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Planning of Linear Construction Projects Using Geographic Information Systems

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Abstract

This paper presents potential applications of Geographic Information Systems (GIS) for planning and management of linear construction projects that are affected by the geographic conditions. Previous GIS applications in construction management area are reviewed. Potential applications are described using examples from a pipeline project. Benefits of GIS for planning and management of linear construction projects are discussed.

Keywords
Geographic information systems, Linear construction projects, Planning

1. Introduction

Linear construction projects consist of repetitive activities that have linear production characteristics. Examples of linear construction projects are pipelines, highways, railways, multiple similar housing units, and high-rise buildings. In linear projects, planners mainly concentrate on the progress rate of activities. Linear scheduling techniques are the commonly used for scheduling of linear projects. One of the main important characteristics of linear construction projects is the effect of geographical conditions on planning and management of the activities. Topography, as an example, has a significant impact on the progress rate of pipeline construction activities.

Geographic information systems (GIS), are information systems for capturing, storing, analyzing, and managing data referenced by spatial or geographic coordinates (Huxhold, 1991). Geographic Information Systems (GIS) present powerful alternatives for planning and management of construction projects. GIS presents solutions for visualization the effect of topography on the progress rate and activity delays due to space conflicts. Within this context, the main objective of this paper is to explore potential GIS applications for planning and management of linear construction projects.

2. GIS Applications in Construction

Geographical information systems have been one of the fastest growing computer-based technologies since 1990s however; this trend has not been reflected in the construction industry (Jeljeli *et al.*, 1993). There have been a numerous construction related GIS applications in recent years. Jeljeli *et al.*, (1993) provided an example for contractor prequalification, and concluded that one of the expected benefits of GIS applications is the creation of a comprehensive data base. Cheng and O'Connor (1994) developed an automated site layout system for construction temporary facilities, including a GIS and a database management system to assist designers. Shanmugan and Parvatham (2002) explored the capability of a GIS-based system for developing the coordination between project participants, and found that the capability of the GIS to represent spatial information and execute spatial queries is better than the conventional database methods. Soe and Kang (2006) proposed a GIS-based system for roadway construction planning to assist construction planners in a unique way by integrating design and construction information.

A number of GIS studies focused on construction project scheduling and progress control. Cheng and Yang (2001) integrated GIS-based cost estimates with construction scheduling for dynamic material planning. Cheng and Chen (2002) developed a GIS-based automated schedule monitoring system to assist the managers to control the erection process for precast building construction. Poku and Arditi (2006) presented the system called "PMS-GIS" (Progress Monitoring System with Geographical Information Systems) to represent construction progress not only in terms of a CPM schedule but also in terms of a graphical representation of the construction that is synchronized with the work schedule.

Previous GIS applications in construction engineering field mainly focused on contractor prequalification, site layout planning, project coordination, material planning, and scheduling of construction projects. There was only one study related to linear construction projects, which explored integration of design and construction information for highway projects. However, GIS promises major advantages for planning and management of linear construction projects that are repetitive due to their geometrical layout.

3. GIS as a Potential Tool for Planning and Management of Linear Projects

Critical Path Method (CPM) is generally used for scheduling of construction projects. However, CPM has several limitations for managing the linear construction projects' resource continuity necessity. At the heart of the linear construction projects is the progress rate, which is measured as the progress per unit time. Due to its simplicity and the ability to display the progress rate, linear scheduling methods are commonly used for linear projects. During the planning phase, the progress rate is usually assumed to be uniform along the different regions. Topographic conditions and the effect of topography on the progress rate are ignored or considered to some extend. However, in actual cases progress rate differs from regions: i.e. mountainous regions to flat regions. In order to improve the planning progress, topographic conditions have to be considered. Line of sight of a linear construction project can be viewed, river crossings, potential obstacles, topography of the terrain can be determined with GIS software. As an example, Figure 1 shows a mountain crossing of a pipeline project. In this figure each different colour represents an activity. In addition, the numbers in the beginning of the activity names indicate the sequence of activities. It can be seen from the Figure 1 that three activities are on progress. Different from traditional planning phase, GIS features help the planner to visualize the topography in a 4D environment. The progress rate of activities while climbing the mountain range (2nd and 3rd activities) will be lower than the flat regions (1st activity). Thus, with the visualization and topographic information (slope) of the project, planning progress can be further improved. Moreover, scenarios related with planned progress rates can be visualized.

In linear scheduling methods, activity delays due to adjacent activity are prevented by space buffers. By the help of buffers, neither unanticipated slower nor higher rate of an activity do not affect the successors' rate up to a certain level. Thus, activity progress rates should be arranged to protect this space buffers along different regions. Buffer plans and controls can be done by GIS software more effectively. As an example of space buffer control, Figure 2 is demonstrated. In this figure, six activities are shown each of them is represented by different colours. With time lapse simulation of activities and 3D spatial data, space and time buffers can be simulated with enhanced visualization feature and time dimension. Space buffers can be planned and controlled using different production rates for each activity.

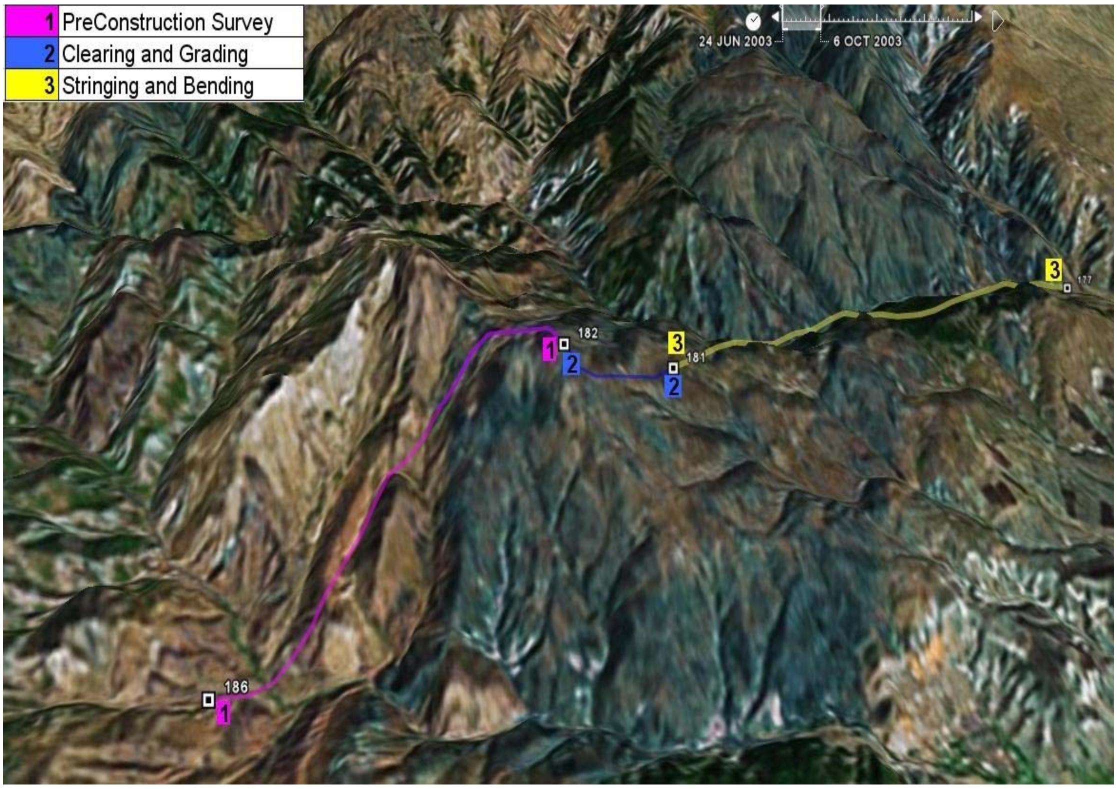

Figure 1: Planned Pipeline Progress along Mountainous Region

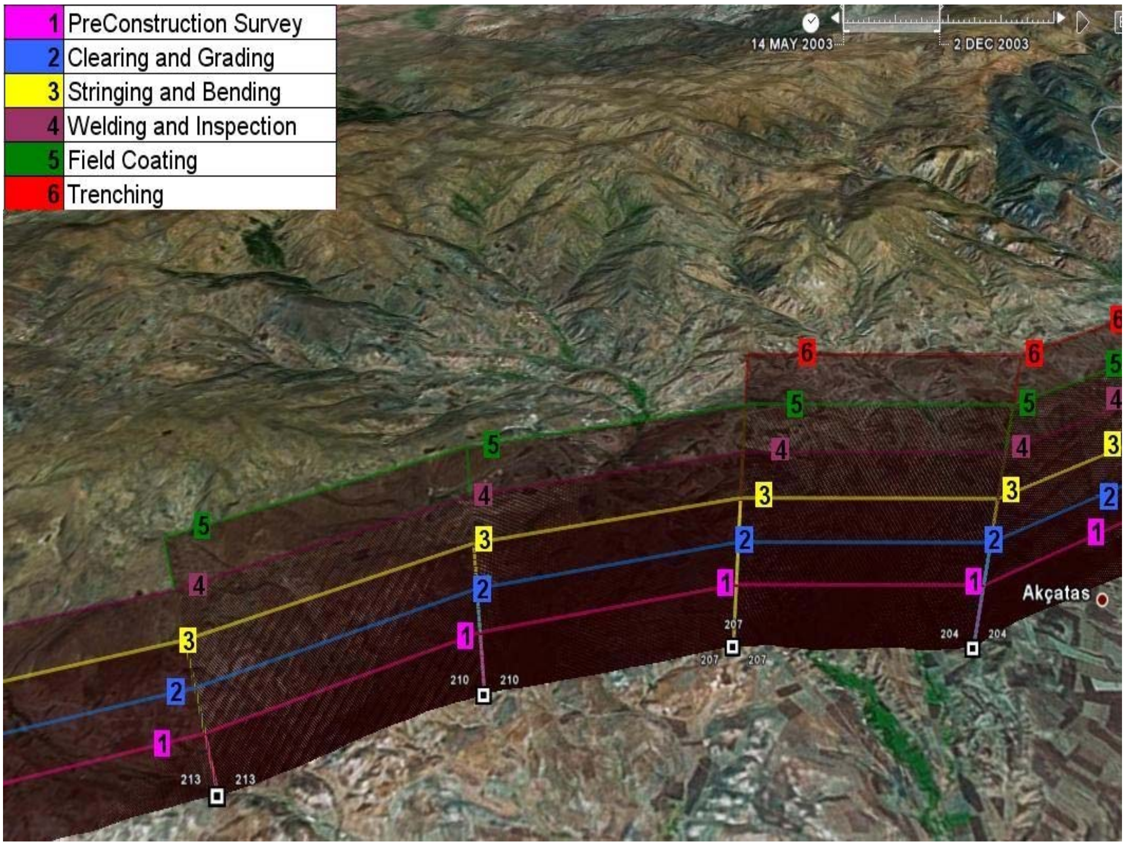

Figure 2: Planned Space Buffers

Another important feature of GIS is the ability to manage both spatial and attribute data. In spatial data, the geometric features are stored whereas; with attribute any additional non-geometrical data can be stored. This feature makes the GIS a potential tool for a GIS based project management system. To demonstrate the ability of GIS to serve as a planning tool, a prototype study was conducted by Sonmez and Uysal (2008). In this study, Google Earth was used. An interface which was developed by C++ was used to model a real pipeline project progresses. By this interface, geographic coordinates and time date was converted to Keyhole Markup Language (KML). In Figure 3, a snapshot of interface is given. The prototype planning system can be improved to serve as a GIS based project management system by including manpower, machinery, material, and cost information along with the schedule information (Figure 4).

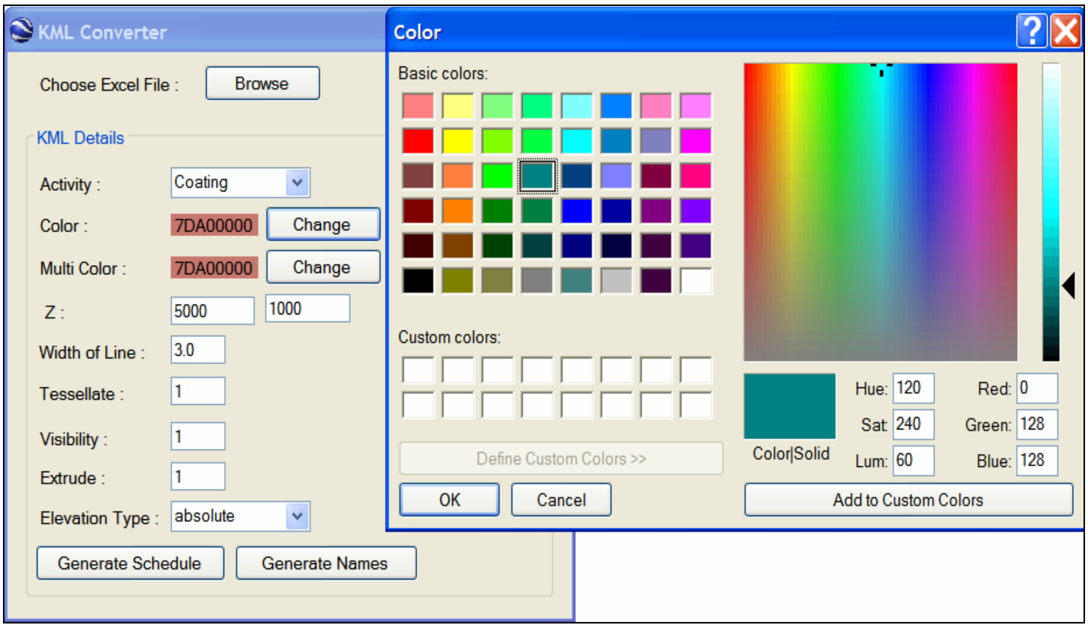

Figure 3: Interface Details

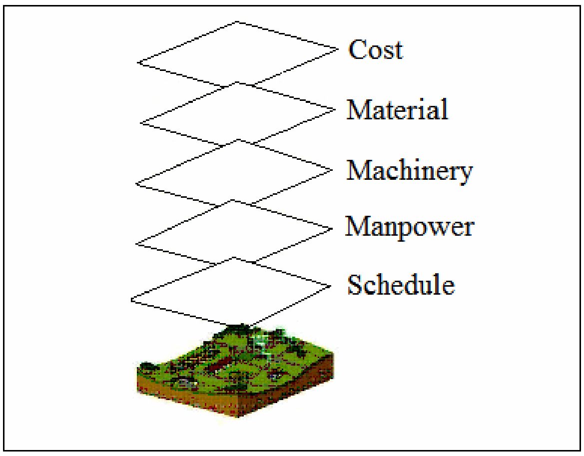

Figure 4: GIS-Based Project Management System

The GIS based project management system will enable effective storing, updating, and sharing of the project information, in addition to enhanced visualization. The cost, material, machinery, manpower and schedule information can be managed properly with enhanced visual representations. This would allow the project participants to visualize the schedule information in 3D view together with attribute data.

4. Conclusions

Potential applications of GIS for planning and management of linear projects were presented, using examples from a pipeline project. The main advantage of GIS is that it enables integration of the project information with the geographical information for enhanced visualization. GIS also provides an effective framework to share and manage the project information to achieve improved communication among the project participants. It is believed that improved visualization of the project conditions, enhanced communication, and effective management of project information will lead to better planning and management practices for linear construction projects.

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