Planning and Scheduling Consideration and Constraints in Automated Construction Environment

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ABSTRACT

Project planning functions are to establish project activities, their logical relationships and interrelationships to each other, and the sequences in which they are to be accomplished. The process of assigning activities' duration and identifying the start and completion times of activities and project is considered as project scheduling. Project planning and scheduling is one of the most important pre-construction tasks determining the success or failure of the project in relation to time. In an automated construction environment employing automated equipment or machines to perform specific or major tasks, some conditions or constraints impacting activities' planning and scheduling are different from those of the conventional construction environment. Therefore, management needs to pay careful attention in determining the planning process and specific constraints set forth by automated equipment or machines. Otherwise, accurate pre-construction project schedule may not be obtained due to inaccurate planning assumptions.

1. INTRODUCTION

Prior to the start of a project construction, a project plan and schedule, determining the sequential order in which and when tasks or activites will be performed, should be developed. The project schedule must satisfy the project objective as within specified time. Critical Path Method (CPM) has been proven to be a successful technique for planning and scheduling of construction projects. Presently, it is used as a tool in the systematic schedule management of construction projects.

With the industrial revolution and the successful automated manufacturing system, the construction industry in developed countries has focused its attention in adopting automated construction equipment for specific activities. The use of automated equipment is aimed to reduce costs, increase capacity or production rate, and/or improve working conditions. Acheiving these goals requires automated equipment to operate under the greatest efficiency. Planning and scheduling of activities executed by automated equipment

requires careful considerations of on-site and off-site factors, limitations and constraints imposed on the equipment.

Planning and scheduling procedures of automated construction environment are partly different from those of conventional one. These differences are from the constraints and limitations that can be classified as technological, managerial, and external constraints. For example, The constraints on the limited number of automated equipment and machines, production rates, weather conditions, etc. can have a major impact on the sequences, inter-relationships, and duration of activities. These types of constraints may not be major criteria when the tasks are performed by conventional equipment or machines.

Typical limitations and negative aspects of newly adopted construction equipment may be loss of flexibility in sequencing work activities, vulnerability to downtime due to a composite of sophisticated mechanical and electrical machinery and controls, more maintenance, etc. Therefore, construction activities performed by automated equipment or machine must have the above mentioned constraints clearly defined as early as possible.

2. OBJECTIVES

The primary objectives of this paper are:

1. to identify the major factor in planning and scheduling of construction activities using automated equipment.
2. to explain the constraints (technological, managerial, and external) of using automated equipment that should be seriously considered during the planning and scheduling stage.

3. FOCUS OF THE PAPER

This paper is focused on the general practical principles of planning and scheduling of the construction equipment using Critical Path Method (CPM). Practical data and discussions are oriented to existing automated construction equipment, mainly tunnel-boring machines.

4. PLANNING AND SCHEDULING PROCEDURES

Increased production capacity and reduced total production costs are frequently used as a justification for applying advanced technology construction equipment. Frequently new equipment comes with its requirements and production data that management are not familiar with. Therefore, planning and scheduling of construction activities using automated equipment needs to look at the equipment requirements and production data more than the conventional equipment.

Applying Critical Path Method (CPM) for planning and scheduling of construction projects starts with identifying the list of activities by using Work Breakdown Structure

(WBS). Then, the activities' logical constraints or relationships and duration need to be defined in order to identify the work sequences and start and completion dates[1]. Activities' duration is normally assigned by an experienced engineer familiar with the operation or by using the historical equipment performance record. Figure 1 shows the conventioanl planning and scheduling process.

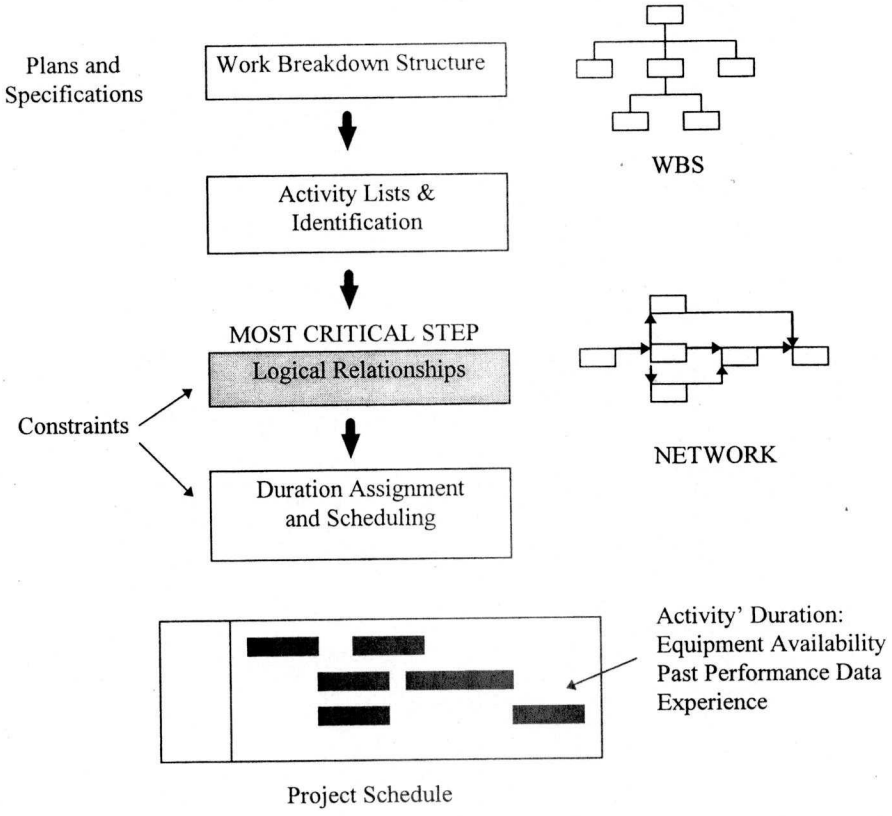

Figure 1. Conventional Activity Planning and Scheduling Process

The work duration is normally comprised of productive, supportive, and non-productive time. Basically, the duration of supportive time (scheduled maintenance, resetting machine, etc.) and non-productive time (unscheduled downtime, delays, etc.) is not well documented. However, for activities requiring conventional construction equipment, the work duration can be subjectively and realistically estimated based on the equipment availability, past performance data and experiences of engineers or operators. From all steps

listed in figure 1, defining logical relationships between activities is the most critical step regarding the commonly found mistakes that make the schedule unrealistic.

Planning and scheduling of activities using automated equipment requires planners to pay close attentions to activities' duration assignment due to several reasons. First, the automated equipment has not been employed in the organization before; then, experiences of engineers or operators related to supportive and non-productive time cannot be accurately estimated. Secondly, past performance data pertinent to the work natures may not be available. Finally, the availability of automated equipment may not be as widely as conventional one. The planning and scheduling process of activities using automated construction equipment is shown in figure 2. From all steps listed in figure 2, defining activities' duration should be the most critical step of overall process.

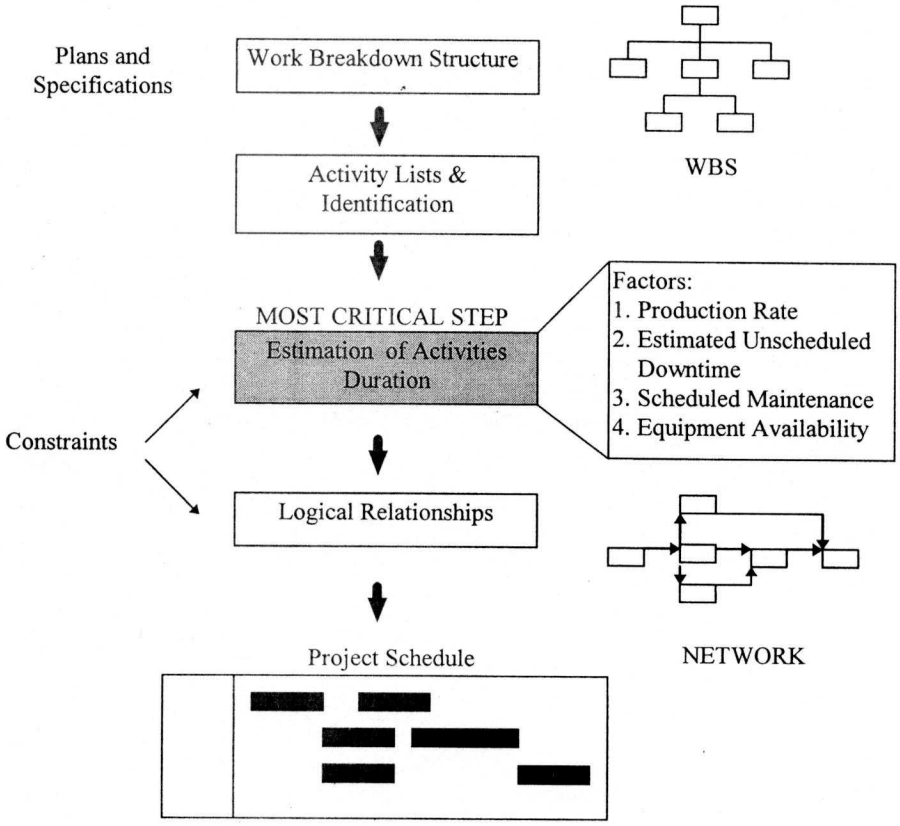

Figure 2. Planning and Scheduling Process of Automated Equipment Activities

5. CONSTRAINTS AND LIMITATIONS

For construction activities employing automated equipment or machines to perform specific tasks, an imposed condition or constraints regarding their availability and productivity should be seriously considered at the early stage. The constraints on the limited number of automated equipment and machines, productivity rates, weather conditions, etc. can have a major impact on the sequences, inter-relationships, and duration of activities. These types of constraints may not be major criteria when the tasks are performed by conventional equipment or machines. Therefore, construction activities performed by automated equipment or machine must have the above mentioned constraints clearly defined as early as possible. Three types of constraints imposing conditions affecting the start and completion date of activities are discussed in the context of planning and scheduling of automated construction equipment. They are technological, managerial, and external constraints.

The automated equipment to be discussed in this paper is related to tunel-boring machines. The tuneling technology or equipment can be considered as one of the most widely used automated equipment. Contractors have been trying to find ways to efficiently utilize this equipment. The discussion is based on the study of tunnel-boring machine for performed by the Construction Industry Research and Information Association (CIRIA) in 1988[2]. This study was focused on the performance of tunnel-boring machines in rock. For the 10 tunnels whose working time utilization was recorded, it was found that cutting time was only 30.0% of overall working time. The cutting time was low and restricted by many constraints to be discussed in later sections.

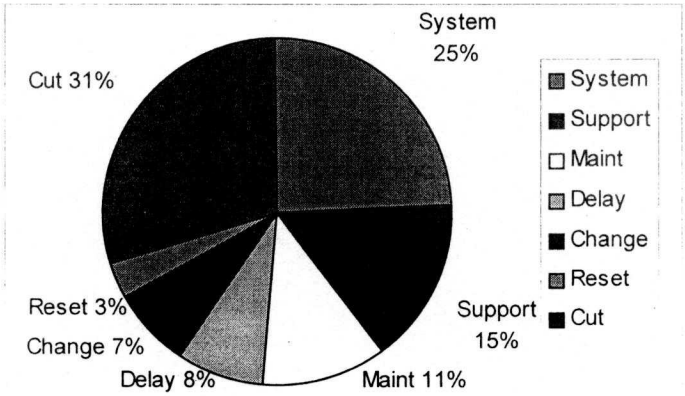

Figure 3. Utilization of Working Time for Tunnel-Boring Machine [2]

5.1 TECHNOLOGICAL CONSTRAINTS

This types of constraints is the first and the most obvious constraint to be defined. Technological constraints defines the logical relationship between activities which cannot be changed unless the technology is changed. The applications of automated equipment or machine can alter the activities' sequences due to the changes in work nature or construction methods.

The CIRIA study found that providing supports or installing the lining around the perimeter of a tunnel to prevent movements of the rock is the important activity to be accomplished before any advancement of the tunnel. The average time percentage for this unavoidable sequencing constraint alone is about 15.3 % of overall working time. Planning and scheduling of automated construction activities should account for this similar nature.

5.2 MANAGERIAL CONSTRAINTS

Managerial constraints normally related to resources such as materials, equipment, and crews. They occur when it is essential to reschedule activities because resources for certain operations cannot be made available as soon as they are needed, or management feels that activities can be better sequenced or delayed from earliest starting dates. For activities performed by automated equipment, management has to consider many constraints related to the nature of the equipment and equipment management principles. There are many management factors that influence planning and scheduling of construction activities, consequently impacting equipment productivity, production rates, or operating time. Those factors should be considered by management such as timing for equipment maintenance, inventory of parts, and security programs, etc.

Automated equipment should be maintained properly with appropriate scheduled maintenance program. However, for some specific automated equipment, scheduled maintenance may result in large proportion of scheduled downtime. Then, activity duration should account for this time when defining activity duration. For example, the CIRIA's study in 1988 found that scheduled maintenance of tunnel-boring machine accounted for 11.2 % of the overall working time. Even with this large percentage of the scheduled maintenance time, the downtime from the back-up system failure was found to be 24.5 % of the overall working time. This high percentage of downtime was mainly caused by unavailability of parts for the back-up system. Management must give careful considerations about the decision on inventory of spare parts because this could have high impact on the duration of overall operation. Those factors mentioned are considered as managerial constraints impacting schedule of activities applying automated construction equipment. Unlike technological constraints, this type of constraints can be altered or eliminated if management want to do so; however, cost and time impact will be the consequences.

5.3 EXTERNAL CONSTRAINTS

Typically, this constraints are environmental, safety or geological concerns. Some automated equipment or machines are sensitive to changing weather or subsurface conditions and causing noise or air pollution when operated. Then, there will be specific timetable for them to perform the tasks. Some of these constraints are naturally difficult to identify when a network is being developed, especially geological constraints.

For example, the CIRIA's study in 1988 found that delays in the advance rate of tunnel-boring machine were partly resulted from the variability of underground conditions and the flexibility or ability of the machine to deal with that variability was limited. This problem causing schedule delays is the typical external constraint for the excavation of tunnels.

6. SUMMARY

Construction automation has received a lot of attention from the construction industry in the last decade. Automated construction equipment is considered as a means to reduce costs, increase capacity, and improve working conditions. Limitations and constraints imposed on planning and scheduling of construction activities performed by automated equipment should be seriously considered during the pre-construction stage. Without this consideration, project schedule cannot be realistically or accurately forecasted. Three major constraints, namely technological, managerial, and external constraints, must be carefully indicated and incorporated during the identification of activities' relationship and duration.

Newly manufactured automated construction equipment normally has many limitations because they may be tested in the limited working conditions. Their performance could be impacted by managerial practices applied in different organizations. One of the most critical limitations is that the adequate historical performance record of automated construction equipment may not be available for accurate determination of project schedule.

7. REFERENCES

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