GEOGRAPHICAL INFORMATION SYSTEM AND ITS APPLICATION TO PROJECT MANAGEMENT IN CONSTRUCTION INDUSTRY

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Abstract:
The construction industry is huge and it involves a large number of activities. Various traditional techniques for scheduling and controlling are still being used in the construction industry which fail to provide the spatial (layouts, drawings) and non-spatial (specifications, cost estimates etc) aspects of information in a construction project. So it was considered that integration between the Project Management and GIS (Geographic Information System) would be a key part of the solution. This integration would show visualisation of construction progress w.r.t. time. In this integration the drawings were drafted using a computer – aided drafting (CAD) program (AutoCAD), the construction schedule was prepared using Project Management Software (MS Project 2003), the updated schedule information (which mainly includes percent complete) which is updated in the Geodatabase (Arc Info). As the updating is being done, a custom application (.net with C# language) had been prepared to automatically update the Geodatabase. Thus the project management software is updated and simultaneously the Geodatabase is also updated and 3-D view of the progress of view can also been seen. The Integrated GIS-Project Management system would help all the parties involved in the construction project (especially for decision making) as they would be able to see all the spatial aspects of project in one system.

Keywords: Geographical Information System; Project management; Scheduling; Construction Industry; Custom application

Introduction:
The Construction Industry has a huge number of tasks involved and cost involved in these projects is also very large. The Project Managers have a hard time monitoring the projects between site and office. They have to come on site to know the progress of work and decide the sequence of work. They are generally confused on what to do next or what would be the changes faced by them in future. So the cost involved is large and it varies w.r.t. to the completion of the project i.e. time. The traditional approach for scheduling and progress control techniques such as bar charts and the critical
path method are still being used by the project managers for planning which a serious disadvantage for the decision is making purpose as the spatial aspects fail to provide the required information. There is pressure on the project managers to shorten the delivery times and thus the current scheduling and progress reporting practices are in need of substantial improvements in quality and efficiency. Integration of Geographical Information System (GIS) and project management software’s with visualization was recognized as one of the most important tools for achieving this goal.

It should be seen perception of a project as well as in the integration of other parties’ activities in the planning process. Furthermore, in large scale projects, a visual representation of the schedule can be extended to monitoring not only the construction process itself, but also all the auxiliary activities, including onsite plant and equipment. In addition, the practical and educational benefits of being able to visualize construction at a fine level of detail are significant. The application of geographic information system in project management will be new in the Indian Construction industry. GIS will allow construction managers and different people involved in project with different backgrounds to get the information about the progress of the project and support Decision Making. GIS will provide a common basis of understanding and communication among these people. Many people think of GIS as a presentation tool. A GIS does in fact create high quality maps that communicate considerable amounts of information in an efficient and attention-getting manner. GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with the data.

Visualizing construction progress in three dimensions provides the construction project manager with a more intuitive view of the construction sequence. 3-D visualization allows the construction manager to view the construction activities during any stage of the construction process. The objective of this paper is to demonstrate that GIS can be integrated with project management software for construction progress visualization and an integrated information system.

**Project Management**

The term Project management is defined as:

“The application of knowledge, skills, tools and techniques to project activities to meet project requirements." (PMBOK)

"The planning, monitoring and control of all aspects of the project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance.” (PRINCE2)

**Geographical Information Systems (GIS)**
In the past twenty-five years, a host of professions have been in the process of developing automated tools for efficient 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. This rapidly evolving technology has come to be known as “Geographic Information Systems (GIS)”. Geographic information system goes beyond description; it also includes analysis, modeling, and prediction. According to the 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, analyze, and display all forms of geographic referenced information.” Kang Tsung Chang describes GIS as a computer system for capturing, storing, querying, analyzing and displaying geographically referenced data. GIS is essentially a marriage between computerized mapping and database management systems. Thus, GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with the data.

**GIS APPLICATIONS IN CONSTRUCTION INDUSTRY**

GIS 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 engineering and construction journals and conference proceedings, in addition to the handful of special publications devoted to GIS (Oloufa et al. 1994).

GIS can be used for:

- Progress monitoring system in construction
- Networking solutions
- 3-D data analysis
- Site location and Client Distance
- Comparison of data
- Construction scheduling and progress control with 3-D visualization
- Government Regulations

**Integrating Project Management and GIS**

The intent of this paper is to demonstrate the benefits of using GIS with construction project management. In this project, integration of GIS and Project Management is developed using ArcGIS, MS Project, AutoCAD, and Visual Studio to assist construction managers in controlling and monitoring construction progress. Successful project control is a challenging responsibility for all construction managers. Visualization of information is an important benefit for any project.
The objective of this paper is to display the progress and sequence of construction work in 3-D while synchronizing this information with a formal CPM work schedule. This would help all parties involved in a construction project to visualize the progress in a natural way, hence minimizing delays and cost overruns. In addition to monitoring the schedule, the system can also be extended to monitor quantities of materials, costs, and resources. Fig.1. shows the path of the paper among the various applications in the system. It also shows the procedure that needs to be used in using the system. A building of G+20 storey building is selected as the study area. The progress reports are described in the following sections.

**STEP I: CREATING AUTOCAD DRAWINGS**

The plan of a G+20 storeyed building was created using AutoCAD, for which only typical floor plan was used for calculations from which a study area was considered.

**STEP II: CREATING WORK BREAKDOWN STRUCTURE (W.B.S.)**

WBS for the project is to be done to make project control effective and manageable. Activities in construction should be Mobilization of Site which generally includes site clearance and preparing an access road for the site etc. Next activity would have to be RCC Work in which SubStructure and SuperStructure should be included SubStructure would include construction of foundation. As the type of foundation for this structure is pile foundation Piling has to be done and which is divided into
different groups (GRP). According to the groups the numbers of piles are decided after the piles have been laid, Pile caps have to be put on these piles simultaneously. On these pile caps a PCC Slab is to be laid which would make the pile foundation complete i.e. the substructure activities would be completed. After the completion of substructure activities, superstructure activities have to be started. The type of formwork used is Mivan formwork i.e. the concreting work is done at the same time for all columns, walls, beams and slab. Superstructure is divided into different floors, and then it is further divided into 2 types i.e. wings (Type B, Type A). The two wings are then further divided into two parts i.e. in total 4 parts (Part I, Part II, Part III, and Part IV). Each and every part is again divided into structural parts i.e. BLDGColumn, Wall, Beam, and Slab. It is then planned that Shuttering and Reinforcement will be done simultaneously for BLDGColumn and Wall and then after that Staging for Beam and Slab will be done. Only after the whole of Shuttering and Reinforcement is done one can start the Concreting activity. And after concreting is over one has to do De-shuttering of the formwork.

Fig.2. Floor plan with elevation, WBS and Activity information with MS Project Schedule
STEP III: INITIATING SCHEDULING PROCESS
MS Project 2003 was used as the scheduling tool. The project was scheduled based on the activities identified in the WBS described in Step 2. MS Project was used to schedule the project showing the start and completion dates, locating the critical path(s), showing the sequence and interrelationships between the activities. Fig.2. shows the floor plan and front elevation of G+20 storey building, WBS and Activity information with MS Project schedule for the building whose plan and elevation are presented.

STEP IV: DIGITIZING AUTOCAD DRAWINGS TO GIS FORMAT
After creating drawings in AutoCAD, the dwg files were transferred to ArcMap a module of ArcGIS. The topologic data structure of the basic design layers in AutoCAD was created as layers in GIS based on the layers and activities identified in the AutoCAD drawings. The Migration of Raw data into GIS format is shown in Fig.3.
STEP V: CREATING FEATURE CLASSES W.R.T. ACTIVITIES
The feature classes (Polygons, lines or points) created for activities were merged together into activities defined earlier in MS Project schedule. Thus, the activities which belong together but are located at different positions were joined together as one “feature class”. For example all the various components of the Column were merged into one merged feature class called the “BLDGColumn” activity.

STEP VI: CREATING DATABASE W.R.T. FEATURE CLASS, ACTIVITIES
The attributes needed for each layer were created in a database. The database includes information about Z_Factor, TotalVolumeIncum, TotalReinforcementQtyInkg, StartOfConcreting, PercentageOfConc, CurrentQtyOfConcreting, StartOfReinforcement, PercentageOfReinforcement, StartOfShuttering, PercentageOfShuttering, TotalPercentageOfCompletion, DrawingNo, TotalCostForConcreting, TotalCostForReinforcement, Z_Actual, MoneyUsedForReinforcement, MoneyUsedForConcreting, LastUpdated, Name, ComponentName, Material, BaseHeightInmm, WallPosition for each activity.
STEP VII: CREATE UPDATES OF MS PROJECT SCHEDULE

The percent complete information on the activities is entered in the database by the user in step V. This information will be used in step VII to calculate the percent complete for each activity, which is obtained by calculating the average of the percent complete of the activities.

STEP VIII: RUN-TIME APPLICATION

The run-time application is developed using Visual Studio 5.0 in C# language. With the help of this run-time application a User Interface was developed. Here the user would come to know about the location of the source file. The user interface displays present date and time. It has drop down lists for the user to select accordingly. Fig.4. shows the User Interface Window.

![User Interface](image-url)

Fig.4. User Interface
STEP IX: IMPORT INFORMATION ABOUT ACTIVITIES AND UPDATE GIS DATABASE

The percent complete information is transferred with the help of custom run time application to MS Project every time a progress evaluation is made and the application is run. MS Project was run to generate the updated schedule network. The updated schedule shows the progress for all the activities as of the new date of the update (e.g. at the end of every month or daily updates) and the percent complete information.

STEP X: SHOWING PROGRESS OF ACTIVITY IN 3-DIMENSIONAL VIEW

The project’s 3D view was created in ArcScene a module of ArcGIS. The activity layers created in Step V were converted into 3D layers in ArcScene.

STEP XI: PREPARING REPORT AS PER REQUIRED FORMAT

The progress of work was shown in graphical format and in different colors. The amount of work done on the various activities could be seen in 3D view. The project was updated as progress information became available and the corresponding MS project schedule was sent to ArcScene. The updating was done with the help of a custom runtime application.

The various formats of reports can be generated as per the user’s requirement. Fig. 5. shows the progress for days 1, 3, 5 and 7 for all the activities involved in the project with summaries and MS project schedule. Progress information can be viewed for an individual activity as well as for a number of selected activities at the same time.

Fig. 5. Activity Days 1, 3, 5 and 7 with 3-Dimensional view and summary
BENEFITS AND LIMITATIONS OF THE SYSTEM

Traditionally, the CPM schedule did not provide any information pertaining to the spatial aspects or context and complexities of the various components of a construction project. Therefore, to interpret progress information, project members normally look at 2D drawings and conceptually associate components with related activities. Different project members may develop inconsistent interpretations of the schedule when reviewing only the CPM schedule. This causes confusion on many occasions and usually makes effective communication among project participations difficult. This system allows project planners and managers to see in detail the spatial characteristics of the project. All the project members should be able to visually observe the progress, which will help in effective communication of the schedule. The system has to be run periodically over the duration of the project.

CONCLUSION

This system will benefit project managers, site engineers and clients in the following manner:

PROJECT MANAGER

- Up-to-date information about the progress of work
- Helps in controlling big project sites
- Comes to know about the Cost incurred/Spent and the quantity of materials used on site
- Reduces time for decision making as all information is in one system

SITE ENGINEER

- Controlling the project site by knowing the progress of work
- Helps in easy decision making for procurement of funds or materials
- Helps in informing the contractors beforehand about the start of their work
- Helps in knowing how much more material is required
- Helps in reducing wastage of materials
- Helps in ordering the ideal quantity of materials thus by reducing over ordering of materials

CLIENT

- Helps in knowing the exact status of the project
- Has a 3-D view of the progress of work thus knowing where large cost has been incurred

Because of the limitations of this version of Integration of Project Management with GIS, the interfaces between ArcGIS, AutoCAD, and MS Project, only one database should be available and that is the one that is essential to the operation of the system (i.e., percent completion information), and
the system is designed for use in single-user desktop environments. The database of the study area was prepared for columns, walls, beams, slabs, doors, and windows. The database of staircase, site layout, reinforcement detailing, drainage, plumbing, electrical and gas pipelines can also be added for further detailed knowledge of the progress of work. The scheme of integration of GIS with project management software can be further improved by core software professionals. Links of Photographs showing the present status of work can also be added. It should be further explored to integrate GIS with ERP (Enterprise Resource Planning) analysis, billing software’s and SAP (System Applications Product).

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**GIS Software used: ESRI ArcGIS Desktop 9.2 (ArcMap, ArcScene, ArcCatalog)**