

Simulation of Construction Sequence using BIM 4d Techniques

Harsha Vardhan Tirunagari, Venkatesh Kone

Abstract: Project scheduling in construction refers to a roadmap of all activities of the project that should be done in a given order and within the time allotted to each activity. In 1910 Henry Laurence Gantt created Gantt chart to plan, coordinate and monitor construction sequence over time. It became the most used technique for scheduling, but it does not visualize the construction progress to users and also do not have the ability for clash detection. As the global construction projects are expanding day by day there is a rise in demand on resources, so there is an increasing need for a sustainable process for construction scheduling. 4D BIM (Building information modelling) is the proposed solution for the above problem. Through this technology, stakeholders and contractors can envision project success from design to construction while construction project managers can aggregate model data and quickly react to changes in real time. 4D BIM is adding the 3D model to time (schedule). It is a process that can add a lot of value to design and construction saving both time and money. The present papers studies about the importance of 4D BIM in construction scheduling and reveals the perceived value of 4D BIM in construction. This study mainly concentrates on simulation of construction sequence using 4D BIM for integrated project delivery and effective utilization of 4D application in BIM to resolve design conflicts and monitoring the project status by visualizing the time constraints.

Index Terms: 3D model, 4D BIM, Simulation, Visualization

I. INTRODUCTION

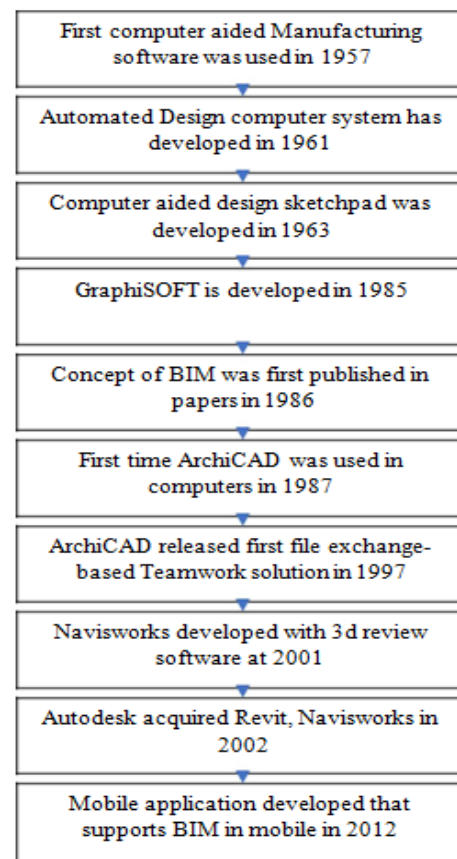
In the early days of construction, there were only complex drawings available which were used for construction planning, with the change in time and technology, new innovative tools like BIM are being used. Building Information Modelling (BIM) is an intelligent model-based process of creating datasets, with all the information available for planning, managing buildings, and infrastructure. Building information modelling is an upcoming technology in the construction industry that provides a realistic view of the components in building with 3d when compared to models in CAD [1]. BIM was not just started in the 21st century, it has a long history and the BIM concept was first published in papers in 1986.

A. History

In this 21st century, the construction industry was adopting a new tool using 3d digital models, that we called Building Information Modelling (BIM). BIM involves in creating and using 3d models to develop and communicate project decisions from drawing boards, tracing paper, 2d

hand drawing, sketching to graphics tablets and then to AutoCAD, but now we reached a world of 3d.

The percentage of companies that are using 3d is almost 20% in 2007, this went to 49% in 2009 and to 71% in 2012 [2]. In early 1970 basic 2d and 3d computer aided designs were used, next BIM occurred with the introduction of 4d or time in 1986 and this was developed to 5d in 2000 for not only to generate construction schedules but also to estimate cost. The detailed progress of BIM development is shown in the following flow chart 1 which is very well explained by [2].



Flow chart 1: History of BIM

B. Building Information Modelling

Building information modelling was popularly known as a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it and forming a reliable basis for decisions during its lifecycle. It is the process of designing a building model using one coherent system of computer models rather than individual sets of drawings.

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Cost overruns and time delay are very common problems in the construction industry because of sudden price fluctuation, changes in design, bankruptcy from the client which cannot be prevented entirely but adopting new technology like BIM can reduce these impacts [3]. Through Building Information modelling, at any point in the complete project life cycle, the information is there that helps you to minimize the time-consuming errors and the information can be accessed by project holders from anywhere.

Through BIM you can do modifications in your design before it is built, and realistic visualization can get you immediate approvals. BIM has been one of the biggest technology trends that are said to transform the world's construction industry. Building information modelling is a mirror of the development process from computer-aided sketchpad to Revit and Navisworks through which 3D architectural model, integrated structure, MEP, site logistic planning and quantities extraction is done [4]. BIM provides insights into a design's constructability that reduces errors, improve efficiency and effectiveness of the construction phase and helps to provide a better understanding of the future operations and maintenance of the building.

The biggest benefits of BIM are cost saving, the quantity of documentation, time-saving, financial control, elimination of errors which are said by evaluating several statistical methods through software called Statistica [5]. In practice, BIM is a set of technologies and processes that lead to better outcomes at different stages of the construction lifecycle from conceptual planning design in engineering procurement and construction operation and maintenance and demolition. One of the key features of BIM is being able to calculate quantities absolutely with precision because it involves objects, so everything in the model is being calculated as that entity so you can get a schedule of quantities which are fair.

Nowadays the reasons for project failure are a time delay, poor material management, unplanned activities during construction that cannot be solved by traditional methods, but applying BIM in project management reduces time, reduces lifecycle expenses and increases efficiency, productivity [6]. BIM utilizations like coordination, construction planning, and fabrication make construction project more efficient [6]. What BIM brings is a complete transformation by helping construction projects move from design desk to physical reality, it proves redundant data that erases communication and brings operational efficiencies that improve coordination among departments and gives an overall efficiency to the whole lifespan of the project with large infrastructural projects.

C. 4d BIM

As the information model is created, you can add scheduling data to different components generating accurate program information and enabling step-by-step visuals of your project developments and this process that is known as 4d BIM. Construction project management through traditional construction is more inefficient, so new technology was introduced through 4d modelling by adding 3d BIM model and scheduling by M.S office project to develop 4d models [7]. A solution for the growing complexity of infrastructure and shortage of resources is

scheduling with the application of 4d BIM [7]. 4d BIM involves time-related information being associated with different components of an information model for a specific element or work area that could include details on its lead time construction and installation. 4d BIM is a powerful tool for communicating the impact of built assets with local stakeholders both during delivery and once completed everyone can see and comprehend a clear impression of how the asset will appear rather than having to envisage that from plans or Gantt charts. BIM is an emerging 3d model process that provides information to all the people in a project which is generally used in complex multiphase constructions and infrastructure, but till now this application was not widely used in India [2]. BIM gives precise results with improved accuracy that saves time and money [2]. You can work with 4d at any stage of projects and indeed it can add a lot of value in implements at the front end when assessing the feasibility of schemes.

Even though Building Information Modelling is an emerging tool of the construction industry with wide range of benefits, many construction companies in developing countries are not adopting this tool because of the gap between BIM and project manager [8]. Building Information Modelling is also really useful during tendering if you want to get a very quick handle on a project or to demonstrate and build confidence around your methodology as part of the selection process clearly.

The information you'll gain from the process will be quite a high level in the early stages and will build in detail as the project progresses one important point to note is that 4d BIM refers to a particular way of linking data to an information model. BIM is the most effective and powerful tool in project management. The barriers to adopt 4d BIM in the Swedish construction industry are both technical and non-technical barriers like software's, complexity, investment, lack of client demand [9]. 4d construction management through BIM technology is used for complete safety management of the project life cycle [10].

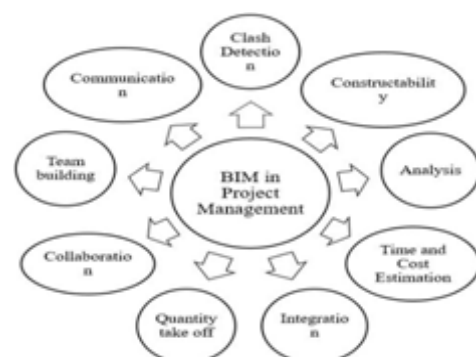


Figure 1: Project Management Knowledge Areas Considering BIM on Construction Projects

Building information modelling can support environment planning, waste reduction and management using 4d capabilities [11]. 4d simulation is adding scheduling of construction activities to the model at the planning stage and



can be executed in different stages of construction [12]. They are some technical aspects of BIM which are widely used in project management which is very well explained by [8] is shown in following figure 1.

II. RESEARCH SIGNIFICANCE

In India, there is rapid growth in the construction industry with the help of the latest technology, but uncertainties and complexity in the project leads to cost overruns, time overruns, wastage of resources, which cannot be handled by the traditional method, so need for a sustainable process for a construction schedule is mandatory to solve these issues. A new innovative and advanced system is proposed for construction project scheduling to resolve design conflicts and integrated project delivery.

III. DESCRIPTION

There are various BIM tools in the market that are used by construction firms. The percentage of the usage of BIM tools by construction firms is shown in following Table I.

Table I: Percentage of Usage of BIM Tools By Construction Firms

(Source: Burcin and Samara) [1]

BIM TOOLS	PERCENTAGE (%)
Autodesk Revit	41.6
Autodesk Navisworks	12.4
Graphisoft Archicad	10.7
Bentley	8.0
TEKLA	6.5
VICO	5.8
Innovaya	3.4
Gehry Technologies Digital Project	3.1
Solibri Model Checker	2.6
Beck Technology DProfiler	1.5
Dassault systems CATIA	1.4
Synchro Project Constructor	1.0
Bentley Generative Components	1.0
Nemetschek Vectorworks	0.9

When comes to 4d simulation there are software's that are available, they are Navisworks Manage (Autodesk), ProjectWise Navigator (Bentley), Visual Simulation (Innovaya), Synchro Professional (Synchro), Tekla Structures (Tekla), Vico Control (Vico-Software).

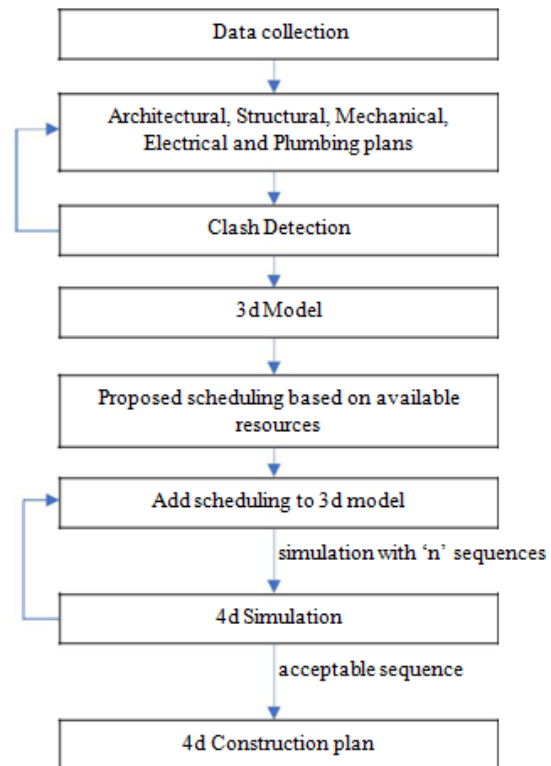
A. Selected BIM Tools

Out of all the BIM tools, this paper implements two BIM tools, 1. Autodesk Revit for 3d modelling, 2. Autodesk Navisworks Manage for 4d simulation.

Autodesk Revit: Autodesk Revit is a software used to create and design Architectural, Structural, Mechanical, Electrical and Plumbing projects. In AutoCAD, you create objects and elements from scratch in 2d and 3d using lines, arcs, cubes and meshes wherein Revit you create projects using objects, models like walls, tubes, and roofs. Using Revit you can visualize your model and can make changes in the design at any stage easily. The software was developed by Charles River and acquired by Autodesk in 2002.

Autodesk Navisworks: What Navisworks does is, it takes all the different formats and puts them together into one model. Navisworks simply combine all the models and allow them to be viewed, navigated and analyzed all together in one environment. Navisworks allows you to view, navigate, measure, quantity take-offs, clash detection, clash management, and simulation. The software was developed by Sheffield and acquired by Autodesk in 2007.

B. Methodology:



Flow chart 2: Workflow steps of the proposed methodology

With the growing complex and uncertain problems in the global infrastructure and reduce of the natural resources, this study is proposing a methodology using 4d BIM to eradicate all the problems in the planning stage. It means scheduling is done with the application of the 3d model for better coordination. The first step in the proposed methodology is collect all the data that are required to start a project. After that, using all the data prepare architectural, structural, mechanical, electrical and plumbing plans. Once all the plans are prepared append the plans and overlap all the plans. Clash detection will be done if there are any errors and again have to check all the plans to remove errors. After this 3d modelling is completed and based on the available resources scheduling is done for the 3d model. Later that scheduling should be linked to the 3d model and simulation is done with the 'n' number of sequences until all the possible resource smoothing is done. After that with the acceptable sequence, 4d simulation is done and the 4d construction plan is prepared. The detailed workflow steps of the proposed methodology are shown in the flowchart in Flow chart 2.



C. Procedure

To perform a 4d simulation of a construction sequence a 3d model should be created first and schedule should be added to it. Revit 2018 is used to create a 3d model and Navisworks Manage 2018 for 4d simulation. To develop a 3d model, the template should be created first and there are few templates like construction template, architectural template, structural template, and mechanical template. For this 4d simulation, to design a basic 3d structural model, a structural template is selected. Once the structural template is selected, the next step is to create grids and based on the grid's columns, beams, analytical levels are created. After this slabs and slab openings are created and live, dead, wind, seismic loads are applied. Later slab detailing and concrete detailing is done and finally, a simple structural 3d model is developed using Revit. After all the detailing is done, quantities from schedule/quantities option in the architecture tab can be extracted. Through Revit, we can extract individual quantities of all the elements which are useful to calculate accurate cost of the total project. Reinforcement detailing, and load detailing are shown in following Figures 2 and 3.

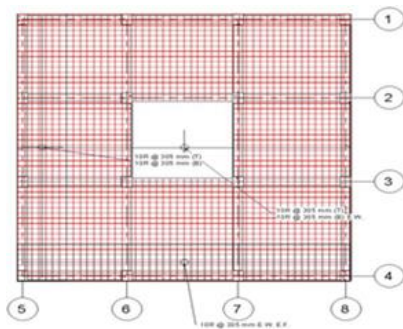


Figure 2: Reinforcement detailing of the model

Once the 3d modelling is completed, it should be saved in rvt, rfa, rtc format, so that it can be exported to Navisworks Manage.

Next step starts with Navisworks, the foremost thing is to import the 3d model and the building elements by appending it to Navisworks Manage. The next step is to open Timeliner in home tab. The Timeliner tab has 4 options and they are tasks, data sources, configure, simulation. Tasks can be added manually in Navisworks Manage or can importschedules from csv, Microsoft Project and Primavera. In this research, scheduling is done manually in Navisworks Manage.

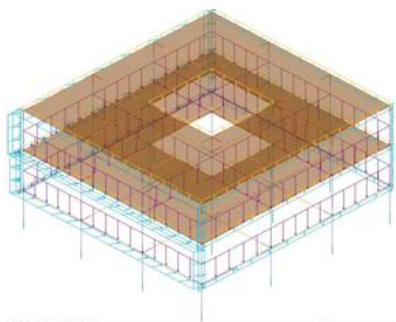


Figure 3: Load detailing of the model

The key to create a 4d simulation of the construction process is linking the elements in the building model with these tasks and can attach individual elements or sets of elements to each of the tasks in the timeline. Creating the sets can be challenging but it is really the key to working effectively with in Navisworks Manage. To create sets of elements, the home tab is selected in Navisworks Manage, select sets option and then manage sets. Now model elements are attached to specific tasks in the timeline.

After individual elements or sets of elements are attached, select tasks option in Timeliner bar and activities are assigned as per the construction process. While adding tasks both planned start and end time are assigned for the given tasks. Next setup the simulation by looking at the options available under the simulate options. Here the interval size is selected, that will determine which increments are displayed and also can select the playback duration of the simulation. After selecting all options in the simulation tab, the next step is to run the simulation and watch Navisworks steps through every day/week on the project schedule. It shows the activities that are scheduled for that day/week and in turn brings the different building elements that are associated with those activities creating a 4d simulation. Each layer of the building is seen and that's how 4d simulation works. The model can be simulated with 'n' number of sequences and can do as many changes as possible and finally with acceptable sequence 4d simulation is generated.

IV. RESULTS AND DISCUSSIONS

In the 4d simulation, the items can be seen that appear from start date to end date. On the top left of the simulation, date, ongoing project sequence and its finished percentage are shown. This is convenient for the contractor to show the virtual view of the project progress and also very easy for the contractor to change in design for the building model. Thesimulation of the project progress is shown in the following figure 4 in weekly based interfaces.

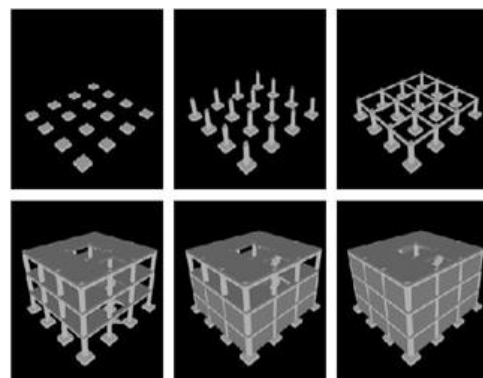


Figure 4: Simulation in weekly based interfaces

This study brought up 4d modelling as a promising tool for the construction industry. 4d modelling is a powerful construction planning application for construction management.



They are many benefits of 4d modelling that are not possible to achieve through traditional methods. 4d modelling helps to planners and project team to achieve efficient planning of construction work. BIM can be used in every phase of construction like planning, designing, fabrication, execution, monitoring, and maintenance phase of the project. There are two types of benefits for 4d modelling they are tangible benefits and intangible benefits.

Tangible benefits:

1. Time and Cost savings
2. Clash detection
3. Risk mitigation
4. Enhanced productivity

Intangible benefits:

1. Visualization
2. Better Communication

They are many other benefits through 4d modelling like resolve and identify workspace conflicts, marketing, publicity purposes, monitoring procurement status of project materials, visualize time constraints, a waste reduction which is not possible to achieve through the traditional process.

V. CONCLUSIONS

Usually, scheduling is done by using management software like MS Project and Primavera even though, Construction Schedules don't have good eminence in the construction industry due to its complexity and uncertainties. This study identified that the 4d simulation is to improve the preconstruction planning by visualizing the construction process in a regular interval of time.

BIM in construction industry supports to achieve Integrated project delivery which involves all the people and stakeholders from starting stage to finishing stage of the project to get optimized results and that increases the value of the owner.

Building Information Modelling was already adopted by most of the developed countries and it was now becoming popular in developing countries like India and China. From recent years, construction companies in India are adopting BIM and sooner Building Information Modelling plays an important part in construction projects.

Even Building Information Modelling has many benefits which cannot be achieved by traditional methods they are some challenges for the adoption of BIM like cost of the software's are very high, users need high-end systems to run those software's, the cost of the training for the employees is high, Ownership of BIM data, and copyright issues.

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