

# IMPACT OF 4D VISUALIZATION TECHNIQUES IN CONSTRUCTION PLANNING PROCESS

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## Abstract

Construction planning is a fundamental activity involving the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any interactions among the different work tasks. This thesis aims to study different aspects of 4D technology and to find out its impact on the construction planning process, and how to benefit most from this technology. This research examines the value of implementing 4D modeling technologies in construction engineering education. A thorough literature review was conducted. Questionnaire survey was done in top fifty construction companies in Thiruvananthapuram district. From the questionnaire survey it is founded that all the selected construction companies are not using 4D Visualization Technique. Different case studies were analyzed to determine the benefits and limitations of 4D modeling on the construction planning process. 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 study concluded 4D modeling as a promising tool for construction planning. It is recommended that 4D modeling should be widely introduced into construction industry.

**Keywords-** 4D modeling, Construction engineering education, Questionnaire survey, Case studies, 4D tools.

## 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. When a student in design and engineering disciplines is learning to develop a construction schedule for a building, they will typically develop the schedule by interpreting 2D drawings, identifying activities and building a logic sequence network. Developing a construction schedule is difficult since one has to construct the building step-by-step in their mind after visualizing the 2D drawings. 4D modeling technologies, visually representing the construction schedule time along with the 3D model components, can provide a common visual language for students when learning how to develop construction schedules for buildings. The 4D visualization is a technique who generalized reflective analytical activities and also cognitive activities of site management. 4D CAD model gives double efficiency with limited time resources. Also 4D models are helpful to

speed up the construction process hence reduces the mistakes and remove them quickly. Concerning with the safety aspects information of design phase and scheduling are properly calculate to formulate a 4 dimensional (4D) model, after that actual site monitoring data continuously compared with the 4D model between the construction process. 4D CAD based upon the project planning, formalizing, scoping and synchronizing the structure. 4D-models identify schedule shortcomings and also detect delays for safety management using visualization. Therefore, the safety measures are properly visualized by 4D models by verifying cost. 4D visualization has a potential to overview all details of project from start to finish. Automatically view project work and resources at a given time table without analysing traditional Gantt charts and important design documents.

## II. LITERATURE REVIEW

### A. Construction Progress by 4D Modeling Application

4D model tools give the construction progress information in the form of project viewing, review and simulation. 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. 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.

### B. Construction Planning Aspects by Function and Planning Methods

Throughout the development of construction industry, there have been a numerous of methods implemented in construction planning such as Gantt chart, critical path method, linear scheduling and the last planner. Gantt chart is a time schedule developed by Henry L. Gantt, a predecessor who initiated applying "scientific management methods" in the industry. Gantt chart exists as several variants of which form and application depend on scope of the projects. More advanced than Gantt chart, CPM not only shows activities required for the projects, it as well provides information on the relationship between each work tasks. Linear scheduling method (LSM) and also

called location-based scheduling (LBS) was firstly formulated in the early 1950s. It is mainly applied for construction projects such as multiple housing units, railway, highway and high-rise building.

### C. Introduction to BIM

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. 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.

### D. 4D Planning and 4D Modeling Processes

4D modeling allows the simulation and evaluation of the planned construction schedule. Grouping of the objects in the building model should be done according to the construction phases and linked to relevant activities in the construction schedule. For example, if a concrete slab is to be poured in three steps, then the model of the slab should be divided into three sections so that the sequence can be effectively planned and illustrated. In addition, temporary activities and structures like scaffolding and tower cranes should also be included in the building model. The contractor knowledge is very significant when building a 4D model for planning process. If the model is built during the design phase of the building, then the contractor can give his valuable feedback regarding constructability, estimated construction cost and sequencing. 4D simulations for planning process acts as a communication tool for identifying potential bottlenecks and as method to improve collaboration among different project teams.

### E. Implementation of Visualization as Planning and Scheduling Tool in Construction

In this paper, the study on 4D graphics for construction planning and site utilization (acronym 4D-GCPSU) is delineated. A 4D site management model to incorporate a 3D geometrical model together with a project activity schedule has been proposed. Specifically, the construction activity is annotated with the pertinent requirements on resources including human, material and equipment. It is found that construction planning and communication at site management level often entails flexible short term re-planning. In order to cater for this need, the major objective of this study is thus to furnish a 4D graphical visualization capability for construction planning purposes. Moreover, the model incorporates other useful aspects of site management comprising the construction schedule with resources allocation, site facilities layout, site workspace usage as well as cost estimation. AutoCAD furnishes a graphical programming environment for the planner to generate a 3D geometrical model regarding the construction project whilst Microsoft Project displays a bar chart scheduling environment relating all the pertinent construction activities from the project inception to completion.

## III. METHODOLOGY

The approach used to conduct this thesis is deductive approach. A topic of interest was first selected and the hypothesis was derived for this study, that is: How 4D-modeling beneficial for construction

planning process. To carry out the study, the quantitative methods for collecting data were mainly used. The study area had been recognized as the Thiruvananthapuram District in Kerala. Thiruvananthapuram district is situated between north latitudes  $8^{\circ} 17'$  and  $8^{\circ} 54'$  and east longitudes  $76^{\circ} 41'$  and  $77^{\circ} 17'$ . The Southern most extremity, 'Parasala', is 56 km away from Kanyakumari, the "land's end of India". The district stretches 78 km along the shores of the Arabian Sea on the West, Kollam district lies on the North with Tirunelveli and Kanyakumari districts of Tamil Nadu on the East and South respectively.

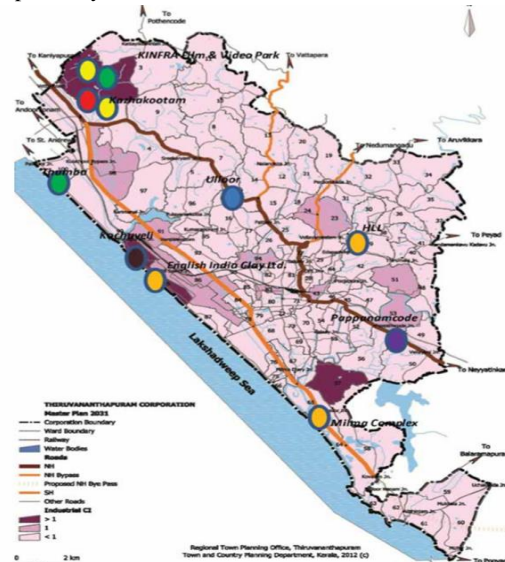


Fig 1 Study Area

The district can be divided into three geographical regions, Highlands, Midlands, and Lowlands. Chirayinkeezhu, and Thiruvananthapuram Taluks lies on the midland and lowland regions, while the Nedumangad Taluk lies in the midland and highland regions, and the Neyyattinkara Taluk stretches over all the three regions.

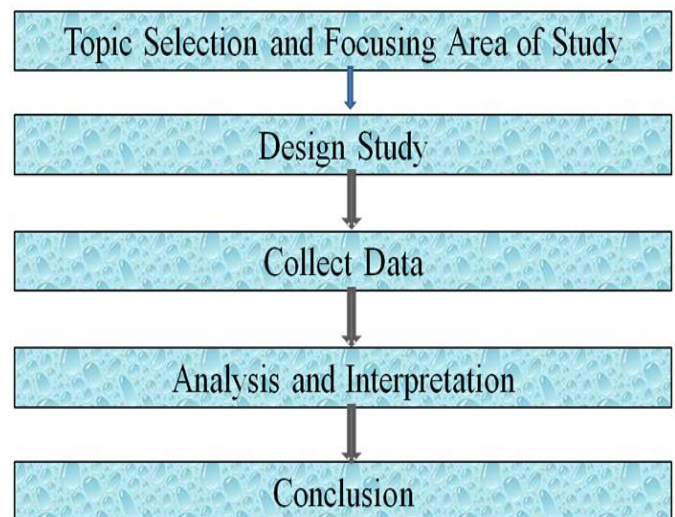


Fig 2 Methodology

About fifty construction companies in Thiruvananthapuram district were selected and questionnaire survey was conducted. Some of

them are Turret Builders, Iyer and Mahesh Architects, Prs Builders, Crescent Construction Company, Artech Realtors, Silvercastle construction company, Sparrow Construction Management and Consultancy, Vasthu Niketha, Nikunjam Constructions etc. Two sets of questionnaires were prepared. From the questionnaire survey it is founded that all the selected construction companies are not using 4D Visualization Technique. So it is clear that analysis should be done by using case studies.

#### IV. CASE STUDIES

Analysis is done by using case studies. In order to produce more reliable results, a total of 9 case studies covering projects with a variety of scope were selected from the literature. All the case studies involved the implementation of 4D BIM in the construction practices. The case studies were selected keeping in view the different diversity of projects. The projects also varied from small to large scaled projects located in different parts of the world.

##### A. Case Study for Validation

A commercial building is used for the case study which was located in Thiruvananthapuram. The selected building is of B+G+3 for which used 4D modeling application in assisting construction planning. It consists of the activity as RCC work, brick masonry and plastering. Then the 4D model is developed by the linking of the 3d object in the model to the activities in time Schedule. 4D model is developed with the help of the following softwares:

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

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.

Microsoft office project: This is software used for scheduling the project plan and imported into Naviswork manage software.

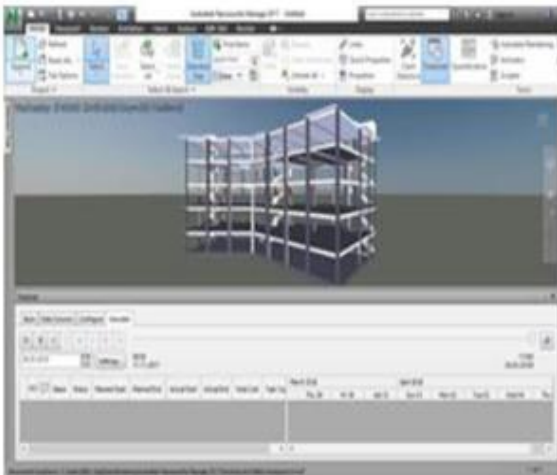


Fig 3 4D Model

Firstly 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 Naviswork

Manage. In this study 145 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.

#### V. RESULTS AND DISCUSSION

The selected building is of B+G+3 for which used 4D modeling application in assisting construction planning. From case study it is observed that 4D modeling has some benefits as well as shortcomings.

##### A. Benefits of 4D Modeling

The major benefits of 4D modeling for construction planning identified after reviewing the case study which is discussed below.

###### 1) Accurate quantities take off:

4D modeling enables the planner to measure quantities more accurately and efficiently, which enables a more effective planning process.

###### 2) More accurate and detailed work plan:

4D modeling allows project team to generate precise and comprehensive work plan which would be more difficult to achieve with traditional planning methods.

###### 3) 3D coordination and 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 labourers to reduce design errors and better understanding of the work which maintained the accuracy of work.

###### 4) 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.

###### 5) Better communication:

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.

###### 6) Saving in project time and cost:

4D Model helps in reducing time and saves cost. The rework was also reduced.

###### 7) Visualizing and interpreting construction Sequence:

The different color code for 3D components while simulating the schedule gives effective visualization as it shows Green color while activity in progress which helps the 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.

###### 8) Planning of temporary structures and works:

Traditional 2D planning methods like CPM scheduling and Gantt charts usually do not consider temporary works and structures during the planning process which might result in difficulties at site during execution. However, 4D planning enables the planner to plan the temporary works and structures as well by incorporating them into the model.

### **B. Shortcomings 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. They are:

- It requires skilled and trained staff to execute the workflow process with a 4D model in a short time and it may be costly.
- Unaware about this technology is a major problem so it could not implement with full efficiency on site.
- Used software Autodesk NavisWork Manage for 4D model which unable to facilitate print sheet of the output result in proper report format.
- 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.
- Development of 4D models from 2D documents is a timely and challenging task.

## **VI. CONCLUSION**

From this study it can be concluded that 4D modeling is 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. 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 take offs 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. 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 by 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 is also simplifying the adoption of 4D modeling process and making 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 construction industry.

## **SCOPE FOR FUTURE**

A good topic to study further can be why 4D is not yet widely accepted within the construction industry? In future research, the validity and reliability of the study should be increased.

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