GIS Based Project Management Information System for Infrastructure Projects - A Review Paper

Riki Panchal[1], Akshay Jain[2], Dr. Debasis Sarkar[3]
[1] M.Tech Student, Pandit Deendayal Petroleum University,
[2] Lecturer, Civil Dept., Pandit Deendayal Petroleum University
[3] Associate Professor and Head of Civil Dept., Pandit Deendayal Petroleum University
PDPU, Raisan, Gandhinagar- 382007

Abstract:

This paper is an attempt to review research work undertaken to develop GIS based project management for infrastructure projects. This review paper gives an idea of the recent trends in the field of construction project management (CPM) and applications of GIS technology. This paper also evaluates the efficiency of GIS based models adopted for the betterment of the project planning and execution. Various traditional scheduling and progress control techniques are used such as bar charts and the critical path method which fail to provide accurate information pertaining to the spatial aspects of an infrastructure project. There was a need to develop a system through which geo-spatial based project planning and monitoring is possible. There were many efforts made by researchers to develop an integrated system to represent construction progress not only in terms of a CPM schedule but also in terms of a geographical representation of the construction activities. It can be concluded by referring different research works that GIS can be very useful tool for planning and monitoring of infrastructure or construction projects.

About the Author:

Ms. Riki Panchal

Ms. Riki Pravinbhai Panchal is pursuing her M.Tech in Infrastructure Engineering and Management from Pandit Deendayal Petroleum University (PDPU), Gandhinagar, Gujarat. She has completed her BE. (Civil) from M S University, Vadodara. Her M.Tech thesis is on GIS based Project Management Information System. She has also attended several national conferences. She has worked on various software such as Microsoft Project (MSP), EPANET, Primavera P6 for various research projects in the field of Infrastructure design and management.

E mail ID: riki.pmt13@sot.pdpu.ac.in

Contact No: +919974706536

Introduction

Project scheduling/rescheduling occurs in all stages of projects, from feasibility stage to monitoring stage to completion (Ahuja et al. 2004). According to them, the traditional scheduling and progress monitoring techniques such as Gantt charts, Critical Path Method (CPM), Programme Evaluation Review Technique (PERT), etc. are widely in use by the project managers of various industries for planning purpose of their respective projects since the late 1950s. The increasing number of aging infrastructure systems combined with the declining maintenance budget present tough challenges to infrastructure management agencies such as municipalities, municipal corporations, road and building department under state and national government authorities to sustain acceptable performance levels and to meet the high demands of these systems. Many initiatives and research projects have been launched with the aim to develop and implement new technologies that can potentially assist in meeting these challenges (Halfawy et al. 2002). Since these traditional scheduling techniques fail to provide the necessary spatial aspects of information which is prerequisite for any infrastructure projects, many limitations of techniques come into picture in the decision making stage of any project (Vijay K. 2010). Hence, there is a dire necessity to come up with some geo-enabled information technology with the capability to present spatial perspective to infrastructure projects so that these projects can be designed, planned and managed more precisely using more frequent geo-spatial information analysis and sharing system.

Geographical Information System (GIS) can play significant role in introducing Geo-enabled Project Planning and Management. GIS integrated project management will be very helpful to create geo-spatial information useful for managing 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. (Naik et al. 2011)

Scope and Need

In the past fifteen years, many 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. Also, for the monitoring of the project it provides management with a clearer overview of data that they are using to make decisions and to see the results of those decisions sooner and in a crisper more comprehensible format. The 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, hence there is a need for integrating them on a common platform to create 4D view of the project using GIS environment.

Trends in Construction Planning

Developing the construction plan is a critical task in the management of a construction project. Effective plan generation requires competent and experienced personnel. However, emerging evidence suggested that there is a shortage of skills in the area of construction planning, with the number of experienced planners having the knowledge or ability to effectively plan construction projects. It is commonly acknowledged that the scheduling of construction activities is only a section of the entire construction planning process. During the formulation of a complete construction schedule, planners and site managers are required to simulate various construction processes, required to build the project. This simulation can either be done intuitively by the planner or by using a computer based simulation techniques. Computer-based decision support tools have provided the construction planner with the ability to plan construction tasks efficiently using techniques such as Critical Path Method (CPM) and Critical Chain. The building block of these methodologies is the construction task, which concentrates mainly on the temporal aspect of construction planning. Although 4D CAD in the construction industry has been developing since 1987, the interest in this area has grown rapidly in recent years. This technological development as having the potential to provide an improved relationship between construction designers and constructors. 4D CAD was seen as a natural progression to 3D CAD models, as it adds a further dimension. It provides the ability to represent construction plans graphically, by adding the temporal dimension to 3D CAD models, i.e. linking a 3D graphical model to a construction schedule, through a third party application (Heesom and Mahdjoubi. 2004).

Role of GIS in Project Management

GIS is a computer based system for capturing, storing, quarrying, analyzing, and displaying geographic data. GIS is a special class of information system, which can be divided into four Components involving a computer system, GIS software, human expert, and the data. GIS activity can be grouped into spatial data input, attribute data management, data display, Data exploration, data analysis, and GIS modelling. GIS can handle both spatial and Attribute data, spatial data relate to the geometry of the features, while attribute data describes the characteristics of the different features and stored in the tabular form. In the georelational data model, split data system is used to store spatial and Attribute data in separate files and linked together by the feature Identification Descriptor (ID). These two sets of data files are synchronized so that both can be quarried, analyzed, and displayed. GIS role have proliferated in the construction industry in recent years. (Palve. 2013)

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

(i) Project Management Information System

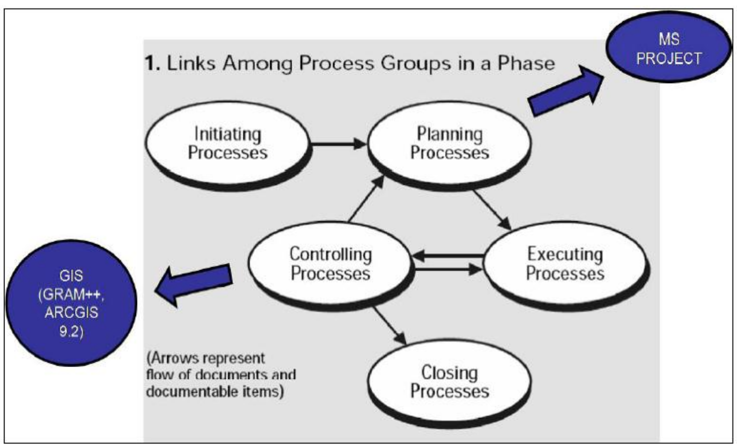

Fig: 1 – Links among Process Groups in a Phase and the various applications in the Processes
(Source: Kolagotla, 2010)

Project management processes can be organized into five groups of one or more processes each as shown in Fig 1:

a) Initiating processes: recognizing that a project or phase should begin and committing to do so.
b) Planning processes: devising and maintaining a workable scheme to accomplish the business need that the project was undertaken to address.
c) Executing processes: coordinating people and other resources to carry out the plan.
d) Controlling processes: ensuring that project objectives are met by monitoring and measuring progress and taking corrective action when necessary.
e) Closing processes: formalizing acceptance of the project or phase and bringing it to an orderly end.

(ii) GIS and PMIS Integration

The intent was 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 the project 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.

Below figure shows the path of the project among the various applications in the system. It also shows the procedure that needs to be used in using the system.

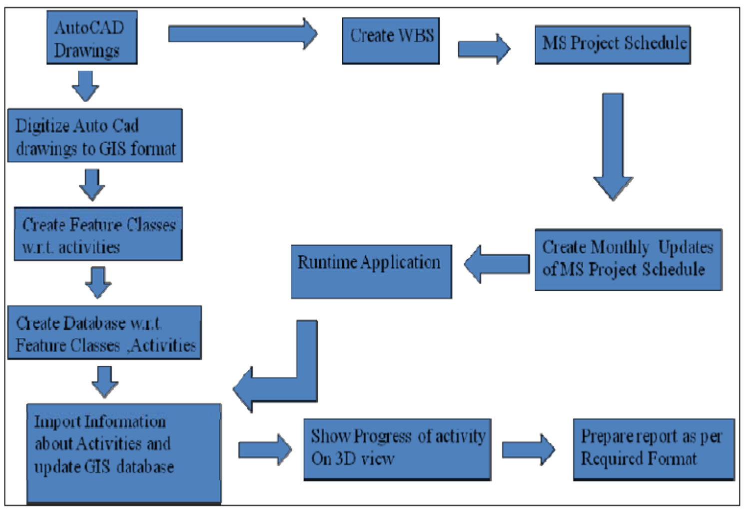

Fig: 2 – Flow Chart showing the Integration of Project Management and GIS (Source: Kolagotla, 2010)

(iii) Requirements and challenges of developing integrated infrastructure management system

The primary goal of an infrastructure management system is to maintain an accurate, updated, and reliable data of the current physical and performance characteristics of the infrastructure system, and to enable infrastructure managers to efficiently access this data to make accurate predictions of the infrastructure performance, to plan maintenance operations, and to optimally allocate maintenance funds. Realizing this goal would require addressing a wide range of requirements:

a) Modeling and management of infrastructure physical, functional, and performance data as well as gathering condition data in a timely and effective manner;
b) Utilizing the knowledge of deterioration models, simulation models, cost models, optimization models, and effective operations to support the knowledge-intensive decision-making process;
c) Interoperation and data exchange between different function-specific software tools;
d) Modeling, management, and coordination of maintenance operations and effective communication of accurate and timely information;
e) The ability to customize the system to specific project or organization policies, and to accommodate various operations that reflect industry practices. Satisfying each of these requirements represents a major challenge to be addressed.

The aforementioned requirements have enormous implications on the design of integrated infrastructure management frameworks. The framework should have a modular architecture to accommodate future modification, extension, and technology improvement. Another major design consideration is the necessity to separate the responsibilities between the function-specific tool set and other framework components. Tools would provide users with the functionality to perform specific tasks, while the framework components would provide the functionality to integrate and manage different processes (Halfawy et al.2002).

(iv) Model based approach and Component based approach

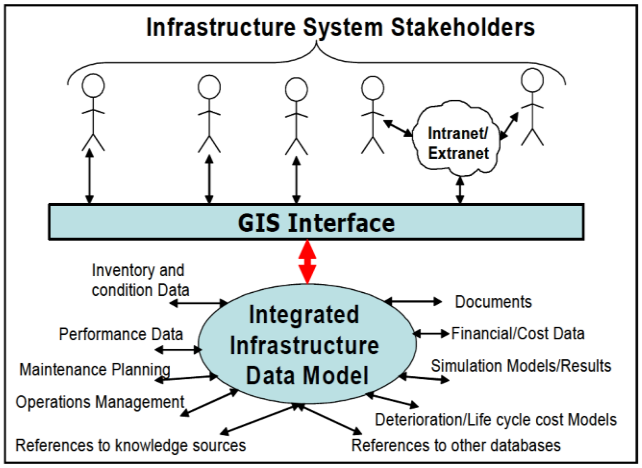

Fig: 3 – The Model-Based Approach to Infrastructure Management (Source: Halfawy et al.2002)

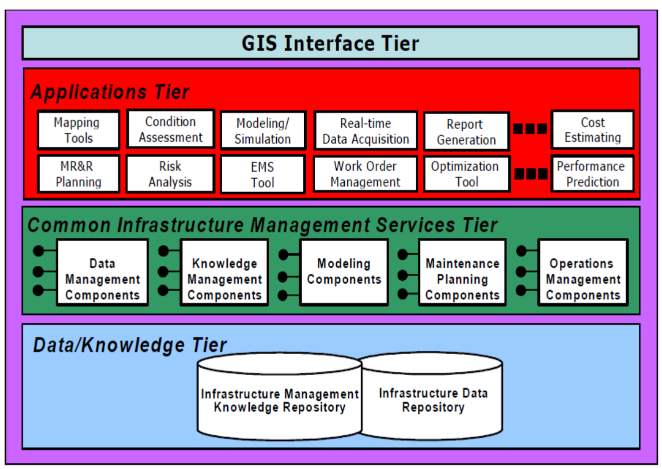

Fig: 4 – The Four-Tier Component-Based Framework for Integrated Infrastructure Management Systems (Source: Halfawy et al.2002)

Project Monitoring System with GIS (PMS-GIS)

To demonstrate the benefits of using GIS in construction project management, a system called PMS-GIS (Progress Monitoring System with GIS) is developed using ArcView GIS, Primavera Project Planner (P3), and AutoCAD 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 of PMS-GIS. The objective of this study is to display the progress and sequence of the construction work in CAD format with different colors and labels and in three dimensions while synchronizing this information with a formal CPM work schedule. This form of presentation is expected to 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 (Poku. and Arditi. 2006).

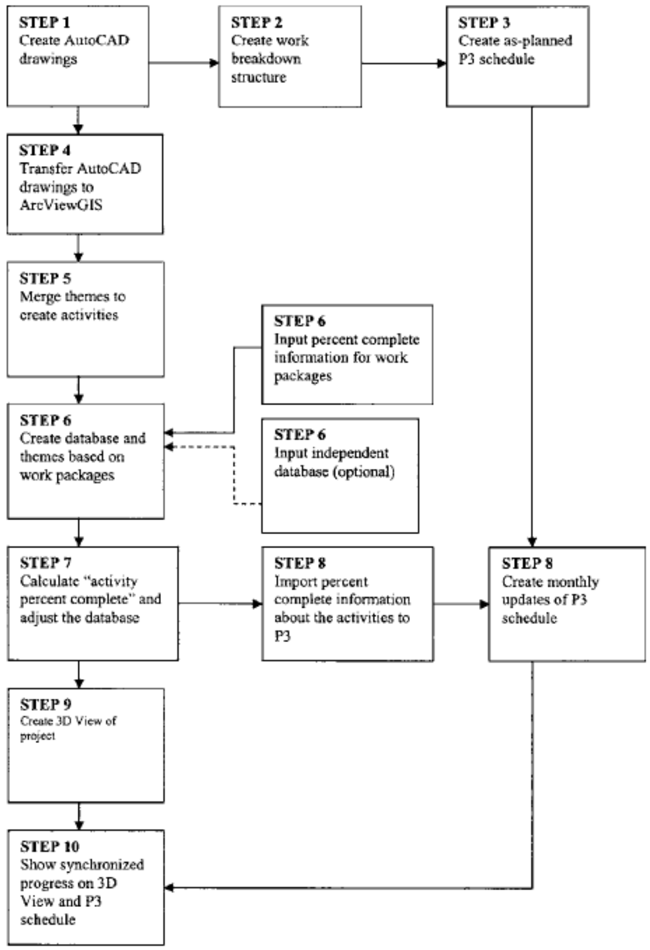

Fig: 5 – Design and information flow chart
(Source: Poku. and Arditi. 2006)

(i) Methodology and Model development

The 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. 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 4th dimension
Step 6: Simulating the output
(Naik et al.2011)

(ii) Benefits and Limitations of the system

Traditionally, the CPM schedule does 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, users normally look at 2D drawings and conceptually associate components with related activities. Different project members may develop inconsistent interpretations of the schedule when viewing only the CPM schedule. This causes confusion on many occasions and usually makes effective communication among project participants difficult. GIS based PMIS allows project planners and managers to see in detail the spatial characteristics of the project by showing on the same screen a bar-chart schedule and a 3D rendering of the project marked for progress. With GIS based PMIS, all project members should be able to visually observe the progress, which will help in effective communication of the schedule. The system is run periodically over the duration of the project.

While the updating and maintaining of most 4D systems are cumbersome, PMS-GIS can be handled by the user as long as the user is familiar with ArcViewGIS. The current version of PMS-GIS requires that some updating tasks, such as transferring information from P3 and AutoCAD to ArcViewGIS, be performed manually. However, it should be possible for P3, AutoCAD, and ArcViewGIS to communicate automatically with each other seamlessly, and work is underway to automate this process. But the user will have to generate the drawings in AutoCAD, define the work breakdown structure in terms of activities and smaller work packages, and populate the database with information. (Poku. and Arditi. 2006)

Conclusion

Reviewing the literature for past one decade it has been observed that PMIS has substantial use for controlling and monitoring infrastructure projects. Adequate research has been observed in terms of development of deterministic, probabilistic tools and also use of software. But it appears that integration of PMIS with GIS would prove to be a better tool for developing conceptual and schematic framework for monitoring of infrastructure projects. Thus the present research aims at developing a GIS based PMIS monitoring model for an infrastructure project.

References

1. Bansal, V. K. and Pal, M. (2006). "GIS based Project Information system for construction management" *Asian Journal of Civil Engineering (Building and Housing)* Vol. 7, No. 2, pp 115-124.
2. Halfawy, M. R., Pyzoha, D. and El-Hosseiny, T. (2002). "An integrated framework for GIS based civil Infrastructure management systems" *Annual Conference of the Canadian Society for Civil Engineering,* Canada.
3. Hartmann, T., Gao, J. and Fischer, M. (2008). "Areas of Applications for 3D and 4D models on construction projects" *American Society of Civil Engineers*, Vol. 134, Issue 10, pp 776-785.
4. Heesom, D. and Mahdjoubi, L. (2004). "Tends of 4D CAD applications for construction planning" *Construction Management and Economics* Vol. 22, pp 171-182.
5. Kolagotla, V. (2010) "Geographical Information System and its Application to project management in construction industry" *International Conference on Design & Construction of Urban Transport Structures*, Hyderabad, India.
6. Koo, B. and Fischer, M (2000). "Feasibility study of 4D CAD in commercial construction" *American Society of Civil Engineers*, Vol. 126, Issue 4, pp 251-260.
7. Liberatore, M. J., Johnson, B. P. and Smith, C. A. (2001). "Project Management in construction: Software use and Research directions" *American Society of Civil Engineers*, Vol. 127, Issue 2, pp 101-107.
8. Naik, G. M., Aditya, M. and Naik, S. B. (2011). "Integrated 4D model development for planning and scheduling of a construction project using Geographical Information System" *International Proceedings of Economics Development and Research,* Vol.15, IACSIT Press, Singapore.
9. Palve, S. N. (2013) "Applications of GIS in Infrastructure Project Management" *International Journal of Structural and Civil Engineering Research* Vol. 2, No. 4, pp 110-122.
10. Peachavanish, R., Karimi, H. A. and Boukamp, F. (2006). "An ontological engineering approach for integrating CAD and GIS in support of infrastructure management" *Advanced Engineering Informatics* Vol.20, pp 71-88.
11. Poku, S. E. and Arditi, D. (2006). "Construction Scheduling and progress control using Geographical Information Systems" *American Society of Civil Engineers*, Vol. 20, Issue 5, pp 351-360.
12. Simao, A., Rodrigues, J. C. and Antunes, C. H. (2011). "A GIS based multicriteria spatial decision support system for planning urban infrastructures" *Decision Support Systems* Vol. 51, pp 720-726.
13. Ahuja, V. and Thiruvengadam, V. (2004) "Project scheduling and monitoring: current research status", *Construction Innovation*, Vol. 4 Issue 1, pp 19–31.