

# Integrated 4D Model Development for Planning and Scheduling of a Construction Project using Geographical Information System

Dr. Gopal M. Naik<sup>1</sup>, Aditya M<sup>2</sup> and Suman B. Naik<sup>3</sup>

<sup>1</sup> Associate Professor, Department of Civil Engineering, University College of Engineering (A),  
Osmania University, Hyderabad – 500007, A.P., India

<sup>2,3</sup> Students, UCE (A), Department of Civil Engineering, University College of Engineering (A)

**Abstract.** The current day demand of construction industry requires a highly accurate planning, scheduling and management of the process of the project which can enable the overall optimization of the cost, time and resources. The older system of usage of MS Project and Primavera for scheduling, AutoCAD drawings and taking a lot of strain and explaining the status of the project to the client is very difficult and time consuming, owing to the fact that the client and the store manager might not be fluent with the technical terms used in the schedules and graphical representations. Instead of using the older, traditional methods of CAD drawings and schedule sheets, one can integrate them on a platform to create a 4D view of the project using GIS environment. The aim of the study is intended to demonstrate the understanding of the methodology to create the GIS based 4D model for optimization and real time monitoring of the project. ArcScene module of ArcGIS is utilized, along with Primavera P3 and Microstation V8i for this study. Integrated GIS based 4D model has been developed and utilized for the visualization of the construction progress of the project. A factory building of CIGFIL Polymers, located at Hosakote, Bengaluru has been selected for this study. Different stages of the construction process and activities are generated in different layers using ArcGIS software and Primavera P3 has been used for creation of the schedules and these are linked with the GIS layers. It is observed from the study of actual building information at site and the building simulation model, overlapping and rework can be avoided.

**Keywords:** Integrated Scheduling, 4D Model, Geographical Information System

## 1. Introduction

The traditional approach for scheduling and progress monitoring techniques likes bar charts, CPM, PERT etc are still being used by the project managers for planning. These are a serious disadvantage in the decision making purpose, as they fail to provide the necessary spatial aspects and data. There is a gradual increase in the pressure on the project managers to shorten the delivery time and decrease the costs involved in the process, without a decrease in the quality of the product, i.e. the building. Geographical Information System (GIS) and project management tools in a combination can be used to access the spatial aspects and the time and cost involved in the project. GIS allows project managers and different people involved in the project with different backgrounds to get the accurate information of the project and monitoring of activities. The project manager and client can use the visualization aspects at any stage of the project to monitor the activities and cost flow.

## 2. Overview

Growing pressure to shorten the project delivery times, new practices and increasing complexity of today's construction projects have resulted in an increase in the number of commercially available computerized planning and scheduling tools (Retik 1997). But, the construction industry has acknowledged that its current scheduling and progress reporting practices are in need of substantial improvements in quality and efficiency. Research efforts to incorporate visualization into scheduling and monitoring have been motivated by the failure of traditional methods to provide information

related to spatial aspects (Koo and Fischer 2000). Researchers have suggested that project managers can use 4D methods and simulation for effective resource allocation (Fischer 2000). Bansal and Pal (2008) have described the linking of the activities in a critical path schedule with the 3 dimensional model, which makes the project sequence easier to understand. Some commercial tools allow the planner to build a 4D model and create the graphical simulation, though, it still lacks features like generation and manipulation of a 4D model within a single environment.

### **3. Geographical Information System**

In the past twenty five years, a lot of professions have been in the process of developing automated tools for effective storage, analysis and presentation of geographic data. These efforts have apparently been the result of increasing demands by users for the data and information of a spatial nature. According to Environmental Systems Research Institute (ESRI), a GIS is defined as ‘an organized collection of computer hardware, application software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographic referenced information’.

#### GIS in Construction Industry

Geographical Information System applications have proliferated in the construction industry in recent years. This fact is illustrated by the growing number of articles finding their way into civil publications devoted to GIS (Oloufa et al. 1994). GIS can be used for progress monitoring system in construction, networking solutions, 3D data analysis, site location and client distance, comparison of data, construction scheduling and progress control with 3D visualization. The intent of this paper is to demonstrate the benefits of using GIS with project management. The methodology developed utilizes the functionalities of ArcGIS, Primavera and Microstation Softwares. Visual studio can be further used to assist the project managers in control and analysis, monitoring of work by creation of a frontend application, by synchronizing the construction work in three dimensions and its schedule. This would help all parties involved in a project to visualize the progress in a natural way, hence minimizing the delays and cost overruns. In addition to monitoring of work flow, it can be further used to monitor the quantities, costs and resources.

### **4. Methodology and Model Development**

The present study is to discuss the methodology for the creation of a GIS based 4D model of the project and simulate it to monitor the workflow at the site. Different stages of the construction process and activities are generated in different using ArcGIS software. Primavera P3 has been used for creation of the schedules and these are linked with the GIS layers. A factory building of CIGFIL Polymers, located at Hosakote, Bengaluru has been selected for this study. The steps that are involved in this process of generation of the 4D model are described in the following sections.

Step 1: Creation of Architectural Drawings

Step 2: Identification of the Work Breakdown structures

Step 3: Scheduling the activities

Step 4: Modelling the 3D model in ArcScene

Step 5: Integration of the 4<sup>th</sup> dimension

Step 6: Simulating the output

#### Creation of Architectural Drawings

The first step is the creation of the plans of the project. For a better model, it is required to have the plans at different stages of the project, i.e., different plans for foundation level, footing level, pedestal level etc. These plans can be generated in Autocad or Microstation. Microstation was used in this present project for the creation of the plans at different levels. The more the number of plans, the more will be the accuracy of the 3d model.

### Identification of the Work Breakdown Structure

The process of identification of the WBS involves a different approach for different projects. For the present project, the levels of work identified for WBS are: Footing PCC, Foundation, Pedestal, Plinth Beam, Floor, Columns, Wall Bottom, Wall Top and the Roof.

These levels are to be identified based on the elevations of the components.

### Scheduling the Activities

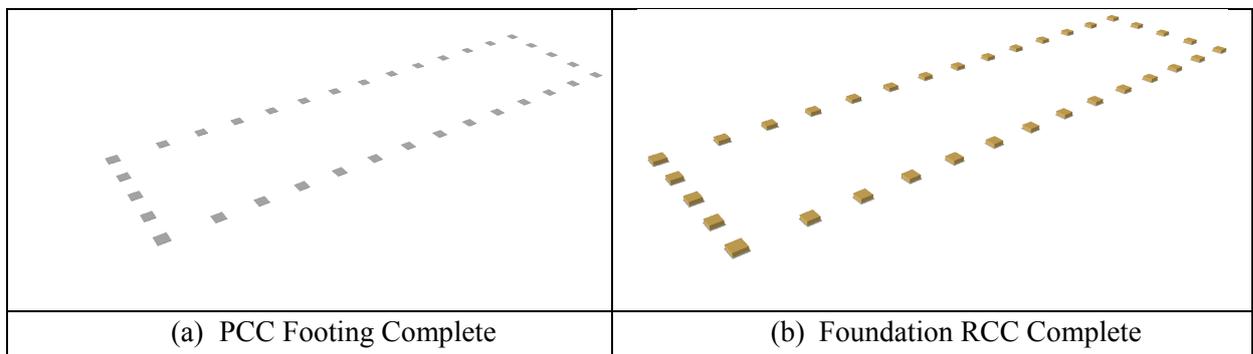
The activities are scheduled based on the Critical Path Method. Primavera Project Planner (P3) is used as the tool. Sufficient float is identified for each activity and the final schedule is made.

### Modelling the 3D model in ArcScene

This step involves the exporting of the levels for Microstation drawings into ArcScene. First, a Projected Coordinate System based on the Indian Coordinate system is defined. Using the projected coordinate system as a base, the microstation drawings are then converted into ESRI Shapefiles. The elevation details, which are already identified, are now used as the base heights and extrusions. After the layers are added to ArcScene, base height, i.e., the height of the object from foundation level and extrusion, i.e., its 3D height are given. The current used base heights and extrusions are given in Table 1. Layers wise 3D views of Base Heights and Extrusions of the Building are shown in Figure 1.

Table 1 Extrusions and Base heights of Layers

Layer Name	Base Height	Extrusion
Footing PCC	0.0 m	0.1 m
Foundation	0.1 m	0.6 m
Pedestal	0.7 m	1.5 m
Plinth Beam	2.2 m	0.3 m
Floor	0.0 m	2.5 m
Columns	2.5 m	5.0 m
Wall Bottom	2.5 m	3.0 m
Wall Top	5.5 m	2.0 m
Roof	7.5 m	1.0 m



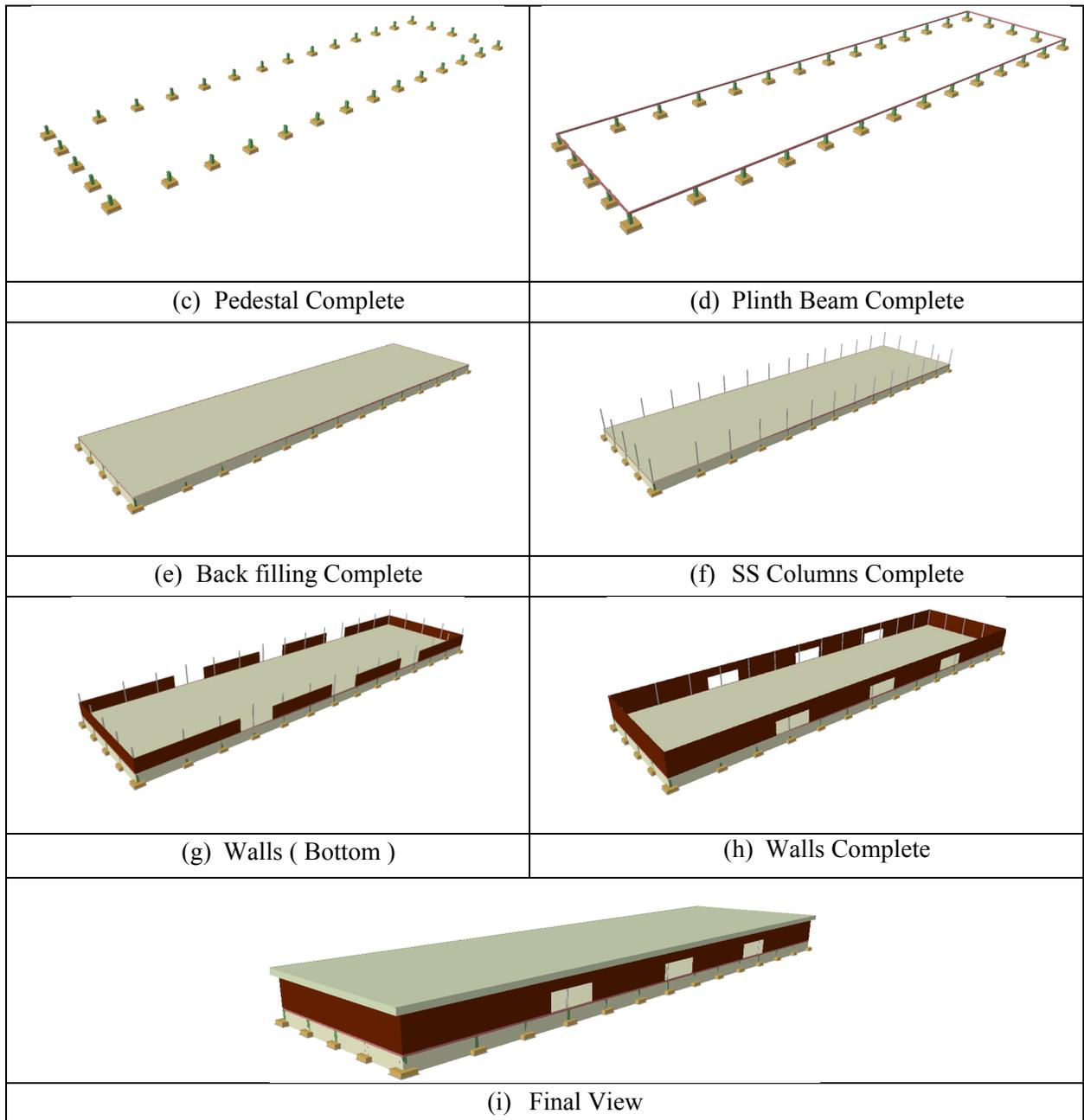


Figure 1 Layers wise 3D views of Base Heights and Extrusions of the Building

#### Integration of the 4<sup>th</sup> Dimension

The crucial step of the process is the integration of the schedule with the 3D model of the project. Using the export option in P3, the schedule, along with its details is exported as a database. Each level of the project is then time enabled and then, using the activity codes and the layer ids, both are linked together.

#### Simulating the Output

The final step is the simulation of the project. The time feature of the spatial data is utilized for this process. The process of simulation sequence is shown in figure 2. Each activity is linked with its start and end times. Then, the timezone is changed and required time offset is selected. Thus, the simulation is obtained.

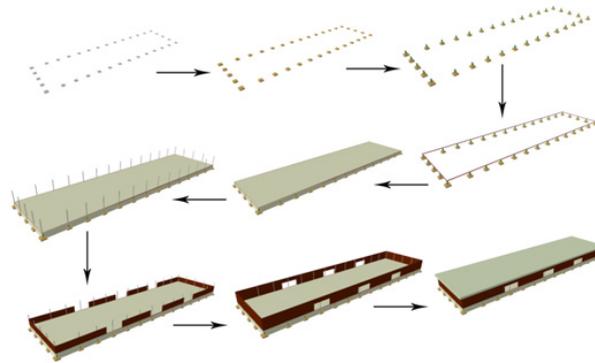


Figure 2 Process of Simulation Sequence

## 5. Conclusions

Integrated GIS based 4D model has been developed and utilized for the visualization of the construction progress of the project. Different stages of the construction process and activities are generated in different layers using ArcGIS software and Primavera P3 has been used for creation of the schedules and these are linked with the GIS layers. At a specific time interval, one can utilize the actual building model and the scheduled building model to compare the work flow. Major rework has been avoided because of identification of clashes from the GIS Layerwise 3D views of the Building. It is observed from the study that, the actual building information and the building model information, overlapping and rework can be avoided upto 20% for time and upto 25% for material and labour cost of the project. The present study is in the initial stage and further research for calibration and validation of the model for different projects is carried out.

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