Research Journal of Applied Sciences 7 (4): 222-228, 2012
ISSN: 1815-932X

4D Model Through GIS for Planning and Scheduling of Residential Construction Projects

[1]V. Rajesh Kumar and [2]T. Navaneethakrishnan
[1]Parisutham Institute of Technology and Science, Thanjavur, India
[2]A.N. Prakash Construction Project Management Consultant Pvt. Ltd., Bangalore, India

Abstract: Construction industry requires a highly accurate planning, scheduling and management of the process of the project which can facilitate the overall optimization of the cost, time and resources. The traditional system of using of AutoCAD drawings, MS Project and Primavera for scheduling does not satisfy the clients in making them understanding the project status and also find time consuming. Hence, an efficient method is proposed in this study implementing Geographical Information System (GIS) as a platform to link the plan of building and its corresponding schedule of executing the construction of building. GIS is relatively an emerging field for managing the spatial and the non-spatial data. The aim of the study is intended to demonstrate methodology of creating the GIS based 4D Model for optimization and real time monitoring of the project. The plan of the building drafted using the drafting software (AutoCAD) and the corresponding schedule of the building generated by Project Management Software (MS Project) were interlinked using GIS platform. This enables the planner to get a clear picture in the planning stage and better control for the progress of the work in the most appropriate manner rather than the conventional methods of controlling the progress of the work with the help of management software. GIS based enclosure also paves the way to include the non-spatial information like bill of quantities, labour requirement, safety recommendations, etc. and can be stored as a tabular form for the corresponding drawing. A case study of one storey residential building at Thangam nagar in Erode, Tamilnadu, India has been selected for the study.

Key words: Geographical Information System, planning and scheduling, 4D Model, construction industry, India

INTRODUCTION

Construction space (Zhang *et al*., 2001) is an important part of construction resource, the same as time, labor, material, plants and cost. Unfortunately, construction site can only be arranged with project manager's own experience.

Thus, incorrect decision or operation will be made when project managers use their experience inappropriately or lack of enough experience. The traditional layout method is too limited to meet the need of large-scale modern construction site management. Visual and intelligent management of the construction site has become an urgent need. Consequently, the research in this area becomes a hot spot. The construction industry has acknowledged that its current working practices are in need of substantial improvements in quality and efficiency and has identified that computer modeling techniques and the use of prefabricated components can help reduce times, costs and minimize defects and problems of on-site construction.

Information technology and more specifically visualization have been highlighted as one of the most important tools for construction management towards achieving this goal. Such visualization tools could assist the site manager in obtaining a better perception of the project and could be achieved by integrating the schedule management of the project with an animated virtual environment display. Research efforts to incorporate visualization into project scheduling and progress control have been motivated by the failure of traditional techniques such as bar charts and the Critical Path Method (CPM) to provide information pertaining to the spatial aspects of a construction project (Koo and Fischer, 2000).

Several research efforts in construction visualization have been conducted relative to scheduling. They involve linking activity-based construction schedules and 3D Computer-Aided Drafting (CAD) models of facilities to describe discretely evolving construction product visualization, called 4D CAD (Kamat and Martinez, 2001).

Corresponding Author: V. Rajesh Kumar, Parisutham Institute of Technology and Science, Thanjavur, India

4D planner is a powerful visualization, simulation and communication tool that provides simultaneous access to design and schedule data. It provides a graphical simulation of the work plan that allows early problem identification including interference detection and supports scenario analysis. 4D planner facilitates interdisciplinary construct ability reviews and provides a means to graphically represent the results of the planning process, thus helps all project participants make faster and better informed planning decisions (Williams, 1996). The use of 4D planning also assists the planner in avoiding scheduling conflicts, analyzing constraints and evaluating alternative construction methods (Vaugn, 1996). Visualizing construction progress in three dimensions alongside a CPM-generated bar-chart provides the construction project manager with a more intuitive view of the construction sequence. Three dimensional visualization allows the construction manager to view the construction activities during any stage of the construction process. The benefits of linear scheduling and 4D visualization include the ease with which different scheduling strategies can be explored and visualized, the links between 3D objects and activities can be maintained and the completeness of the product model representations can be validated (Staub-French *et al.*, 2008).

A tool that has flourished within civil engineering in recent years is Geographic Information Systems (GIS). A GIS is a computer system for processing (assembling, storing, manipulating and displaying) geographically related information. GIS is a special class of information system which has four components involving a computer system, GIS Software, human expert and data. GIS activities may be grouped into spatial and attribute data management, data display, data exploration, data analysis and modeling. The spatial and non-spatial data in GIS are synchronized so that both can be quarried, analyzed and displayed. Spatial data is related to the geometry of features while attribute data stored in the tabular form describe the characteristics of different features of a layer in GIS. Each row of table represents a feature while column represents characteristic of features. The intersection of a column and row shows a value of particular characteristic of that feature. GIS uses vector and raster data models to represent the spatial features.

The vector data model uses points and their x, y coordinates to construct spatial features (points, lines and areas). The features are treated as discrete object in the space. The raster data model uses a grid to represent spatial variations of features. Each cell of grid has a value that corresponds to the characteristic of a spatial feature at that location. Raster data is well suited to represent continuous spatial features. Specifically applied to modeling civil engineering phenomena, GIS has been recognized in a majority of the civil engineering disciplines as a beneficial technology. The Geographic Information System (GIS) which combines a CAD-like design program with a relational database management system for spatial data analysis, appears to have potential in solving these problems. The development of GIS resulted from a need for automation by organization that was faced with the overwhelming resource strain of map manipulation for large projects. Thus, the technology has most commonly been used for automated mapping and facilities management in the utilities and government sectors.

GIS is a promising tool for solving construction layout problems and thus opens up a new way of thinking for the management of spatial information in construction planning and design (Cheng and Yang, 2001). Database is the essential part of any information system employed for construction management so the usefulness of geographical information system need to be explored. GIS not only speed up the modeling process and data extraction from the various resources but ensures data integrity and accuracy also. GIS form an effective foundation for planning construction activities. Poku and Arditi (2006) demonstrated that Geographical Information Systems (GIS) can be utilized for construction progress visualization in three dimensions alongside a synchronized CPM-generated work schedule. Expert geographic information systems (expert GIS) have the potential to expand the use and utility of both expert systems and GIS in civil engineering practice by making GIS easier to use and expanding the range of tasks that expert systems can address. Bansal and Pal (2006) utilized GIS system in developing an information system that supports the rate analysis of a sample construction project. Bansal and Pal (2008) proposed an approach for linking of the activities in a critical path method schedule with the corresponding elements of a 3D Model makes the project sequence easier to understand. It is found from the study of actual building information at site and the building simulation model that some overlapping and rework can be avoided through GIS based 4D Model development (Naik *et al.*, 2011).

The present study aims at linking the plan with corresponding themes related to elevation as shape file using GIS Software, developing schedule for construction activities using construction management software and inter-linking the schedule with shape file using GIS and synchronizing the same with time. A case study of one storey residential building at Thangam nagar in Erode has been selected for the study. The data like plan and construction activities, time spent for the selected buildings were collected from one of the leading construction company Yes and Yes Hi-tech promoters located at Erode, Tamilnadu, India.

Software used for the study: The method was developed using major software: AutoCAD, Primavera and ArcGIS and Additional Software Microsoft Project. AutoCAD (Version 2007) is one of the leading drafting software from Autodesk Inc. Civil engineering technicians, drafters and surveyors use AutoCAD Software for civil engineering design and construction documentation. AutoCAD will help in deliver higher-quality project deliverables for the transportation, land development and environmental industries.

Primavera Project Management (Version 5.0) is designed for planners and schedulers and a recognized standard for CPM scheduling and resource plans. It helps to plan and schedule projects and resources; organize project dates for quick status reports and to compare actual performance to original plans. ArcGIS (Version 8.1.1) includes ArcReader, ArcView ArcEditor and ArcInfo. ArcReader allows one to view and query maps created with the other Arc products.

ArcView allows one to view spatial data, create maps and perform basic spatial analysis. ArcEditor in addition to the functionality of ArcView includes more advanced tools for manipulation of shapefiles and geodatabases. ArcInfo includes capabilities for data manipulation, editing and analysis. Microsoft Project (Version 2002) is a project management software program developed by microsoft designed to assist project managers in developing plans, assigning resources to tasks, tracking progress, managing budgets and analyzing workloads.

MATERIALS AND METHODS

A method has been created using GIS (Fig. 1) to develop 4D Model of construction projects and simulate it to monitor the workflow at the site. The steps involved in the process of generation of the 4D are creating architectural drawings, identifying work breakdown structures, scheduling the activities, modeling in ArcScene, integrating model with scheduling and visualization cum evaluation.

Architectural drawings: The plan of the building (collected data) was drawn using drafting software package AutoCAD and differentiated with layers, i.e., different layers for foundation level, footing level, pedestal level, etc. Layers are used to group information in a drawing by function and to enforce line type, colour and other standards. Layers are the equivalent of the overlays used in paper-based drafting. The more the number of plans, the more will be the accuracy of the 3D Model.

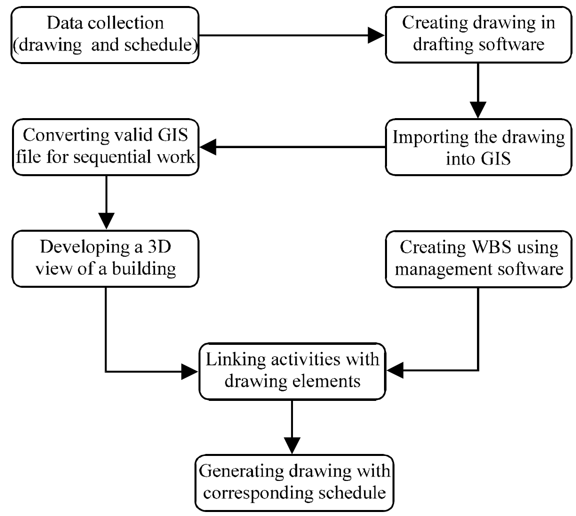

Fig. 1: 4D Model creation

Work breakdown structure: A Work Breakdown Structure (WBS) is a hierarchy of work that must be accomplished to complete a project which defines a product or service to be produced. The WBS is structured in levels of work detail, beginning with the deliverable itself and is then separated into identifiable work elements. Each WBS element may contain more detailed WBS levels, activities or both. When creating a project, the project manager typically develops the WBS first, assigns documents to each WBS element and then defines activities for performing the element's work. The process of identification of the WBS involves a different approach for different projects. Creating work break down structure was done to make the project control effective and manageable. Each of these parts is monitored as a different view in ArcView module of ArcGIS Software.

Scheduling process: The initial proposal of the study involves the scheduling done in the project management tool Primavera Project Management (Version 5.0). This tool enables the effective scheduling related to the work to be handled and it results in providing the critical path for the project. The critical path is longest path in the project. The duration of the project is the sum of the activities duration in the critical path. The activities are scheduled based on the Critical Path Method (CPM). The project was scheduled based the activities identified in the work breakdown structure. The critical activities are planned in a way that will result in the timely completion.

Delay in these activities will directly impact the duration of the project. So, resource allocations for the critical activities are very much essential for the time management. Thus, it will enable to control the project under the proposed completion of time. Primavera was used to schedule the project, showing the start and completion dates, locating the critical path (s) and float times of activities and also showing the sequence and interrelationships between the activities. The activities are to be identified based on the work-break down structure for the scheduling of the project. The details list of activities and the projected Schedule of the project is shown in Fig. 2. The prepared schedule was saved in an excel format. Using the export option in Primavera, the schedule along with its details is exported as a database.

Modeling 3D view: The drawing file created using AutoCAD file was imported (which will be in non editable format) into ArcGIS (Fig. 3) and converted into raster file format (Fig. 4). It is then geo-referenced using a Projected Coordinate System and was converted into a poly line shape file whose uniqueness can be defined by its attribute table with columns mentioned as fields. The shape file is editable and any changes can be done in the file through its attribute table. The elevation details which are already identified were used as the base heights and extrusions and added as new field elevation in the table.The Arc GIS provides one of the important features 3D Analyst which was used to create Triangulated Irregular Network (TIN). TIN displays three dimensional view for the shape file having the field characterized as an integer. The field Elevation was selected for creating TIN file. The TIN file (Fig. 5) was created for four different level variations. This in terms helps the observer in the better understanding of the work progress and ease access of control over the work. The feature of the file will be a total polygon thus it resembles a development of the building. The 3D file developed in the methodology is based on the data in resource tables which can be updated on the basis of past practice.

Integration of model with scheduling: The decisive step of the method is integrating the schedule with 3D Model of the project. A new field object was also introduced for the shape file to identify the polyline and its feature. This field helps to identify the feature of a particular polyline even by single click made on the separate feature. GIS was capable of executing the xls file of the developed schedule. The attributes needed for each layers were created in a database. This file will have details included in the Primavera namely the activity, start date, end date, duration, predecessor, float and etc. The attribute table in

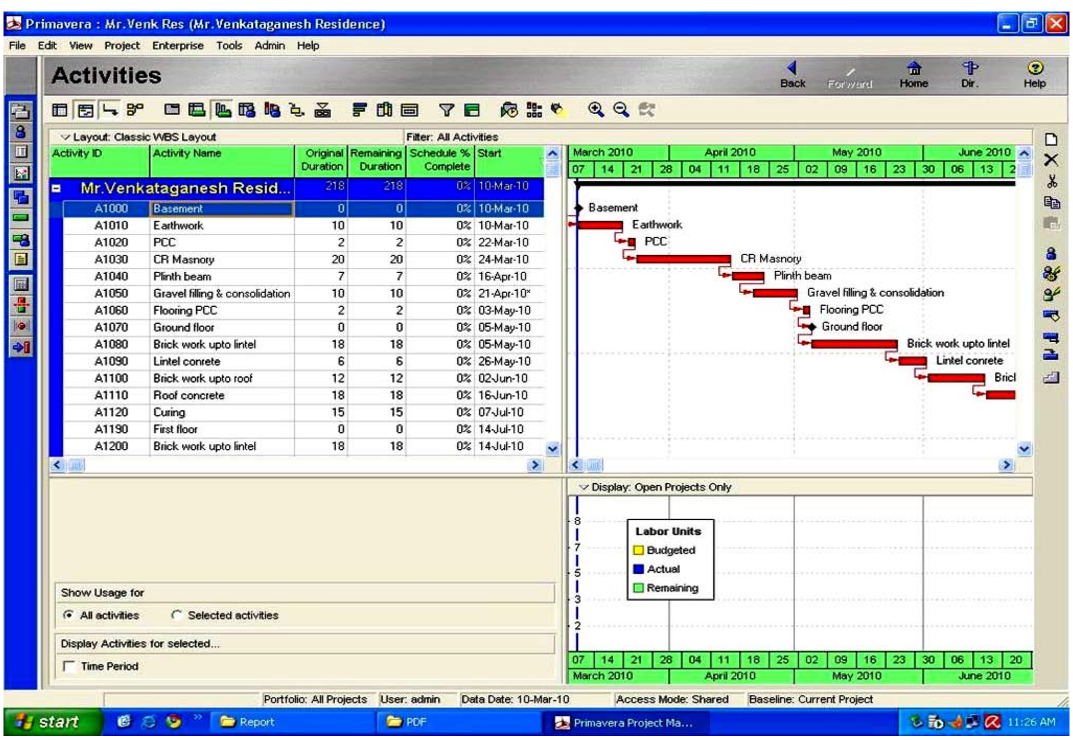

Fig. 2: Scheduling of activities using Primavera

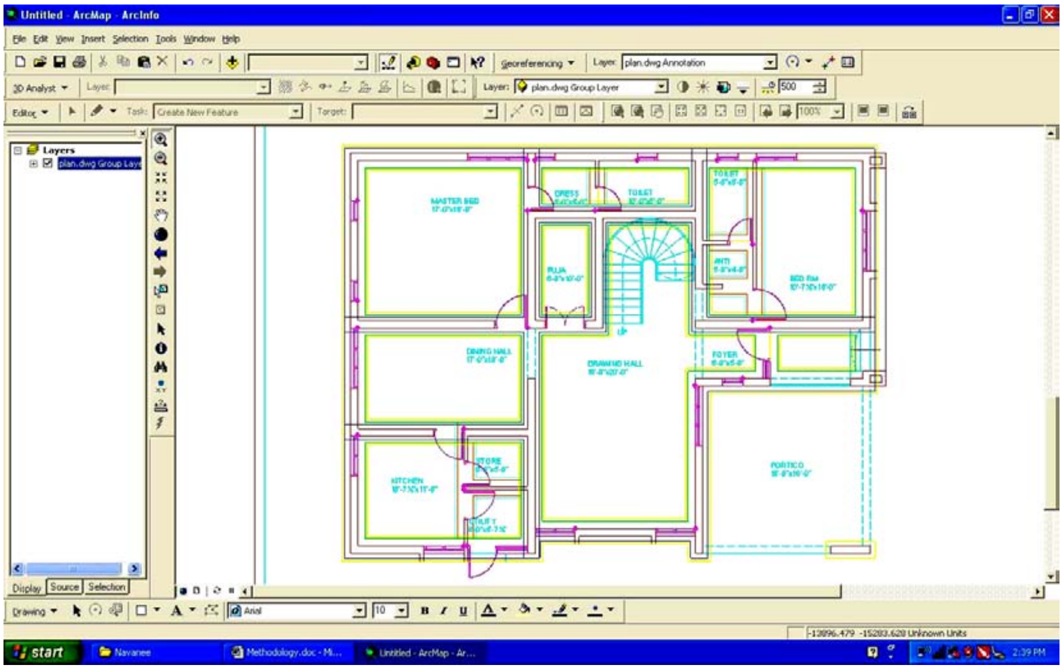

Fig. 3: Imported plan of the building

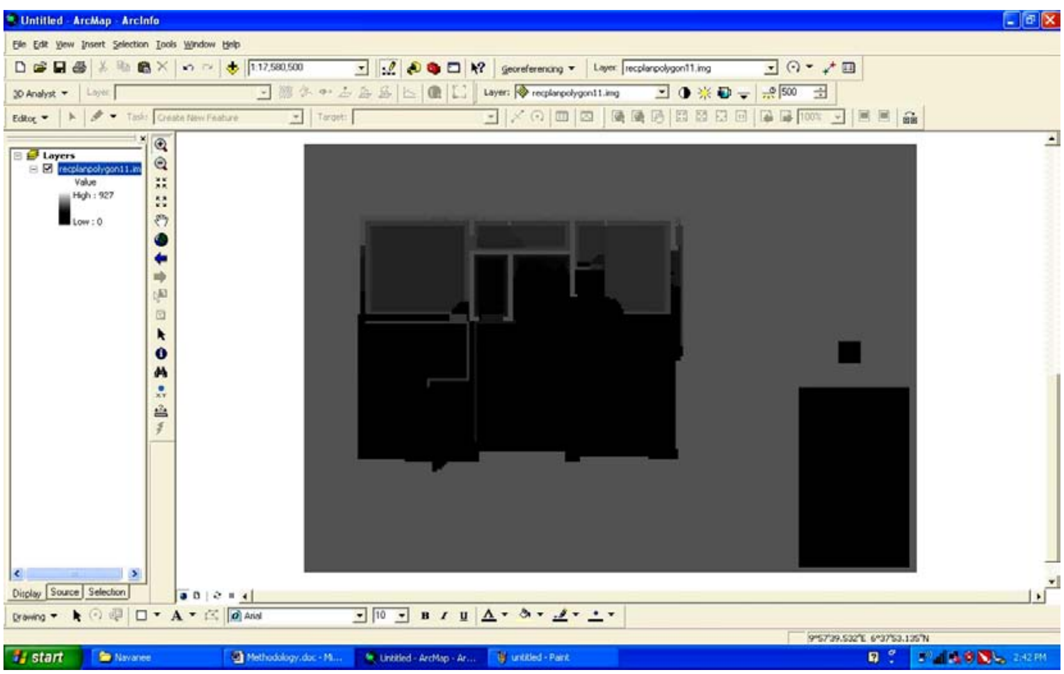

Fig. 4: Created raster

the shape file and the table developed from Primavera will have the similar objects as feature in the shape file and activity in the schedule table. Hence, it helps to identify the feature in the file with the schedule in the table. It is possible to prepare all this information as an independent database and later import it to ArcGIS. Thus, it links the drawing with the schedule in a single platform. The developed GIS-based application in planning and scheduling procedure can work well for repetitive tasks or activities.

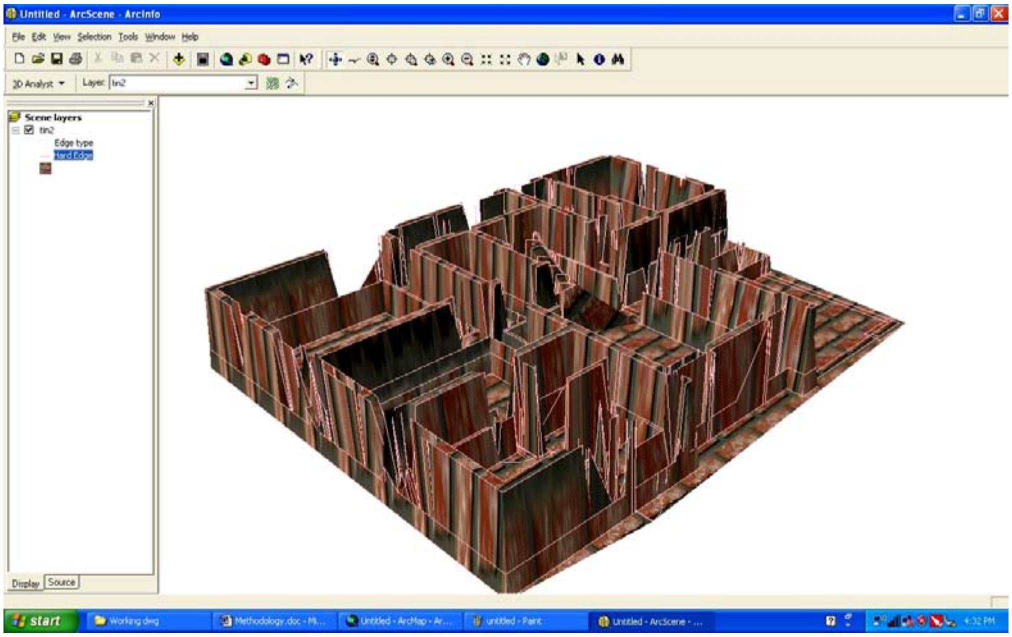

Fig. 5: Triangulated irregular network

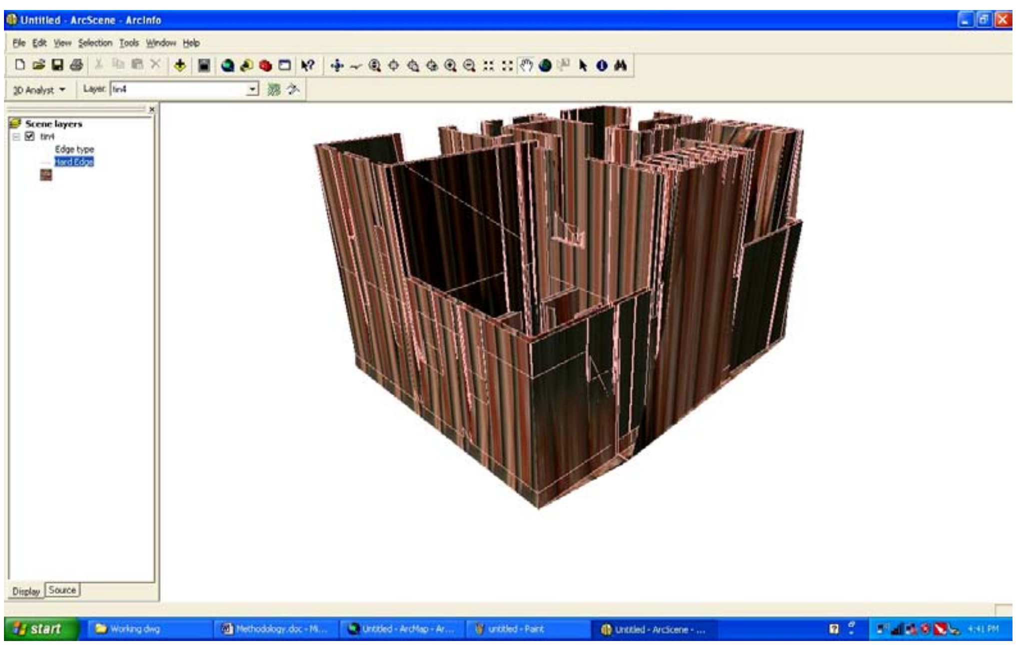

Fig. 6: Generated 3D view of the building

RESULTS AND DISCUSSION

Visualization cum evaluation: The components that are scheduled to be in operation on and before a date will graphically be displayed in a 3D space. The GIS based approach also facilitates the understanding of a 3D Model and the topological relationship between different components in many ways like zooming, pan, fly, navigation, etc. Figure 6 shows a 3D view of the building considered for study in which the roof slab is set transparent to display the internal details more clearly. The users also have the option of rotating 3D components around the x, y or z axis to observe the developed 3D Models from any direction and angle. This 3D drawing helps the builder, contractor, client and worker a clear view of idea regarding their work progress, i.e., the work they have made and the course of work to be done for the mentioned period of time. The result also helps the worker regarding the course of action to be taken. Moreover, it clearly shows the model output of the work. The 3D drawing along with the mentioned detail regarding the schedule helps the greater knowledge. This process of work will replaces the current method of practice that has been used for the different construction.

The study is a GIS based methodology to represent and integrate drawing and construction schedule in a single environment. The drawing on the work area and schedule as a table as the attribute data in a GIS environment may improve and speed up the construction planning as well as ensure data integrity and accuracy. The proposed methodology integrates the construction schedule with corresponding plan to make the project sequence to understand easily. GIS allows the user to manipulate the schedule and 3D components in a single environment which in turn facilitates the rapid generation of alternatives. The schedule in GIS allows easier understanding of the project as well as helps to detect possible problems in it as well as it promotes interaction and collaboration among the project team members from different fields. GIS allows users to use its database management capabilities to maintain and update the construction database. Most of the 4D CAD technologies do not have the project management capabilities and are used mainly for the planning and design phase of the project. On the other hand GIS based developments can be used at any stage of the projects.

CONCLUSION

This study concludes that GIS can be an efficient supplement to project scheduling tools like Primavera and Microsoft Project. It allows even an inexperienced user to identify unseen problems in the CPM schedule. Schedules can only convey what is built when whereas the schedule in GIS conveys what is being built when and where. The major conclusion drawn from this study is that GIS based developments not only provide a construction schedule visualization tool but can also be used as a project management tool at any stage of the project in which the schedule and the 3D components can be manipulated in a single environment.

REFERENCES

Bansal, V.K. and M. Pal, 2006. GIS based projects information system for construction management. Asian J. Civil Eng., 7: 115-124.

Bansal, V.K. and M. Pal, 2008. Generating, evaluating and visualizing construction schedule with geographic information systems. J. Comp. Civil Eng., 22: 233-242.

Cheng, M.Y. and S.C. Yang, 2001. GIS-based cost estimate integrated with material layout planning. J. Const. Eng. Manage., 127: 291-299.

Kamat, V.R. and J.C. Martinez, 2001. Visualizing simulated construction operations in 3D. J. Comp. Civil Eng., 15: 329-337.

Koo, B. and M. Fischer, 2000. Feasibility study of 4D CAD in commercial construction. J. Const. Eng. Manag., 126: 251-260.

Naik, G.M., M. Aditya and S.B. Naik, 2011. GIS based 4D model development for planning and scheduling of a construction project. Int. J. Innovat., Manag. Technol., 2: 447-451.

Poku, S.E. and M.D. Arditi, 2006. Construction scheduling and progress control using geographical information systems. J. Comp. Civil Eng., 20: 351-360.

Staub-French, S., A. Russell and N. Tran, 2008. Linear scheduling and 4D visualization. J. Comp. Civil Eng., 22: 192-205.

Vaugn, F., 1996. 3D and 4D CAD modeling on commercial design-build projects. Proceedings of the 3rd Computing in Civil Engineering Congress, June 17-19, 1996, Anaheim, California, pp: 390-396.

Williams, M., 1996. Graphical simulation for project planning: 4D-planner. J. Comp. Civil Eng., 1: 404-409.

Zhang, J.P, Y. Maz and C. Pu, 2001. 4D visualization of construction site management. Proceedings of the 5th International Conference Information Visualisation, July 27, 2001, London UK., pp: 382-387.