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Potential of GIS to Find Solutions to Space Related Problems in Construction Industry

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***Abstract*—**Geographic Information System (GIS) is a computer-based tool used extensively to solve various engineering problems related to spatial data. In spite of growing popularity of GIS, its complete potential to construction industry has not been realized. In this paper, the summary of up-to-date work on spatial applications of GIS technologies in construction industry is presented. GIS technologies have the potential to solve space related problems of construction industry involving complex visualization, integration of information, route planning, E-commerce, cost estimation, etc. GIS-based methodology to handle time and space issues of construction projects scheduling is developed and discussed in this paper.

***Keywords*—**Construction, GIS in construction, Scheduling, Project Management.

I. Introduction

GIS is a computer tool for capturing, storing, quarrying, analyzing and displaying the geographic information. Like any other information system, 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 co-ordinates 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 [1].

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II. GIS in Construction Industry

GIS provide spatial solutions to many fields of civil engineering such as transportation, water resources, facilities management, urban planning, construction and E-business. Its applications in construction industry are discussed in this section [2].

A. Subsurface Profile

Camp and Brown [3] suggested the use of GIS to develop a procedure for generating subsurface profiles from well-log data. The well-log database was constructed from a series of borehole and GIS-based procedure was used to create 3D subsurface. Oloufa *et al*. [4] highlighted that site investigation is an important step in estimating and planning new construction projects and suggested the use GIS-based methodology to develop a database for foundations analysis, design and construction planning. As surface and subsurface conditions influence construction methods and choice of equipment, which in turn affect cost and scheduling of projects. Therefore, study by Oloufa *et al*. [4] used database management capability of GIS to store descriptive soil data and to relate this data with the corresponding locations of boreholes.

B. Quantity Takeoffs and Construction Cost Estimation

Cheng and Yang [5] suggested an approach for quantity takeoffs and cost estimation using *Map/Info*. Architectural drawing was divided into different layers, called data layers, for quantity takeoffs. In GIS-based cost estimates, area and perimeter were used as the basic parameters. Thus, data layers were created as polygons in *AutoCAD* and transferred to *Map/Info* in the form of geometric coverage. The geometric information of spatial features such as coordinate, area, perimeter and spatial relationship are derived from coverage. Whereas, user enters thematic information such as identification (ID) code, beam number, floor number, etc. Recently, Bansal and Pal [6] suggested the use of GIS for cost estimation in a more generalized way by adding new scripts into GIS environment for various cost estimation operations. *ArcView*, which utilizes the dynamic linkage between spatial and attribute data, was used for this purpose.

C. Materials Layout at Construction Site

The *MaterialPlan*, a GIS-based tool developed by Cheng and Yang [5] integrates quantity takeoffs with material layout planning. The system uses rules of thumb and experience to decide the size and location of material storage area. It assists planner in quantity takeoffs as well as in assessing material layout design. *MaterialPlan* developed by using a GIS environment integrate estimates with construction scheduling for dynamic materials requirement plan. Based on the information regarding quantities and locations of materials required in the project, the proposed methodology identifies the suitable site to store construction materials.

D. Construction Site Layout

The conventional approach to layout temporary facility (*TFs*) involves designing site layout using sketches, templates and 2D physical model. The developed layout is based upon the incomplete information stored in the different form. Such visual representations of *TFs* do not yield adequate and descriptive results. As *TFs s*hould be located close to their supporting activities to reduce the time for travel, the role of GIS may be explored for this. Cheng and O'Connor [7] developed an automated site layout system called *ArcSite* using GIS for construction *TFs*. *ArcSite* consist of a GIS integrated with DBMS was claimed a new computerized tool to identify suitable area to locate *TFs.* *ArcSite* integrate information required to find suitable location for *TFs* and perform series of complicated spatial operations and database queries to identify optimal site that is difficult to perform manually.

E. Real -Time Schedule Monitoring System

Cheng and Chen [8] developed an automated schedule monitoring system by using GIS to assist construction managers to control erection process for precast building construction. A case study was taken where structural elements were prefabricated in the manufacturing plant and transported to job site for installation. Erection of prefabricated structural components is considered a major critical activity for precast building construction. The schedule for prefabrication and transport of structural elements to job site are developed based on installation schedule. The study suggested that the use of GIS environment improves the real time schedule monitoring system and construction process as well as improves construction efficiency. A study reported by Li *et al*. [9]-[10] integrates Global Position System (GPS) and GIS technologies to reduce construction waste. GPS and GIS were integrated with construction management system in such a way that managers from the headquarters and construction sites get real time information to control cargoes coming through road to sites, so as to reduce the waste generation on sites.

F. Route-Planning

Varghese and O'Connor [11] developed a GIS based system in which the information requied for route planning can be integrated. Study make use of two technologies: expert system and GIS to develop this tool, expert system attempt to model the human reasoning process through a set of predetermined rules while GIS provide data display capabilities. In urban areas, obstacles such as existing public utility lines, railways, canals and roads influence routes significantly. There may be a limited number of feasible crossing points; selection of a suitable route to avoid existing obstacles in a path reduces the risk of damaging the existing utilities. It also minimizes the cost required during construction. Cheng and Chang [12] discussed the development of a GIS based system to automate the process of routing and design of an underground power supply system. The optimal paths for routing is determined using the *network analysis* of *Arc/Info* GIS package.

G. Topography Visualization

GIS is an effective tool to visualize the topographical conditions of construction site. The modeling of construction site facilitates in construction controlling and planning process. *GIS-based visual simulation system* (GVSS) developed by Zhong *et al*. [13] is a tool that offers powerful planning, visualizing and querying capabilities as well as facilitate the detection of logical errors in a model.

III. Spatial Aspects of a Construction Project

Commercially available scheduling tools such as *Primavera* and *Microsoft Project* fail to provide information pertaining to spatial aspects of a construction project. A methodology using GIS is developed to represent spatial aspects of construction graphically by synchronizing with construction schedule. The spatial aspects are depicted by 3D model developed in *AutoCAD* and using Microsoft Excel generates construction schedule. Spatial and scheduling information are linked together into a GIS environment. The GIS-based system developed in this study help in understanding the schedule along with its spatial aspects.

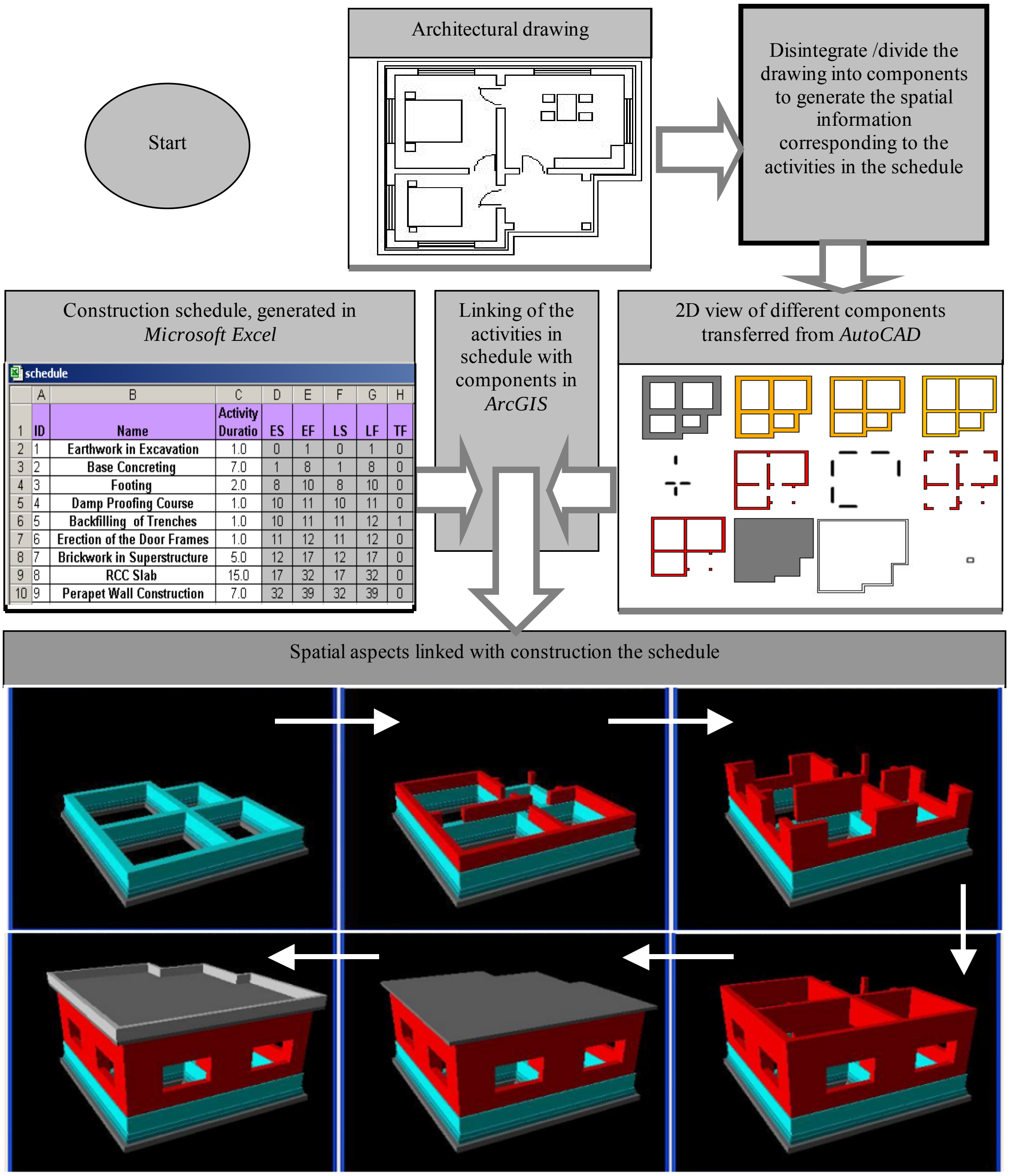
A. Methodology

The construction schedule that acts as a roadmap for the successful implementation of construction project is developed in *Microsoft Excel* and transferred to *ArcGIS* [14]. The spatial information of different activities defined in the construction schedule is generated in *AutoCAD* [6]. The drawings are transferred into *ArcGIS* as layers and may be symbolized and queried. GIS allow working with drawings transferred from *AutoCAD*, however, to edit or modify *AutoCAD* drawing layer features or its associated attribute table layers need to be converted into *shapefiles*. The s*hapefiles* are simple non-topological format for storing geometric location and attribute information of geographic features.

Layers transferred into *ArcGIS* from *AutoCAD* may be merged together according to the activities as defined earlier in schedule generated in *Microsoft Excel*. Thus, components of a drawing that belong to same activity but are located at different positions in space are joined together to construct spatial data for each activity. Linking an activity with its schedule involves in adding a field called *key* to schedule and its *attribute* table. The field *key* is common between two tables (i.e. schedule and *attribute* table of different components) and used to establish the connection between the spatial aspect of activity and the corresponding activity in the schedule. All the entries in the field *key* are to be entered manually and should be unique in both schedule and *attribute* tables of an activity. Linking the schedule with spatial aspects of the construction activities are shown in the Fig. 1.

IV. Conclusion

This paper presents a summary of different spatial applications of GIS in construction industry. As GIS is one of the fast emerging fields being utilized in various engineering projects, its complete potential to the construction industry has



	A	B	C	D	E	F	G	H
1	ID	Name	Activity Duratio	ES	EF	LS	LF	TF
2	1	Earthwork in Excavation	1.0	0	1	0	1	0
3	2	Base Concreting	7.0	1	8	1	8	0
4	3	Footing	2.0	8	10	8	10	0
5	4	Damp Proofing Course	1.0	10	11	10	11	0
6	5	Backfilling of Trenches	1.0	10	11	11	12	1
7	6	Erection of the Door Frames	1.0	11	12	11	12	0
8	7	Brickwork in Superstructure	5.0	12	17	12	17	0
9	8	RCC Slab	15.0	17	32	17	32	0
10	9	Perapet Wall Construction	7.0	32	39	32	39	0

Fig. 1 Linking the schedule with spatial aspects of the construction activities

not been realized yet. GIS improve the construction planning and design efficiency by integration of spatial and attribute information in a single environment. Researches reported in this area are limited, as efforts in the direction to use GIS in construction industry have not embraced the issue associated with its implementation in industry practice.

GIS is an effective tool to integrate spatial and non-spatial information of the construction project in a single environment. The methodology presented in this paper integrates construction schedule with corresponding spatial details so as to make understanding of the project sequence easier. This link allows easier understanding of the project as well as helps to detect possible problems in it. Non-spatial schedules only convey what is built 'when', whereas schedule in GIS conveys what is being built 'when and where'.

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