Application of Building Information Modelling (BIM) in Construction Planning Process

Amala Merlin Jose[1], Jeevan Jacob[2]

[1]*Pursuing Masters in Civil Engg. from APJ Abdul Kalam Technological University, Kerala India*
[2]*Associate Professor in CE Department, M A College of Engineering, Kothamangalam*, Kerala, India

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Abstract - *Proper planning of the logistic operations and the construction site layout is an important task to avoid waiting time, double handling, transportation wastes, workflow conflict etc. Therefore, proper planning can strongly support the Lean thinking through minimization or even complete elimination of the transportation, inventory and motion tasks. In fact, much has been written on ways to minimize site logistics waste but few studies have addressed the use of 4D BIM for logistic operations and transportation waste reduction on jobsites. A thorough literature review was conducted and different case studies were analyzed to determine the benefits and limitations of 4D modeling on the construction planning process. As 4D models visualize the schedule as objects within the graphical model, the temporal and physical aspects of the project are inextricably linked. For validation a 4D model is developed for a commercial building linking 3D CAD components to an as-planned CPM schedule using commercially available 4D tools and the benefits and limitations were analyzed. The paper concluded 4D modeling as a promising tool for construction planning. The most significant benefits of 4D modelling determined are better visualization of construction work, better communication among project teams and increased planning efficiency. Despite of few shortcomings, it is recommended that 4D modeling should be widely introduced into construction industry.*

Key Words: Building Information Modelling (BIM), Visualization, 4D modelling, scheduling

1. INTRODUCTION

Since traditional construction planning is inefficiently used for construction project management, there is need for advanced techniques such as 4D modelling.

The aim of 4D BIM models in production planning is to provide a virtual environment for simulating, viewing production processes and operations, and for identification of spatial conflicts that can occur in the three dimensions and across time. 4D BIM, an abbreviation for 4D Building Information Modeling, refers to the linking of individual 3D CAD model with time or schedule-related information. The term 4D is used to refer to the fourth dimension: time, i.e. 4D is 3D plus schedule (time). The development of the 4D models enables the various participants (architects, designers, contractors, clients, and so on) of a construction project, to visualize the entire duration of the activities and display the progress of construction activities throughout the lifetime of the project.

4D BIM provides best solution for construction visualization limited by 2D project planning and scheduling with 4D visualization. 4D visualization has a potential to overview all details of project from start to finish. It could automatically view project work and resources at a given time table without analyzing traditional Gantt charts and important design documents. Moreover, it provides quick and clear communication through immediate scheduling work updates with intelligent linking process. Also, it could proactively detect problems of space time clashes so as to overcome the problem as early as possible. The aim of this paper is find the impacts of 4D visualization on construction planning process

1.1 Problem Description

"Plan your work and work your plan." (Vince Lombardi)
The applicability of this quotation is very high in the construction industry where the ultimate success is significantly influenced by the planning [3].

Construction planning is a challenging and essential activity in the execution and management of construction projects [6]. According to Chevallier & Russell cited in [5], effective planning is one of the most significant aspects of a construction project and the success of the project is greatly influenced by it. However, Kelsey cited in [5] stated that emerging evidence indicates a shortage of skill in the construction planning area, with a decreasing number of experienced planners having the ability or knowledge to effectively plan construction projects. A wide range of planning methodologies have been researched and implemented but they are not qualified enough to satisfy the desire of construction parties. There is still an enormous disparity between execution and plan [1].

The construction plans are usually being generated by a computer based tool as 2D charts or drawings from a long period of time with the absence of spatial features of actual construction [10]. Activity based critical path method (CPM) is the most used technique to schedule the construction process these days. Construction planners split up a project into a number of small activities and each activity is included in the bar chart and a network which represents the proposed schedule of the project [7]. The computer based CPM scheduling has helped the construction planner to plan

the construction tasks efficiently. However, the major disadvantage of a CPM network is in the development of correct sequencing alternatives. This process usually relies on how delays and priorities are identified which heavily depend upon the experience and instinct of the scheduler/planner [3]. According to Akbas cited in [7], another difficulty in the use of CPM scheduling for construction planning is linked to the spatial configuration of project. The spatial configuration of each construction project is unique and constitutes an immense foundation of planning decisions. The CPM schedule fails to provide enough information regarding the spatial configuration and complexities of the project components [8]. Therefore, the user has to look at 2D drawings and conceptually connect the components of the building with the related activities from the CPM schedule to identify the spatial aspects of a project. Analyzing detailed CPM schedules in combination with 2D drawing might lead to a complex process, which limits the possibility to identify problematic sequences, mistakes and opportunities. Conflicting interpretations of the schedule might be developed by different project members when viewing the 2D drawings and CPM schedule. This in turn might lead to ineffective communication among different project participants [7]. In parallel to the construction schedules, many construction enterprises build 3D models with the aid of widely used CAD applications for their projects. However, those 3D models cannot display the exact status of a project at a specified time but can only provide static images. The data integration between the schedule information, 3D model and other information is not present. Without the visualization of the construction progress at the construction site as the time elapses, planners must rely much on their experience, imagination and judgment to perceive data from paper based documents and come up with the appropriate method of construction, thus receiving minimum benefit from the computer [10].
All such circumstances might affect the performance of the construction projects adversely. The construction industry needs to consider the use of technology to improve working practices and efficiencies in order to make construction more attractive to both investors and potential recruits. Given that planning has a significant impact on the ability of any organization to achieve this, the focus of their attention should be on using technology to improve the construction planning process [1].

2. LITERATURE REVIEW

2.1 Construction Planning

Increasingly, construction planning is playing an important role within the development of construction industry [1] It involves tracing back from the result and identifying the sequences of events which lead to that result. This is a challenging job for the planner since the final outcomes of construction projects are not possible to observe until they are completed [6]. Zanen & Hartmann pointed out that it is important to effectively plan ahead in the early stage of a project; to specify potential errors, prepare possible solutions and to assign work tasks to the right people with the right techniques. Those are what will enhance the percentage of success. However, construction planning is not a process only limited in the period before construction's actual start; it should be considerably taken into account during the project life cycle and would require re-planning if something wrong should happen [6].

The aim of planning is to generate required activities as well as their interdependence and thereby ensuring that the project will be completed within the best manners of economics, safety and environmental acceptance [11]. Fundamentally, construction planning associates with the identification of essential activities that lead projects to their final outcomes. Planners have to thoroughly analyze the sequences, the implementation and also impacts of such various activities. Afterwards, based on the evaluation and experiences from previous projects, decisions will be made to determine what strategies and performance methods are the most beneficial. In other words, through construction planning, suitable technologies are selected; work tasks are assigned; resources are allocated and project participants as well as the interaction between them are identified [6].

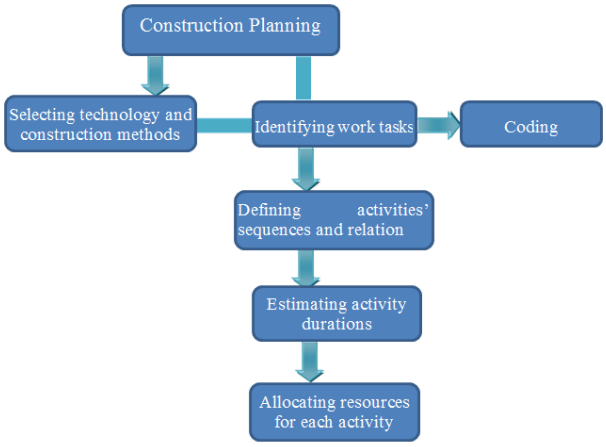

Fig -1: Construction planning aspects by function [6]

2.2 4D BIM

One of the most promising developments which the architecture, engineering and construction industries have achieved in the past few years is Building Information Modeling (BIM). BIM is used to construct virtual models of a building digitally. These computer generated models contain accurate geometrical data of the building components and other necessary data needed to support the fabrication, construction and procurement activities. BIM also contains several of the functions required to model the lifecycle of a building, providing the platform for new design and construction capabilities. When efficiently utilized, BIM facilitates a more integrated design and construction process which results in high quality of buildings at reduced project duration and lower cost [4].

BIM aims at improving collaboration between stakeholders, reducing the time needed for documentation of the project and producing more predictable project outcomes. BIM has massive potential and versatility as a receptacle for project information [2].

BIM can be used from the starting phase of a project, in the planning approval process and in checking whether the project conforms to the regulations till various design stages of a project. Different BIM software packages can ease the working of architectures, building services engineers and structural engineers and enhance their performance. 3D visualizations are also possible by the applicability of BIM to see the project alive before it is built. BIM allows different checks and function to be performed to improve the design and cost data can also be extracted by the utilization of BIM. In addition to this, a time dimension can also be added to the BIM to assist with scheduling, planning and construction management and after the completion of the project, BIM can be used by the building operator to support the operation and maintenance activities [2].

4D BIM requires linking construction plan to the 3D model, which makes possible to visualize how the building and site would look like at any point in time by simulation the construction process. 4D tools allow planners to visually communicate and plan activities in the context of time and space [4]. This makes possible the adoption of alternative approaches to site layout, scheduling and crane placement etc. during the construction phase. The production rate information can also be contained in the model which will permit lines of balance schedule analysis. This allows the efficient configuration of the tasks based on their production rate and location in the project. A significant difference in the efficiency of a project can be made by making improvements in production rates and repetitive tasks [9].

3. CASE STUDY

A commercial building is used for the case study which was located in Pathanamthitta. The selected building is of B+G+3 for which used 4D modelling application in assisting construction planning. 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.

3.1 Software tools selected

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

1. *Autodesk NavisWork Manage 2017*: It is project review software that supports intelligent 3D model-based design with scheduling, visualization, and collaboration tools.
2. *Autodesk Revit 2017:* 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.

3.2 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 Software with Autodesk Revit 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 Autodesk Revit were exported separately to Autodesk NavisNork 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. (Figure.2)

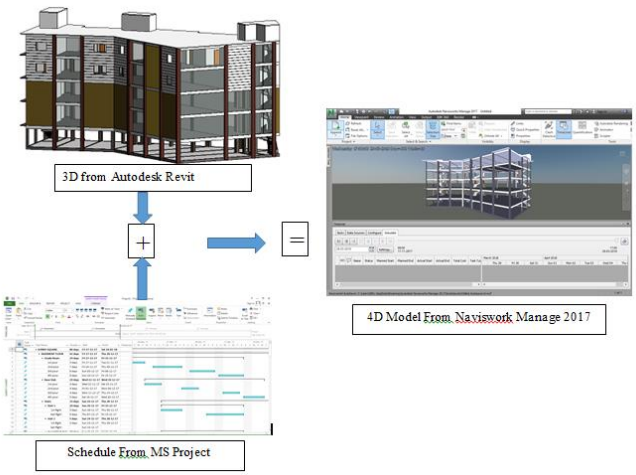

Fig -2: Steps for Establishing 4D Model

Step-1) :- Exporting 3D model from Revit 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, labour and equipment cost from MS-excel

3.2 Simulating Construction Schedule

Autodesk NavisWork 2017 allows users to define tasks directly in the software tool itself and then link building components with these defined tasks. In Figure 3 each task can 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. 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 colour while any variation between them displayed in red colour. 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, labours & 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.

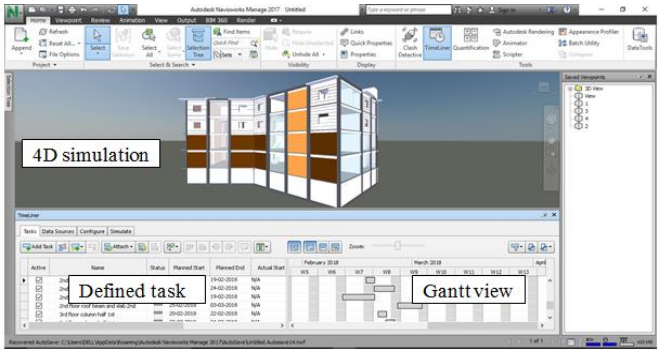

Fig -3: Interfaces of Autodesk NavisWork of 4D Simulating.

3.3 Time taken to Develop 4D Model

In this study 125 Man–hours spent to develop a 4D model of B+G+3 building having the following elements of the building as grade beam, base slab, 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

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.

3.4 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.

1. *Time in developing the 4D model*

About 125 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%

2. *Benefits of 4D model*

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

Visualizing and interpreting construction Sequence: It is great visualization tools which provide 3 dimension virtual representation of construction progress of building. The different colour code for 3D components while simulating the schedule gives effective visualization as it shows Green colour while activity in progress (Figure 4) 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.

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 NavisNork 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.

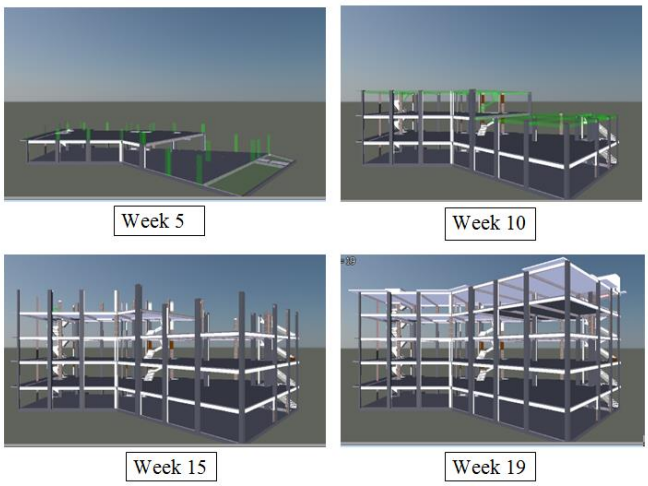

Fig -4: Simulating Interface of 4D Model.

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.

- The Client got the whole picture of project progress from 4D model which is not understood by 2d documents.
- 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.
- 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.
- Planned work sheet with the visualized effect of particular activity helped to site engineer and labour in easily understanding their targeted work.

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 labours 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.

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, Labour camp and access road. The 3D site layout and 4D model could provide a virtual construction site in a realistic manner to analyse 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.

3. *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.

4. CONCLUSIONS

The study brought up 4D modeling as a promising tool for construction planning. The most significant benefits of 4D modeling are found out to be better visualization of construction work, better communication among project teams and increased planning efficiency. In addition, 4D modeling assists in achieving detailed and accurate work plans, planning of temporary structures, quantity takeoffs and managing site logistics. With the help of better visualization and communication, the planners, project team and client can achieve a better and common understanding of the project scope and objectives, which can improve the construction planning and execution process significantly

leading to the project success. Implementing 4D modeling allows planners to detect the problems prior to construction phase which lead to reduction in the amount of rework and clashes. Therefore, a more reliable and detailed work plan can be obtained which assists the project to complete within prescribed time and budget.

Researches and practical case studies also indicated few shortcomings of 4D modeling. The main problem lied in the complexity of the model and how to make the adoption of it more convenient. However, these impediment can be solved be providing appropriate training to help participants in 4D planning perceive better understanding of it and to take most use out of it. Development of new 4D tools also simplifys the adoption of 4D modeling process and makes it more convenient for the project team to learn and develop in 4D technology.

All things considered, it is recommended that 4D modeling should be widely introduced into the construction industry. Implementing 4D technology could be propitious development for construction firms and can help mitigating the most common problems faced in the construction projects with enhanced planning efficiency.

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