

Visualization of Construction Progress by 4D Modeling Application

Mr. Satish A. Pitake¹, Prof. Dhananjay S. Patil²

1-PG Student, Department of Civil Engineering,

2-Associate Professor, Department of Civil Engineering, Rajarambapu Institute of Technology, Rajaramnagar, Islampur, Dist. Sangli, Maharashtra, India

Abstract—Tremendous development in construction industry created large extent of work in infrastructure, residential and commercial field and with the growing complexity of construction projects and the shortage of resources there is a need for more sophisticated tools for construction planning and management. This paper proposes a visual method of scheduling with application of 4D model for better co-ordination and communication among project team. We developed 4D model with the help of software's such as Naviswork Manage, Google sketch-up and MS office project. 4D model tools give the construction progress information in the form of project viewing, review and simulation. As per case study 4D Model is useful in the graphical presentation and communication of the construction schedule. It helped in effective visualization of the construction process as to view activities with their cost on timeline as daily, weekly. Use of 4D Model contributed in time saving and ultimately cost of construction by reducing the delay. 4D models help to improve construction plans as compared to traditional planning tools.

Keywords-4D Model, Visualization, Simulation, Communication.

I. INTRODUCTION

As traditional construction planning is inefficiently used for construction project management and to overcome this there is need of some advanced techniques and we applied 4D modeling.

After applying this software tool we were able to simulate construction progress with Time liner and different views of schedule visualization, improved coordination and communication between project team. 4D Model visualization helps project teams in visualizing spatial attributes of the project and identified problems which are not understandable by looking at Gantt chart or CPM network such as space conflict. Using these tools construction planners can simulate planned and the actual sequence of construction activity with different color code to 3D component of a building. It helps in identifying which activities are on time, early or ahead of schedule, identify clashes & interfering problem and find opportunities for improving construction schedule.

II. MODELING IN 4D

A. Defining 4D modeling

The 4D CAD model can be defined as three dimensional (3D) combined with time (schedule) information-makes it easier for the project team to visualize the sequential construction process such that the appropriateness of construction plan can be thoroughly reviewed. 4 D model is created by linking construction schedule to 3D model. This process of linking a schedule to a 3D model occurs in a 4D simulating program. Figure 1 illustrates the process of linking a 4D model. Some of common software's used for linking 3D model to project schedule are Naviswork Manage, Project Wise Navigator, and Visual simulation.

Naviswork manage used for developing 4D model which helps in improving control over outcome of the project .It allows the project team to see the construction plan physically and its function digitally before it is built which help in faster and more economically.

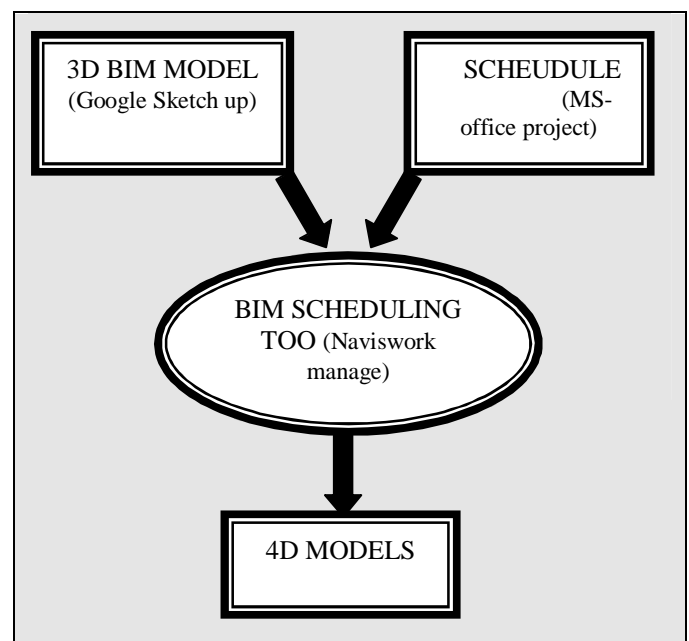


Fig.1 Process for developing 4D model

B. Need of 4D Modeling

The current traditional construction planning method is not effectively running as it affects the construction management parameters as Time, cost and quality by reducing the productivity of the construction industry. To overcome current deficiencies in the field of construction planning and improving construction planning there is a need for new technology. The following are major factors which demands for 4D model.

1. Miscommunication of project information is prevailing factor in two third of problem arising in the construction industry during planning and execution.
2. Unsatisfactory performance of construction project frequently originates from inappropriate design, non-proper construction planning and lack of communication which results in prolonging project duration and over cost.
3. A traditional planning tool which is currently used in construction planning is found ineffective in some extent such as CPM schedule consider only time and precedence constraints. It is unable to cope with non precedence constraints ranging from physical constraint, contract constraint to resources and information constraint.
4. For field person while executing or communicating construction sequence he must mentally link this schedule information with physical building and it may difficult when there is any change which affect on overall sequence of construction of project. CPM schedule find a confusing and not easy to understand when there is complex project and more effort consume to replan and redraw network each time when it get updated..
5. The Indian construction industry is currently experiencing a boom due to large development in infrastructure, commercial and real estate market which show a large volume of work for construction industry therefore it is essential to develop a new project management tool to ensure that all projects are complete in specified time and cost limit.

4D model and its benefits in terms of site-space planning, project time and Cost control can be effectively used in the construction industry. Visualization feature in the 4D model can be a great advantage to improve the communication in the Indian construction industry where many of the personnel are multi-language and multicultural.

III. DEVELOPMENT OF 4D MODEL-OVERVIEW OF CASE STUDY

A residential building is used for the case study which was located in Pune. We selected two buildings of G+8 for which used 4D modeling application in assisting construction planning and previously constructed building which was traditional planned are taken for comparison. It consists of the activity as RCC work, brick masonry and plastering. 4D model is developed by following steps with help of following software's.

A. Software tools selected

The software tools selected in this case study are stated as follows:

1. *Autodesk naviswork Manage 2013*: It is project review software that supports intelligent 3D model-based design with scheduling, visualization, and collaboration tools.
2. *Google sketch-up 8*: It is simple, powerful and affordable 3D based software in which 3D model is prepared for importing the model into Naviswork software. In which we can make the 3D model with its different components which is grouped together for selection of sets to link the particular activity.
3. *Microsoft office project*: This is software used for scheduling the project plan and imported into Naviswork manage software.
4. *Microsoft office Excel*: It is used for estimating the cost of building with the insertion of some formulas.

B. Steps to Develop the 4D Model

1. Transposing the 2D drawing into a 3D model:

- Step-1) Importing the plan of building from Auto-cad drawing in Google sketch up Software with selecting required unit of measurements.
- Step-2) Constructing the 3D elements of the building such as column, beam etc.
- Step-3) Making a group of 3D components as per scheduled activity
- Step-4) Modifying the 3D model

2. Establishing a 4D model

A construction schedule was created using Ms-project. The schedule provided activity durations and relationship between activities. The scheduled data from Ms-project and a 3D model from Google sketch-up were exported separately to Autodesk naviswork Manage. Then the 4D model is developed by the linking of the 3d object in the model to the activities in time Schedule. The method of establishing the 4D model consisted of following steps. (Fig.2)

Step-1) Exporting 3D model from Google sketch up to Naviswork

Step-2) Exporting the schedule from MS-project to Naviswork

Step-3) Linking 3D objects in model to activities in time schedule

Step-4) Checking the relationship between 3D object and schedule

Step-5) Entering materials, labor and equipment cost from MS-excel

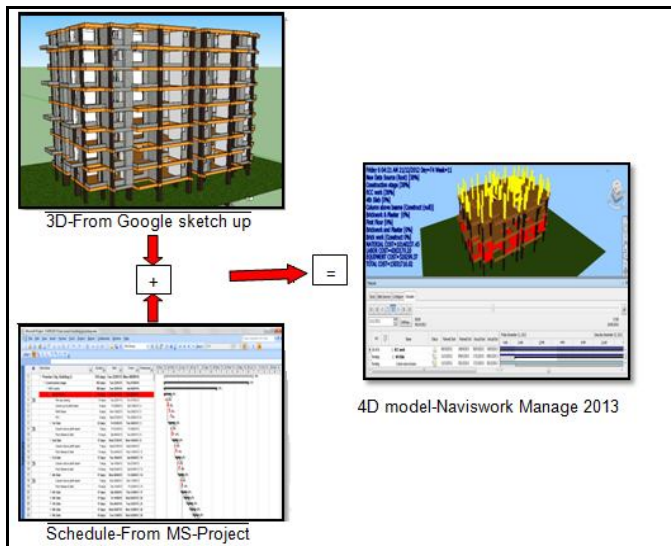


Fig.2 Steps for establishing 4D model.

C. Simulating construction schedule

Autodesk Naviswork 2013 allows users to define tasks directly in the software tool itself and then link building components with these defined tasks. In Fig. 3 each task can be defined directly in naviswork Manage or can be imported by Primavera or MS-project. Each Task shows its planned start date & finish date, actual start date and finish date. There is graphically representation of construction schedule in the form of Gantt chart view where each task takes one row which show planned, actual and planned vs. actual chart with different color based on user preference. There is each task show its status in the form of planned against actual relationship with two bars. Top bar denote planned date and bottom bar denote actual date. If actual start & finish date are same as planned start & finish bar present in green color while any variation between them displayed in red color. The simulation of construction progress can show on weekly, daily, hourly based on the user’s preference. Simulation interface also shows the dates, week, construction sequence, material, labors & equipment cost and task percentage finished. The 4D model shows project phases and site logistics in a practical environment, 4D simulation provide users with different project statuses. It is also suitable for the project manager and contractor to provide the owner with a virtual and intuitive view of the project progress. The 4D simulation provides the contractor with a virtual view of the project status on any date defined under the simulation tab. Besides, it helps the Engineers, contractor to adjust the project schedule according to any design change

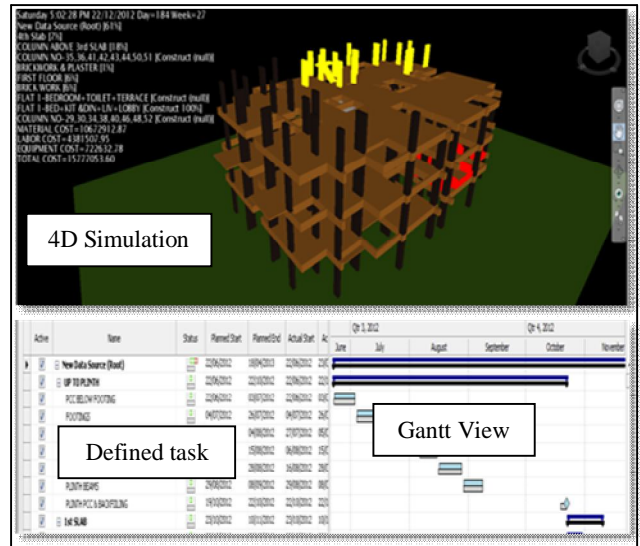


Fig.3 Interfaces of Autodesk Naviswork of 4D Simulating.

D. Time taken to Develop 4D model

In this study 148 Man–hours spent to develop a 4D model of G+8 building having the following elements of the building as footing, plinth beam, tie beams, columns, floor beam and slab, Brick masonry, plastering. In building 3D model total 2280 elements were used. The hours were broken into the following stages.

1. Study and learning of software’s
2. Transposing the 2D drawing into 3D model
3. Establishing 4D model

Table No-I shows the hours were distributed across the stages.

TABLE I
Time Taken for Transposing 2D Drawing to 4D Model.

Stages	Workflows	Time Taken (Man-Hrs)	
		Planned	Actual
1. Study & learning of software’s	Personnel study	40	40
2. Transposing the 2D drawing into 3D model	Importing the building plan from Auto-cad in to Google sketch up	0.5	2D to 3D workflows 89 Man-Hrs
	Building the 3D elements of model	76	
	Making group of 3D elements as per scheduled activity	8.5	
	Modifying & corrections for errors in the 3D	4	

3.Establishing 4D model	Exporting 3D model from Google sketch up to Naviswork	4	3D to 4D workflow 19 Man-Hrs
	Exporting the schedule from MS project to Naviswork	5	
	Linking 3D model objects to activities in time schedule	4	
	Checking the relationship between 3D object and schedule	2	
	Entering materials, labor and equipment cost from MS-excel	4	
Total		148	

and reviewing the case study which is described below.

Efficient planning plays an important role in achieving the success to the project. By reviewing the case study it is observed that 4D modeling help to planners and project team to achieve efficient planning of construction work.

1. *Saving in project time and cost:* Two buildings which are traditionally planned and other two buildings after assistance of 4D model for construction planning taken for time analysis. Its delay and lagging time of activities observed which reduced significantly. Time analysis for different buildings shows delay time and the delay cost as per below.

TABLE II
Time and Cost Analysis for Building D, F and G

Planning Tool	Building	Delay Time(Day)	Delay Cost(Rs)
Traditional	Building-D	95	2374698
	Building-F	22	983260
4D model	Building-F	21	358747
	Building-G	12	588098

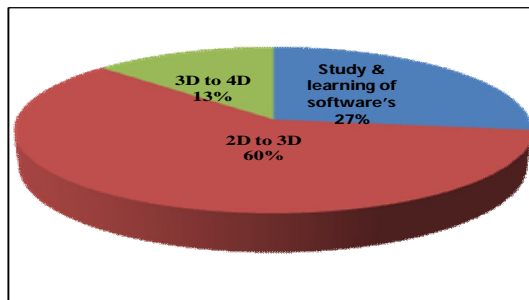


Fig.4 Breakdown of time in different stages to develop 4D model.

IV. DISCUSSION OF RESULTS

The study brought up 4D modeling as a promising tool for construction planning. There are many positive impacts of 4D modeling discovered which are not possible to achieve through traditional planning methods being used.

A. Time in developing the 4D model

About 148 Man Hours are utilized to develop 4D model from 2D documents and schedules. Percent Time consumes in different stage for 2D drawing to 4D Model.

- Study & learning of software's - 27%
- Transposing the 2D drawing into 3D model -60%
- Establishing 4D model – 13%

B. Benefits of 4D model

There are following benefits and shortcoming of 4D modeling for construction planning identified after viewing

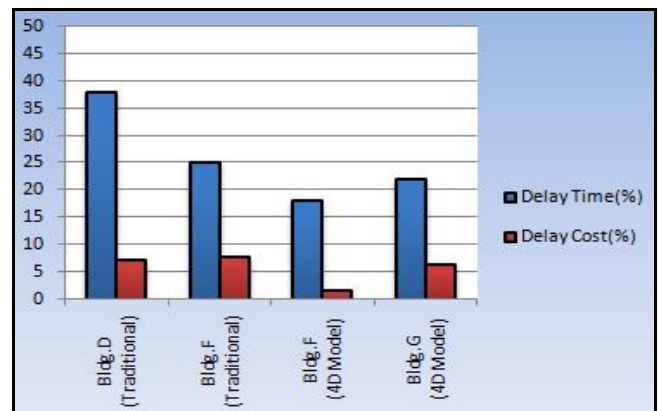


Fig 5 Graph showing Time and Cost in Percent for Building D, F and G

2. *Visualizing and interpreting construction Sequence:* It is great visualization tools which provide 3 dimension virtual representation of construction progress of building. The different color code for 3D components while simulating the schedule gives effective visualization as it shows Green color while activity in progress, yellow color while activity started or finished early and red color when the activity started or finished late (Fig.6) which helps to project team to understand the construction progress and day to day activity more efficiently. Project teams can see the construction progress views as per planned, as per actual and planned against actual which clearly differentiate their planned and actual status of the project.

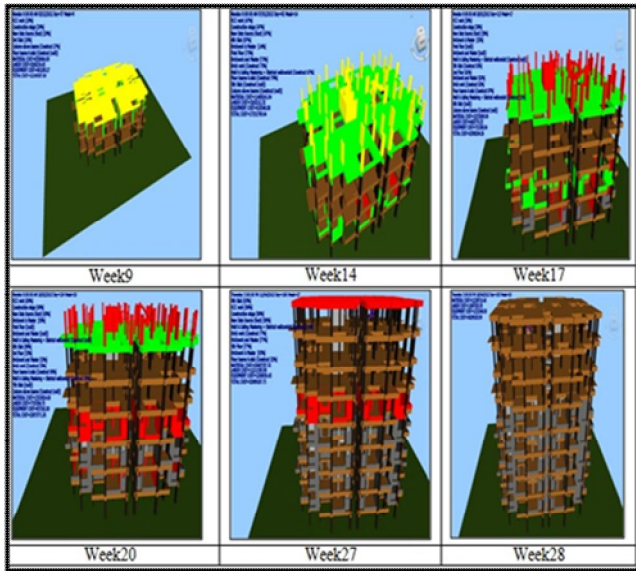


Fig.6 Simulating Interface of 4D Model.

3. *Better communication:* Effective communication between project participants is essential key factor for achieving construction planning success. During construction of any project the most common forms of communication is help to understanding among project participant by visualizing the progress. And it is achieved by using naviswork 4D simulation interfaces. The ability to keep information up to date gave the overall idea and clear vision of project progress to architect, engineer, builders and owner with the ability to make better decision fast.

The 4D model used in a case study is very effective tool for understanding the progress of work. 4D model played an important role in communication between project participants. The following benefits are seen to project team as follows.

1. The Client got the whole picture of project progress from 4D model which is not understood by 2d documents.
2. The contractor, the owner and even the designers able to on the same page at any time to share understanding of project status-information, duties, and construction plans.
3. The contractor defined a date under the simulation tab, the simulation interface showed the ongoing tasks with the percentage of finished tasks on the defined date which understand the progress of work and communication between builder, architect, client, engineers and labors becomes easy.
4. Planned work sheet with the visualized effect of particular activity helped to site engineer and labor in easily understanding their targeted work.

4. *3D coordination and Accuracy of construction:* 4D modeling enables optimization of design suiting the project requirements. Selecting the most appropriate design under project scope, goal and most suitable aesthetics result in improved accuracy of construction.

Visualization of work progress is possible by navigating around or inside the building using camera options available. The orbit camera allows user to navigate around the building

and have a bird's view projection on building. Walk camera also helped to user inside and around the building to see the building components and this visualization helped in identifying how one wants to start the building construction instead of visualizing in mind one could see everything on screen. Activity is linked to the particular 3D components and given out that print of every activity on site while construction of that activity which helped to managers, contractors and labors to reduce design errors and better understanding of the work which maintained the accuracy of work. The measurements of every structure are also available in software to calculate the quantity which helped in costing which saved the extra time of site managers and contractor.

5. *Build site layout environment:* The 2D site layout was used to build the 3D site layout environment, including the location of tower crane, RMC plant, site office, Material testing lab, Store room, Material storage area, Labor camp and access road. The 3D site layout and 4D model could provide a virtual construction site in a realistic manner to analyze access road, space requirement, lay down area for formwork and bricks while the work of multi-floor building. The proper space for proposed water tank also selected from this model.

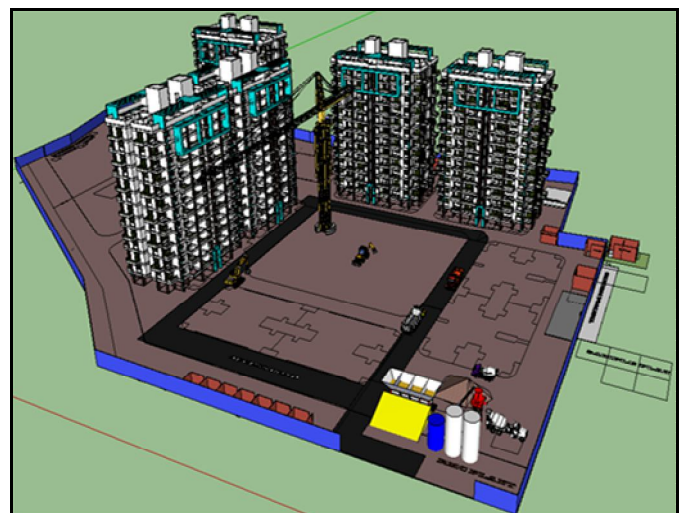


Fig.7 Site Planning Layout.

C. Shortcoming of 4D modeling

Although a major portion of 4D modeling impact on construction planning is observed to be positive, there are few weaknesses which come with the adoption of 4D modeling.

1. Development of 4D models from 2D documents is a timely and challenging task.
2. It also requires skilled and trained staff to execute the workflow process with a 4D model in a short time and it may be costly.
3. The major challenge faced of this project in the case study was the transformation from 2D to 4D model. As model takes more time with its checking and updating to become that model more realistic.

4. The various problems that obstruct the adoption of 4D modeling on the site. Such as unaware about this technology so it could not implement with full efficiently on site.
5. Used software Autodesk Naviswork Manage for 4D model which unable to facilitate print sheet of the output result in proper report format.
6. The software's and its training for 4D modeling is costly as compared to other software tool of planning.

V. CONCLUSION

1. During the study of 4D modeling software's Autodesk Naviswork Manage 2013 found easy to learn and 4D model could obtained by using 3D model from Google sketch up which is also user-friendly and Microsoft project used as scheduling tool.
2. About 148 Man Hours were utilized to develop 4D model from 2D documents in which more time consumes for transposing the 2D drawing into a 3D model.
3. Most significant benefits of 4D modeling are found out to be better a visualization of the construction progress work. From above study it shows that approximately saving 10 to 11 percent in project time and 3 to 4 percent project cost can be achieved by applying 4D model.
4. Deficiency found in developing 4D model as it requires skilled and knowledgeable people otherwise it is time consuming and problematic in how to use more conveniently. These can be solved by providing proper training facility.

5. Visualizing effect of construction sequence and site logistic enhanced better communication among Project team and coordinate the project planning efficiently.
6. As 4D model has been more effective, its proper generation and implementation on construction planning can be more promising.

REFERENCES

- [1] Vacharapoom, Benjaoran and Sdhabhon Bhokha "An integrated safety management with construction management using 4D CAD model" Safety Science 48 (2010) 395–403.
- [2] Eknarin Sriprasert and Nashwan Dawood (2002) "Requirements Identification for 4D Constraint based Construction Planning and Control System" International Council for Research and Innovation in Building and Construction CIB w78 conference 2002 Aarhus School of Architecture.
- [3] Timo Hartmann (2009) "How to link and present 4D model using Naviswork" VISICO Center, University of Twente.
- [4] Timo Hartman and Ju Gao and Martin Fischer "Areas of Application for 3D and 4D Models" Journal of Construction Engineering and Management Vol.134 No.10, pp.776-785.
- [5] Wissam Hijazi, Sabah Alkass and Tarek Zaye "Constructability Assessment Using BIM/4D CAD Simulation Model" (2009) AACE International Transactions BIM04.
- [6] K. W. Chau, M. Anson and J. P. Zhang (2004) "Four-Dimensional Visualization of Construction Scheduling and Site Utilization" Journal of Construction Engineering and Management Vol. 130, No.4, August 1, (2004) pp.598–606.
- [7] Autodesk BIM curriculum and Naviswork Manage 2013 software.
- [8] M.H Tsai, S.C.Kang, S.L Fan. and S.H Hsieh "Experiences using Building information modeling for construction project" International conference paper on computing in civil & building engineering.