Transportation Project Planning and Modeling

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Abstract: - Planning of transportation projects is vital as it involves huge amounts of cost and large construction periods. Numerous tools and techniques have been developed and put to use by different organizations. A variety of methods are being used in the construction industry and each has its own suitability criteria. Linear scheduling methods are more commonly used for linear construction projects like a roadway project. On the other hand, network methods like CPM are more suitable for complex projects having discrete activities. Over the last few decades, several systems and models for planning and scheduling of road construction projects have been developed and tested by many researchers. Each of these methods has their own strengths and weaknesses and that is why there is a continuous research going on in developing the most logical and universally acceptable planning and scheduling system for the optimum planning and scheduling of linear construction projects. This paper discusses some widely accepted and appreciated construction planning and scheduling techniques developed over the years by various researchers.

Key-Words: - transportation; planning; scheduling; construction; repetitive; discrete; linear

1 Introduction
The construction of a road is different from that of a building in many aspects. First of all, the entire construction activity is carried out on the ground under the sun. Hence, the weather and environment always play an important role in the planning and scheduling of the construction activities. Secondly, the variations in topography and geology make it even more challenging to first acquire accurate data and then use it effectively for construction planning. Hence, a large database containing information about the land characteristics and the anticipated weather conditions is a prerequisite to any reliable and workable road construction plan. Because highway projects have extended construction periods and large capital requirements, their planning is vital for all the stakeholders. Through this paper, authors try to summarize various planning and scheduling techniques developed and used in road construction projects and consolidate related research studies published in referred journals.

2 Planning and Scheduling
Breaking down the entire project into small manageable, measurable activities and establishing relationships between them in terms of their beginnings and endings followed by scheduling them using the available resources (Equipment, labor and material) and other constraints (cost and time) will briefly describe the planning and scheduling of a construction project. Construction projects have been classified in many ways. Those which are carried out along continuous sequences along a line are referred to as linear construction projects. Typical examples are road and rail projects, tunneling, pipeline project, etc. A typical building construction will be categorized into a non-linear project. There are some construction projects wherein activities repeat from unit to unit and hence they can be simultaneously carried out at different locations using the available crew. They are commonly known as repetitive construction projects. Examples include multi-storey building, road construction etc. A road construction project is therefore both linear and repetitive; such projects require schedules that ensure the uninterrupted usage of resources from an activity in one unit to a similar activity in the next unit along the length of the project. Because road construction is an equipment-intensive project, resource continuity is all the more important from cost point of view as crew idle time will add to the overall cost.

The critical path method (CPM) most commonly used scheduling technique in the construction industry has some drawbacks when applied to
repetitive construction projects. As elaborated by Kenley [1], the typical characteristics of an activity-based scheduling technique such as CPM are:
(1) Discrete locations and activities
(2) Prefabrication of components
(3) Highly sequential activities
(4) Critical path may be identified
(5) Non repetitive activities
These do not match well with the characteristics of construction projects where large amounts of onsite fabrication is involved and where there is continuous or repetitive work which may be carried out simultaneously at many locations. Due to this, CPM is not the ideal method for scheduling construction projects and definitely not suitable for road construction projects [1].

There are alternate scheduling methods in use mainly for repetitive construction projects. These methods are called by different names like Line-of-balance, Flowline, Repetitive scheduling method, Vertical production method, Time space scheduling method, Linear scheduling etc. Because all these methods are concerned with movement of resources through locations, whether there is repetition or not, Kenley [1] has suggested calling them all location-based scheduling methods.

3 Construction Scheduling Methods
Bar chart model- The Bar Chart is one of the simplest methods of project analysis. A bar chart graphically plots activities versus time, with the activities being listed vertically, and, when possible, in sequential order. The proposed period of execution for each activity is plotted as a bar on the time graph corresponding to the planned times of occurrence. The bar chart's main advantage is its simplicity. A primary disadvantage of the system is its failure to detail interrelationships of the activity because of which, the effect of changes in activity sequencing and/or durations cannot be readily determined.

Network models- A network model like Critical Path Method (CPM) clearly illustrates the logical sequence of activities. From the information listed on a CPM diagram, the project duration may be determined along with the critical activities, the ones whose durations will have direct impact on the total project duration. The major disadvantage is that for a complex project, a CPM schedule becomes extremely detailed making it hard to comprehend.

Linear scheduling method- In the LSM, activities are plotted versus two axes - distance and time usually, distance on the horizontal axis for a linear project like road and distance on the vertical axis for a vertical project like high-rise building. The activities are plotted as lines with constant but sometimes changing slopes. The slopes represent the activity rate of production-the amount of work completed per unit time. To create an LSM schedule, the scheduler determines the appropriate sequence of activities and the corresponding rates of production. Then the information is plotted. Modifications may be made by observing actual conditions and then modifying the appropriate activity characteristics like rates of production, start times, and/or finish times.

4 Scheduling Techniques for Road Construction Projects
Chrzanowski [2] applied both CPM and LSM for a roadway project and compared them with the actual project schedule. They concluded that Linear scheduling model (LSM) could be utilized in conjunction with CPM in such a way that LSM is used for repetitive tasks and CPM for discrete activities. Harris [3] developed a repetitive scheduling method (RSM) for the scheduling of repetitive projects. He clarified the difference between two commonly used productivity rates – Resource Production Rate (RPR) and Unit Production Rate (UPR). The former is the amount of work that can be accomplished by the crew in unit time whereas the latter is the number of repetitive units that can be completed by the crew in unit time. He defined controlling point and controlling sequence using RSM on a Line-of-balance (LOB) diagram. Hamerlink [4] developed a method to determine the controlling activity path in a linear schedule using LOB as the scheduling method which was considered one of the major shortcomings of LOB over CPM. He considered all the three types of activities that could be represented in a linear schedule, namely, linear, block and bar while describing his method for obtaining the controlling activity path. Hamerlink [5] later introduced the concept of float to the LOB method of scheduling based on his earlier work on controlling activity path. Mattila [6] described the limitations of CPM as the arbitrary division of repetitive activities from location to location, the inability to schedule the continuity of resources, the large number of activities necessary to represent a repetitive or linear project, activity rates of progress not indicated and not providing any information on where the work is currently being performed.
Various researchers suggested linear scheduling to offer solutions to those problems.

5 Line-of-balance Scheduling in Road Construction

Arditi [7] developed a LOB scheduling system for road construction. With the help of man-hours required and optimum crew size, a natural rhythm for each activity was estimated which was taken as the optimum rate of output. Based on his study, he concluded that LOB schedule could be more easily prepared than a network schedule and had more acceptances by the contractors and foremen than the network schedule but their first choice remained the bar charts. He also made some practical observations like the improvement in production rate due to learning effect was seen only in the beginning and negligible then on. Suhail [8] recognized two major shortcomings of CPM scheduling of repetitive construction projects – changes in sequence and lack of work continuity. He suggested that any changes in sequence could be easily made in LOB without changing job logic. On the second issue, the productivity rates of activities having float could be altered to maintain work continuity. Hence, he suggested an integrated CPM and LOB system focusing on resource leveling and utilization of float to maintain work continuity specifically for repetitive construction projects. Arditi [9] developed an expert system for highway construction projects scheduling named ROADPLANNER. At the core of the system was a database on equipment productivities and weather conditions. Productivity was measured using input content (complexity of work), and severe weather conditions. Productivity was measured using input and output where input was the work hours spent by crew and the output was the area completed. Since the late 1980’s, four LOB-based scheduling tools were created by the research team led by Professor Arditi of Illinois Institute of Technology. The first tool was named SYRUS (System for Repetitive Unit Scheduling) [15], the second one was called RUSS (Repetitive Unit Scheduling System) [16], the third one was named CHRISS (Computerized High Rise Integrated Scheduling System) [17], and the final one was called ALISS (Advanced Linear Scheduling System) [18].

Pointing out specific shortcomings of each of the earlier systems, Arditi [18] emphasized that in ALISS, all the shortcomings associated with LOB scheduling were removed. The ALISS system is made of five modules. The Input module gets all the information about the project and the activities (linear, non-linear and discrete). The constraints module handles resource, time and space constraints. A resource constrained activity can not start until the resources have been released by the preceding activity. A time constrained activity has to start immediately after the preceding activity is completed. Space constrained activities have to maintain the precedence relationships. The Milestones module makes sure that the schedule satisfies activity milestones and the required project completion date. The criticality module determines

emission on resource driven scheduling, schedule optimization and integration of repetitive and non repetitive scheduling. Perera [12] developed an integrated construction project cost information system using readily available software like MS Access for database management and MS Project as a scheduling tool which are well within the reach of small and medium organizations. Using the activity schedule and the bill of quantities, all kinds of costs were evaluated and fed into the respective systems like material costing, plant costing, man-hour costing etc. Poku [13] developed a system called PMS-GIS (Progress Monitoring System with GIS) for progress monitoring of projects. He used ArcViewGIS, Primavera project planner and AutoCAD in his system. The focus was to visually present the progress of work. The work progress could be visualized by inputting the progress data to the system at regular intervals. Choi [14] studied four highway construction projects and concluded that productivity of construction activities were greatly influenced by poor management, work content (complexity of work), and severe weather conditions. Productivity was measured using input and output where input was the work hours spent by crew and the output was the area completed. Since the late 1980’s, four LOB-based scheduling tools were created by the research team led by Professor Arditi of Illinois Institute of Technology. The first tool was named SYRUS (System for Repetitive Unit Scheduling) [15], the second one was called RUSS (Repetitive Unit Scheduling System) [16], the third one was named CHRISS (Computerized High Rise Integrated Scheduling System) [17], and the final one was called ALISS (Advanced Linear Scheduling System) [18].

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the critical activities and calculates the floats for each; and finally, the Cost module does the cash-flow analysis. ALISS is one of the biggest and the newest contributors in the generation of computationally efficient and effective LOB scheduling systems.

6 4D Technology in Planning and Scheduling of Road Construction
Shah [19] developed a 4D visualization model for earthwork operations. He also made an observation based on a survey that earthwork operations are mainly done on the basis of past experience and mass haul diagram is the predominant technique used in its planning. Using the cut/fill quantities and the productivity rates, the earthwork operation was scheduled. To achieve 4D visualization, a mathematical formula was used to compute the coordinate data of terrain surfaces on weekly basis to visualize the work progress in terms of the heights at cut and fill sections. Liapi [20] presented a 4D visualization model for construction scheduling integrated with traffic planning. 3D models of existing and proposed highway elements and the surrounding area were made and linked with the activities of the construction schedule. The model was implemented on a highway interchange project. Platt [21] conducted his study with the objective of finding the best application of 4D CAD for highway construction projects. The surface model of existing land conditions was generated and was overlaid by the interchange design including the horizontal alignment and the vertical profile. The construction schedule using Primavera was imported into the 4D CAD software named “Navisworks Jetstream V.5”, and linked to the CAD model. He observed that one of the limitations of 4D CAD was the manual linking of 3D CAD model to the project schedule which took a lot of time and effort and its automation would be a great help for future research and improvements.

7 Conclusion
Planning and scheduling of construction projects has been an exhaustively researched and studied area. A number of methods have been developed and implemented by various researchers over the years and continuous improvements are being made to the older ones. Different methods and techniques have been found suitable for different types of projects. Also, there is no consensus on the suitability a particular type of method for a particular type of project. With advancements in computer capabilities and information technology, the generation and presentation of construction plans and schedules has greatly improved. 4D technologies have added a new dimension to the way schedules are viewed and monitored. The animation of the construction process not only makes the plan more understandable to all but any logical errors can be caught at the planning stage itself rather than during the implementation. A number of systems have been developed and implemented for linear repetitive construction projects like road construction and organizations can choose among them based on their needs and ideologies.

References:
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