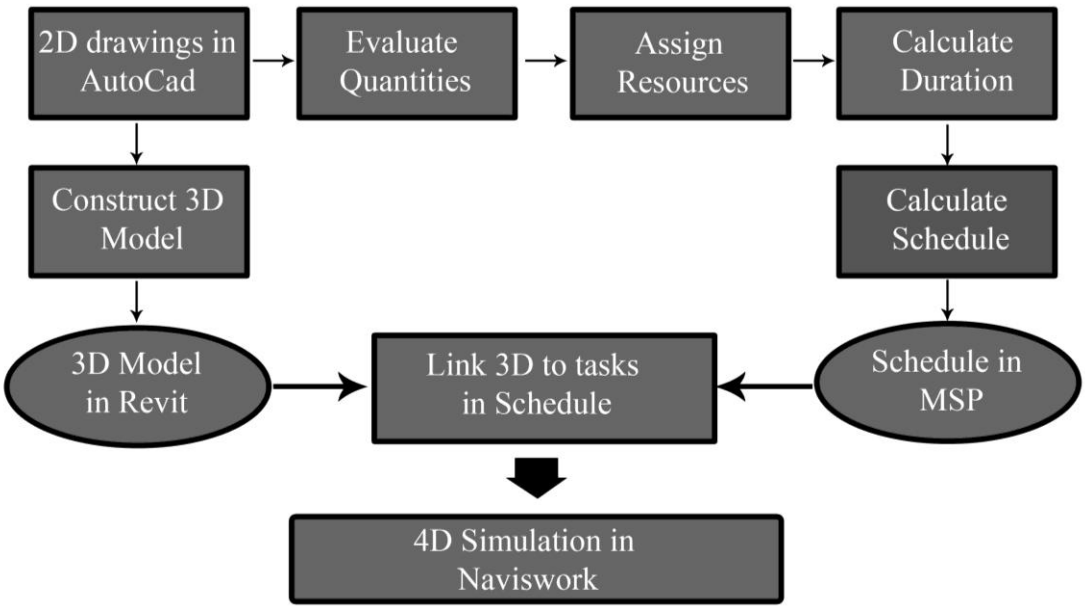

Figure1. *Schematic representation of 4D Simulation process*

2D Drawings in Autocad

The Figure 2 shows the typical floor plan of the Ground, First and Second floor of the project. The areas respectively are Ground Floor -1664 ft² (154.59 m²), First & Second Floor - 1666 ft² (154.77 m²) each. The 2D drawings form the basis for the development of the 3D model in Revit Architecture. The 2D drawings from Autocad can be exported to any desired 3D modelling software which supports Dwg. Format. The estimated quantities are based on the 2D drawings provided by the builder.

Figure2. *Typical Floor Plan of Ground, First & Second Floor*

Scheduling in MS Project Office

On the basis of the information and details provided by the Construction Manager of the building, a MS Schedule is created according to the duration planned by the Builder which is shown in the figure 3.

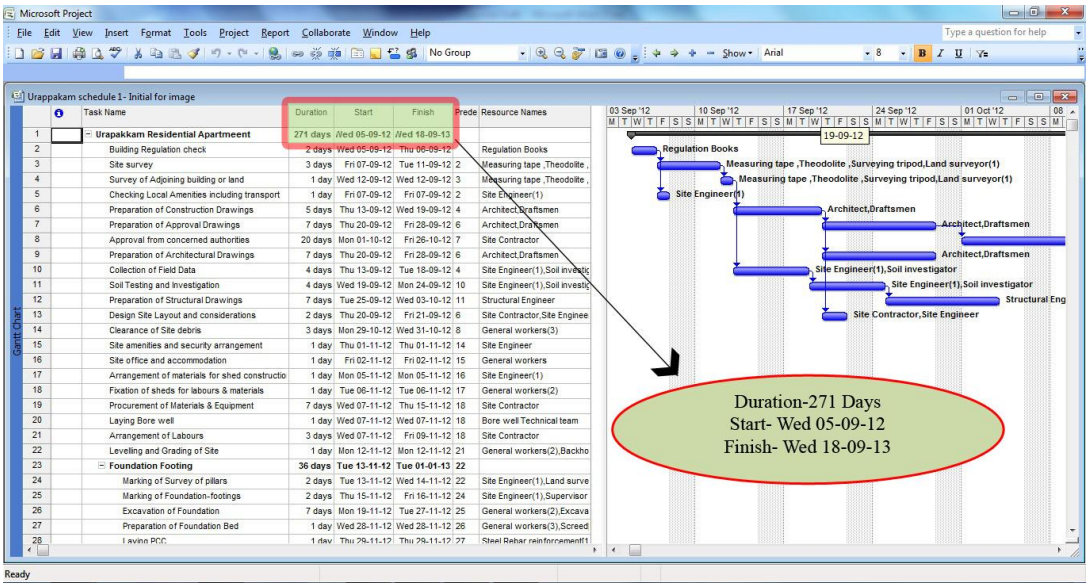

Figure3. *As planned MS Project Schedule for the project*

Due to improper planning and scheduling the project was delayed by 3 months beyond the planned finish date.

A few of the issues faced during the execution which led to delay are described below:

- Conflict 1: Shortage of labor at Ground Floor roof slab.
- Conflict 2: Procurement of Material delayed during First floor.
- Conflict 3: Shortage of labor during First Floor roof slab.
- Conflict 4: Shortage of labor at Second floor wall plastering.
- Conflict 5: Procurement of flooring tiles delayed at First floor.
- Conflict 6: Delay in connection from Electricity Board.
- Conflict 7: Accidental collapse of scaffolding of Exterior Wall.
- Conflict 8: Delay due to lack of uniformity in Bathroom wall tiles.

Table1. *Shortage of Labour – Conflict 1, 3 & 4*

Work Description	Laying Rebar for GF roof slab & beam	Pouring concrete and Compacting for FF roof slab & beam	Plastering SF walls
Work Area	923 ft² (85.7 m²)	1666 ft² (154.7 m²)	5812 ft² (540 m²)
No. of Labors required/day	2 Bar benders	4 Masons	5 Masons
Total Working Days	2	2	10
No. of Labors employed/ day	1 Bar bender	2 Masons	3 Masons
No. of days Extended	2	2	6
Planned Start	28/02/13	09/04/13	06/08/13
Planned finish	01/03/13	10/04/13	19/08/13
Actual Start	08/04/13	20/05/13	18/09/13
Actual Finish	11/04/13	23/05/13	09/10/13

Table2. *Delay in Material Procurement- Conflict 2 & 5*

Material Description(First Floor)	Cement	Fine Aggregate	Coarse Aggregate	MS Rod	Vitrified Tiles-Flooring
Quantity	330	1272	659	2	1730
Units	Bags	ft³	ft³	Tons	ft²
Material Planned Order Date	06/05/13	06/05/13	06/05/13	06/05/13	20/08/13
Material Planned Delivery Date	14/05/13	14/05/13	14/05/13	14/05/13	09/09/13
Material Actual Order Date	14/06/13	14/06/13	14/06/13	14/06/13	10/10/13
Material Actual Delivery Date	04/07/13	04/07/13	04/07/13	04/07/13	13/11/13
No. of Days Delayed	8	8	8	8	10

Table3. *Delay Due to External Agent – Conflict 6*

Description	Electricity Board Connection
Planned Start	07/06/13
Planned Finish	17/06/13
Actual Start	22/07/13
Actual Finish	20/08/13
No. of Days Delayed	15 Days

Table4. *Accidental Delay – Conflict 7*

Work Description	Exterior Wall Painting
Planned Start	01/08/13
Planned Finish	28/08/13
Actual Start	13/09/13
Actual Finish	24/10/13
No. of Days Delayed	10 Days
Cause of Delay	Mishap of Scaffolding

Table5. *Delay Due to Material Replacement – Conflict 8*

Material Description	**Ceramic Bathroom Tiles**
Quantity	2000 ft² (186 m²)
Quantity to be replaced	600 ft² (55.7 m²)
Duration for Replacement	14 Days
Cause of Replacement	Non-Uniformity in colour of tiles
Planned Start	19/06/13
Planned Finish	27/06/13
Actual Start	30/07/13
Actual finish	27/08/13

Due to the above conflicts the Project was delivered on December 2013 instead of September 2013.The Actual Schedule of the project is re-scheduled according to the delays occurred during the execution of the project as shown in the Figure 4. These problems could have been avoided by the using the 4D Planning Technique.

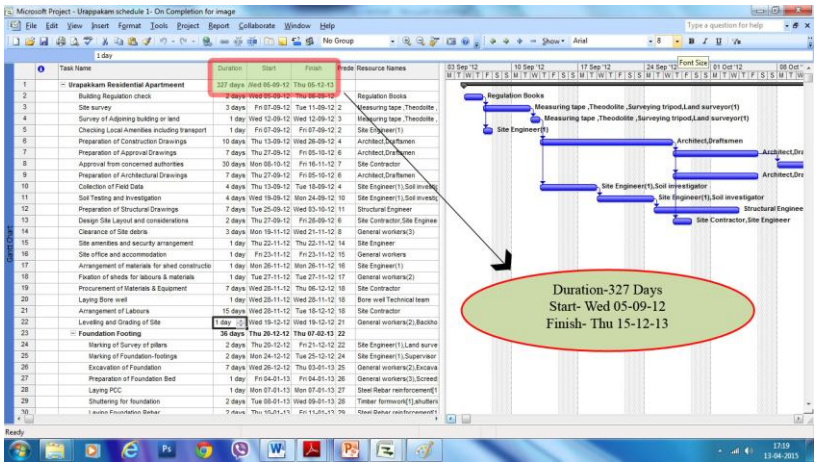

Figure4. *Actual MS Project Schedule for the project*

3D Modelling in Revit Architecture

The modelling process in Revit involves a sequence of stages in which each are going to be linked to the corresponding task in the MS Schedule by Naviswork Manage. The figure 5 shows the stage wise 3D modelling of the project.

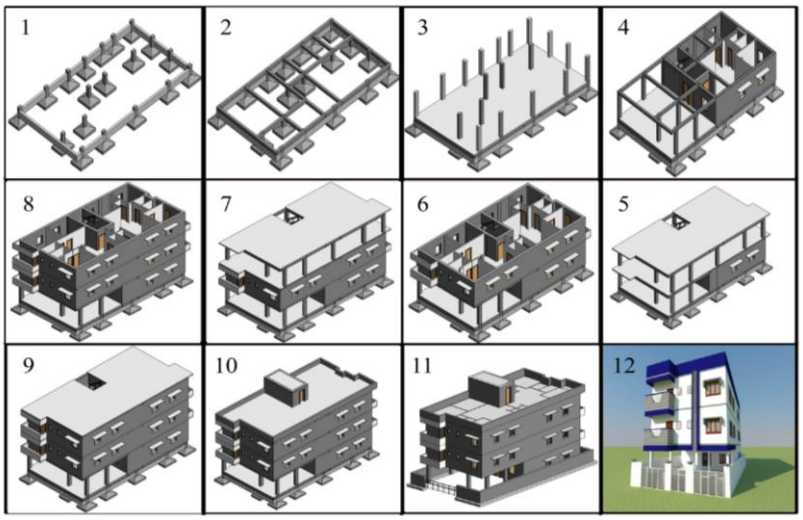

Figure5. *Showing the Sequential Development of 3D Model in Revit Architecture*

4D Simulation

4D simulation involves the step by step construction animation of the building tasks. Here, the work task from MS project office is linked to its corresponding building components. For example, the task of Laying Ground floor slab in schedule is linked or attached to its corresponding 3D slab element in the model. This integrating work of schedule and the 3D model is carried out in Naviswork Manage 2013.

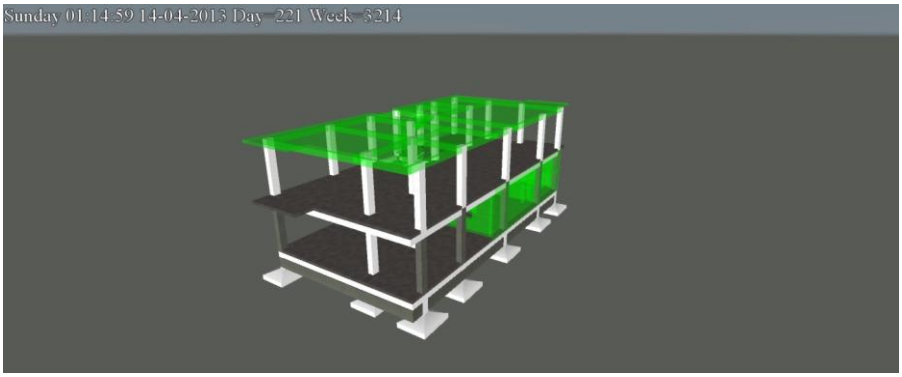

Figure6. *4D Simulation on day - 14/04/2013*

Once all the tasks from the schedule are linked to their corresponding 3D elements, the 4D simulation can be viewed. The simulation shows the progress of tasks taking place on a Day-to-Day basis. Planning of the labor and resources can be done for any particular element of the building by simply scrolling down to a particular date in the course of construction in the simulation. The figure 6 shows the building elements which are planned to be executed as on date in green color which is differentiated from rest of the building. A video of the simulation from the start to the finish date can be exported to give a demo of the project to the client.

Labor Management by Naviswork Manage

The Timeliner feature of the Naviswork Manage software enables you to view the work tasks of the schedule along with the visual of the 3D model. Before executing any particular work task the required amount of Labor and Resources associated with the task is determined from the schedule. This feature of Naviswork enables to visualize the task and pre-plan the requirements without any error. This feature appears in Naviswork as shown in the figure 7.

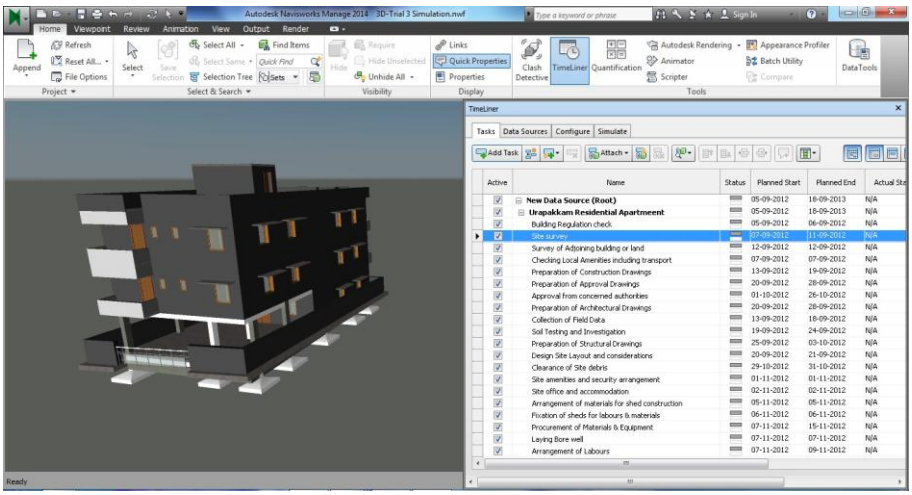

Figure7. *Showing the Timeliner Bar along with the 3D model of the Building*

Material Management by Naviswork Manage

Naviswork helps to manage procurement of materials efficiently at the start of every level of the building without any delay. During the 3D modelling process in Revit Architecture, extra parameters can be added to the 3D elements such as Material Order Date, Material Order status, Material Delivery Date, Material Delivery Status & Material Location under desired property section.

As the construction progresses, the dates or values can be manually entered in the above parameters. Revit enables to create a schedule automatically as the values or dates are entered in the property section. The figure 8 shows the schedule created by Revit with property box showing the values entered for the parameters under construction sub-division. The schedule can be exported to excel if desired.

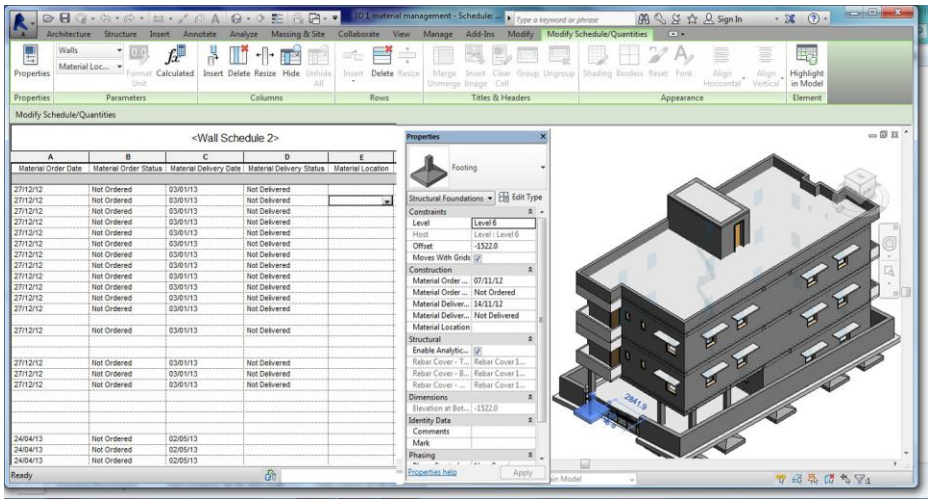

Figure8. *Showing the dates in Revit property section and its Schedule*

Naviswork Manage synchronizes with Revit at every stage of construction as the dates and values are entered in Revit to manage the material procurement. Naviswork creates a separate selection set for the parameters like Material Order Date, Material Order status, Material Delivery Date, Material Delivery Status & Material Location and its corresponding dates and values such as Material Order status- Not Ordered, Material Delivery status – Not Delivered. And on selecting a particular selection set, Naviswork high lightens the selection in the 3D visual screen. The figure 9 shows the Material Order Date for First Floor which is to be ordered on 24/04/13.

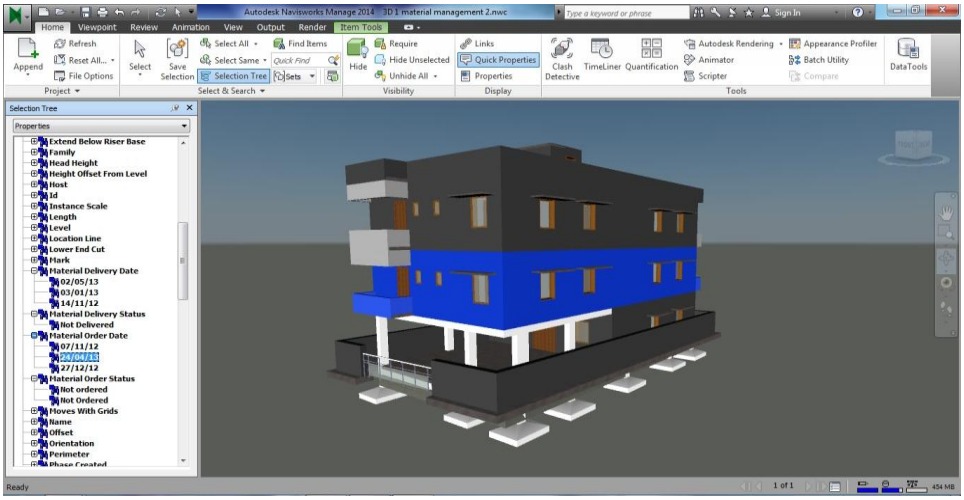

Figure9. *Showing the Selction set – Material Order Date 24/04/13*

RESULTS AND ANALYSIS

The completed project is demonstrated in 4D technique and each stage of construction is considered for investigation. Primarily, a MS project schedule was created according to the planned duration of the builder. The delay of schedule in each work task is computed with area, quantity and is shown in the tables above. Another MS project schedule is created to show the actual work schedule with the delay. The reason for the delay is found to be Lack of planning and communication between the designing and execution team.

By the use of 4D technique, the changes in documentation can be updated in simulation from time-to-time. This keeps the site personal informed of the changes done in the schedule and take appropriate action for the work task. Further, the simulation helps to visualize the construction tasks in a better way.

CONCLUSION

This research proposed a simulation-based 4D modelling approach for planning and scheduling of Residential projects by integrating simulation and 4D modelling techniques. This research investigated the applications of 4D modelling for sequence assessment in the planning stage of Residential projects. This research investigated a new approach integrating simulation with 4D modelling to create a probabilistic 4D model. This approach can be a useful system to avoid delay in project delivery and hence can also avoid loses incurring due to the delay.

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