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Scheduling of Construction Projects by using Metaheuristic Method and by using Commercial Software: A Review

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Abstract—*In recent years, much thought and study has been devoted to the problems and techniques of scheduling large projects. With the growing number of such projects, the increase in the size of project management organizations, and the developing need to examine operations from a "systems approach," the problems of large project management have increased numerically and in complexity. Centralized scheduling of such projects is becoming more and more a necessity, and methods have been sought to make such a goal practical.*

Delays and cost overruns are evidently frequent problems in the construction industries of many developed and developing countries. The vast majority of research efforts in project scheduling concentrate on developing procedures to generate workable baseline schedules that minimize the project makespan in a deterministic environment. The absence of a valid resource-constrained critical path method (CPM) not only hampers the widespread use of mainstream project scheduling software in construction management practice, but also destabilizes the very foundation of any sophisticated, CPM- based time or cost analysis in construction scheduling research.

In construction scheduling, problems can arise when each activity can be started at different time points and the resources needed by the activity are limited. Moreover, activities have required conditions to be met, such as precedence relationships, resource demands, etc. In this paper, a critical approach was taken to review a range of literatures related to the scheduling of construction projects using commercial project management software Primavera P6 and by using a metaheuristic technique, i.e. Genetic Algorithms. The two approaches are proposed to find near optimal solution, and the review work also describes a comparison between the network theorem based software Primavera P6 and Genetic Algorithm approach to resource- constrained scheduling using a direct, time-based representation.

Keywords*: Scheduling, Genetic algorithms, Delays, Project management, Optimization technique.*

1. INTRODUCTION

Construction projects are usually characterized by high complexity. Several factors determine this feature: a great number of activities has to be performed in order to achieve project completion, a variety of resources, both material and human, are necessary to perform activities, and therefore great capital investments have to be managed [4].

In construction industry, planning and scheduling have a lot of importance as they help as a mean of monitoring progress to ensure the project is completed on time and within budget and this depends on the availability of resources. Unfortunately, most discussions of scheduling in the project management arena focus largely on timing issues without taking into account the link between resource availability and capability and the project schedule. Also based on the discussions with the experts involved in construction industry, it was observed that there is normally not much consideration of resources in scheduling and there is low level of implementation of resource constrained scheduling as compared to time-driven scheduling. Since the duration of each activity is dependent upon the availability of resources, the problem arise when work proceeds without taking into account how much the limited amount of labour, equipment and materials will impact the schedule. Therefore the problem of scheduling activities under resource and precedence restriction with the objective of minimizing the total project throughout duration or the objective function is very important to perform the work as planned. The need for the implementation of resource constrained scheduling in construction is necessary in order to complete the projects according to the schedule and within the time and available resources. The aim of this research is to compare the exact and metaheuristic method of resource constrained scheduling in construction industry.

2. PROJECT MANAGEMENT AND SCHEDULING

Projects are of all times. The ancient Egyptian pyramids and the Maya temples are often considered as the world's first large projects. The growing interest in the field of project management has resulted in many new theories, techniques and computer applications to support project managers in achieving their objectives. Project scheduling is the part of project management that involves the construction of a baseline schedule which specifies for each activity the precedence and resource feasible start times that will be used as a baseline for project execution. Such a schedule helps to visualize the project and is a starting point for both internal and external planning and communication. Careful project scheduling has been shown to be an important factor to improve the success rate of the project. This incites researchers to further develop new project scheduling methods.

3. THE RESOURCE- CONSTRAINED PROJECT SCHEDULING PROBLEM (RCPSP)

Although related and often tightly coupled, planning and scheduling are distinctly different activities. Planning is the construction of the project/process model and definition of constraints/objectives. Scheduling refers to the assignment of resources to activities (or activities to resources) at specific points in, or durations of, time. The definition of the problem is thus primarily a planning issue, whereas the execution of the plan is a scheduling issue. Yet planning and scheduling are coupled; the performance of the scheduling algorithm depends on the problem formulation, and the problem formulation may benefit from information obtained during scheduling. In general, a resource- constrained scheduling problem is defined as follows: A project consists of a set of interrelated activities. Each activity could be executed in more than one way, which can be represented using a continuous duration-resource function. Each activity could also be interrupted and/or overlapped. Resources are limited in quantity. Under these conditions, a solution which could find the optimal execution mode for each activity and properly assign the resources to the activities is to be researched to satisfy all the required constraints and produce the best time-cost combination.

4. CHARACTERISTICS OF THE GENERALIZED FORM

4.1 Tasks (Activities)

Tasks have measurable estimates of performance criteria such as duration, cost, and resource consumption. Any task require a single resource or a set of resources and the resource usage may vary over the duration of the task. The estimates of duration and cost may be dependent upon the resource(s) applied to (or used by) the task. The performance measures may be probabilistic or deterministic. A task may have multiple execution modes. Any task may be executed in more than one manner depending upon which resources are used to compete it. For example, if two people are assigned to a job it may be completed in half the time required were it done by a single person. Alternatively, a part might be manufactured using one of three different processes, depending on which machine tools are available.

A single task may be composed of multiple parts. The definition of the parts includes a specification for whether or not the task can be interrupted during the parts or only between parts. For example, a milling operation may require one setup time when performed on a milling machine or a different setup time when performed on a mill-turn machine. Setup can be aborted at any time, but once machine has begun, the task cannot be interrupted until the milling process is complete.

4.2 Resources

Resources may be renewable or non-renewable. Renewable resources are available each period without being depleted. Examples of renewable resources include labor and many types of equipment. Non-renewable resources are depleted as they are used. Examples of non-renewable resources include capital and raw materials.

Resources vary in capability, cost and other performance measures. For example, each vendor may have an associated likelihood of on-time delivery. One work team may be more efficient than another. Resource availability may vary. Resources may become unavailable due to unforeseen interruptions, failures or accidents. Resources may have additional constraints. Many resources include temporal restrictions that limit the periods of time when they can be used. For example, one team of machinists may be available only during the first shift. The constraints may be more complicated as well. Another team of machinists may be available during any shift at a higher labor rate and on the condition that they receive one shift off for every two shifts on.

4.3 Constraints and objectives

Constraints and objectives are defined during the formulation of the problem. Constraints define the feasibility of a schedule. Objectives define the optimality of a schedule. Whereas objectives should be satisfied, constraints must be satisfied. Both constraints and objectives may be task-based, resource-based, related to performance measures, or some combination of these. A feasible schedule satisfies all of the constraints. An optimal schedule not only satisfies all of the constraints, but also is at least as good as any other feasible schedule.

Goodness is defined by the objective measures. When modelling the problem it is often convenient to think of objectives and constraints as equivalent, but when solving the problem they must be treated differently. Project scheduling problems typically specify the minimization of project duration as the primary objective. However, most real problems are subject to multiple, often conflicting, objectives. Other objectives include minimization of cost, maximization of net present value of the project, resource utilization, resource efficiency, number of due dates that were met or not met, and minimization of work-in-progress.

4.4 Dynamic variations

From the time they are first defined, most plans and schedules are destined to change. A project plan is static only when the project has been completed. The schedule for a bridge construction is often modified within the first hour of a shift. Many construction schedules change because of uncertainties in arrival times or due to unexpected equipment failures. Many project plans require modification when initial estimates are found to be inaccurate or when unexpected delays confound resource availabilities. Both planning and scheduling systems must be able to adapt to changes.

5. PROJECT SCHEDULES

A schedule S is defined in project scheduling as a list S = (s_0, s_1,…..s_n) of intended start times $s_j \leq 0$ for all activities j€N. A Gantt chart (introduced by H. Gantt in 1910) provides a typical graphical schedule representation by drawing the activities on a time axis. A schedule is called feasible if the assigned activity start time respect the constraints imposed on the problem. In deterministic project scheduling, a feasible schedule is a sufficient representation of a solution. Figure 1. illustrates a minimum duration schedule.

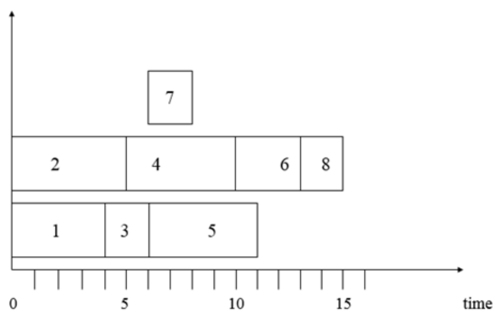

Fig. 1: A minimum duration schedule

6. PROJECT SCHEDULING TECHNIQUES

Many types of project scheduling techniques are used to manage a construction project, ranging from a simple bar chart to sophisticated network schedule and computer programs. Most commonly used techniques are classified into

1. Graphical displays
2. Networking techniques
3. Optimal networking techniques
4. Heuristic search techniques
5. Other methods
6. Commercial softwares

6.1 Genetic Algorithms (GA)

The GA is perhaps the most well-known of the modern heuristics with its origin inspired by population genetics. The GA method is also a local search procedure of the improvement type. That is, you again start out with a complete schedule and try to improve it. Unique to GA the local or neighbourhood search produces multiple new schedules simultaneously using pieces of them to build an ever better schedule. Much has been written using GA to solve scheduling optimization problems.

6.2 Primavera Enterprise (Primavera Systems, Inc.)

Primavera (http://www.primavera.com) was launched in 1983 by Primavera Systems Inc. and was acquired by Oracle Corporation in 2008. The recognized standard for high-performance project management Primavera P6 Professional Project Management, handles large-scale, highly sophisticated and multifaceted projects. Organize projects up to 100,000 activities with unlimited resources and unlimited number of target plans. The start-up activity window of P6 is shown in figure 2.

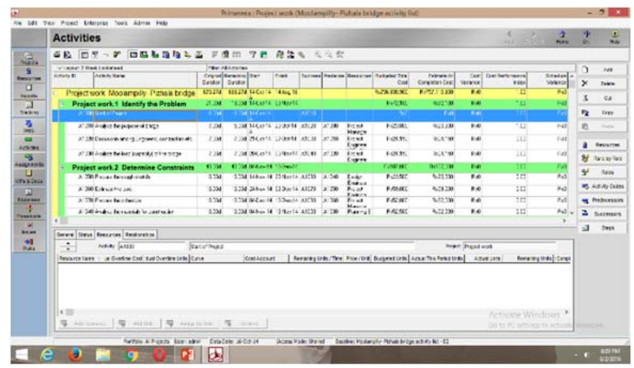

Fig. 2: P6 start-up window

Primavera software includes project management, product management, collaboration and control capabilities and integrates with other enterprise software such as Oracle and SAP's ERP systems. Oracle's Primavera P6 Professional Project Management gives today's project managers and schedulers the one they value most: control.

7. SCHEDULING USING PRIMAVERA P6

Primavera P6 helps from the moment when one begins to think about a project. Oracle Primavera® P6™ Project Management software (P6) is primary tool for reviewing and analysing contractor schedules. This is a very effective tool for construction scheduling; however, it is also very detailed and has many functions that a scheduler needs to understand before such reviews can be performed.

If the activities, their duration and precedence relationship has entered in Primavera P6, it will yield a Critical Path diagram for that schedule. Figure 3. shows the CPM diagram for a typical schedule from Primavera P6.

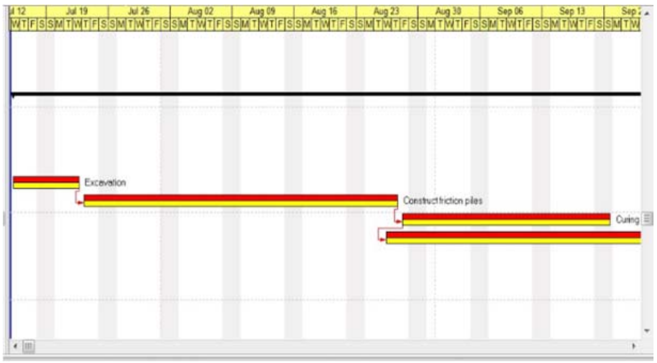

Fig. 3: CPM diagram of a typical project

7.1 Resource Scheduling in P6

Primavera Project Planner provides many, complex options for resource handling in order to accommodate various needs of users. Relatively important options to the current studies are:

1. Resource Option
2. Resource Calendar
3. Assigning resource
4. Resource Priority
5. Resource Levelling
6. Resource Smoothing
7. Resource Splitting
8. Resource Stretching
9. Resource Crunching Option

As time schedule is completed, it is necessary to assign resources. P6 calculates duration for each resource based on the amount entered. For example, if budget 20 hours of work at 4 hours per day, it will take 5 days to complete. When quantity and units per time are entered, and these are assigned to drive resources, P6 calculates resources duration automatically. This is the only case in which P6 calculates the resource duration.

Resource levelling and allocation are the options when there is scarcity of resources. The two choices of resource levelling are forward and backward. I there is not enough resource for an activity, the activity will be moved backward in the backward method, while the activity will be moved forward (delayed) in the forward method. In other words, an activity can start earlier than its early start time in the backward method, whereas an activity can be delayed over its late start time in the forward method.

8. SCHEDULING USING GENETIC ALGORITHMS

The proposed GA approach is based on the theory of the survival of the fittest and was originally developed by Holland. Applied to RCPSP the GA solution requires the initial generation of a random population of chromosome. Each chromosome contains a random permutation of the schedule activities. If the new solutions are better than those in the population, the individuals in the population are replaced by the new solutions. The Algorithm flow chart is illustrated in figure 4.

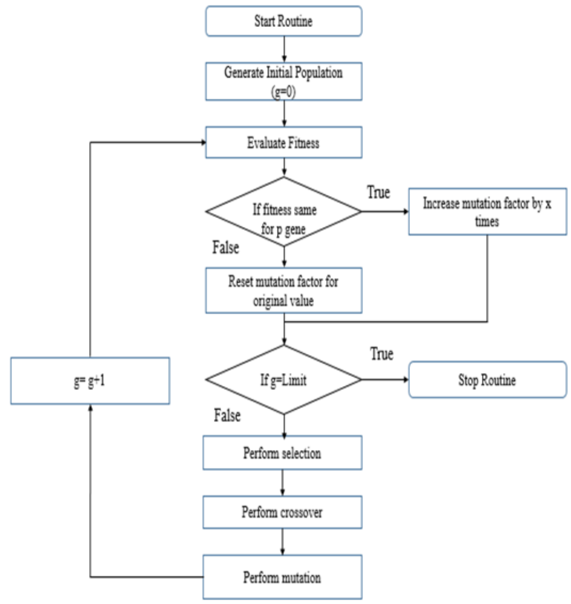

Fig. 4. Algorithm flow chart

8.1 Design of chromosomes

The chromosomes are designed on the basis of priority of execution of activities. The permutation encoding is used to represent the problem. When each gene in the chromosome represents an activity and its position represents the sequence of that activity to be scheduled (i.e. the order of an activity in the permutation of the activities means the priority the activity is scheduled to start. So the permutation-based representation actually indicates the sequence to start the activities). The number inside the cell indicates the priority of execution and number outside the cell indicates the activity ID. Figure 5. explains the chromosome structure.

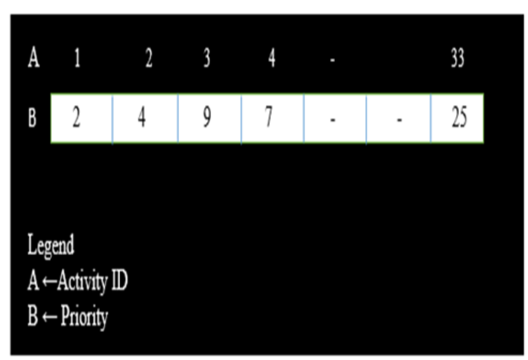

Fig. 5: Chromosome structure

8.2 Selection

The algorithm uses tournament selection (stochastic universal sampling). This is because they have less stochastic noise, or are fast, easy to implement and have a constant selection.

8.4 Crossover

The crossover method employed can be single point crossover or the double point crossover. Single point crossover is the simplest form: a single crossover position is chosen at random and the parts of two parents after the crossover position are exchanged to form two offspring. The idea is here, of course, to recombine building blocks (schemas) on different strings. Single point crossover assumes that short, low order schemas are the functional building blocks of strings, but one generally does not know in advance what ordering of bits will group functionally related bits together. Figure 6. explains single point cross over.

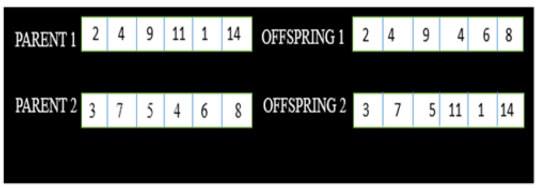

Fig. 6: Single point cross over.

8.5 Mutation

If the entire population has only one type of string then the crossover of two chromosomes does not produce any new ones. The mutation operation is used to escape from this scenario. The inverse mutation operator is used here, which generates new population by subtracting the priority given in the parent chromosome by the total number of activities.

8.6 Fitness

The fitness of the RCPSP is measured by the achieved duration of the schedule. The evaluation criterion in the current work is the makespan of the RCPSP problems. The lower the duration – the higher the fitness, therefore the fitness is equal to the duration of the schedule in days.

8.7 Termination

The termination of the entire process will be after the selection of the best or fittest solution. The number of generations that involve depends on whether an acceptable solution is reached or a set number of iterations are exceeded. After a while all the chromosomes and associated costs would become the same if it were not for mutations. At this point the algorithm should be stopped.

9. SUMMARY

Most of the literatures explained about the methods and commercial software's used for resource scheduling. But the work on comparison between a commercial software and metaheuristic method for resource constrained project scheduling problem (RCPSP) is found very rare in literature. Hence, on the basis of the literature gone through, here in this thesis making an attempt to compare the solutions from commercial software, i.e. Primavera P6 and metaheuristic method i.e. Genetic Algorithm.

This research, which deals with level of implementation of resource constrained scheduling using Primavera P6 and Genetic algorithms, was carried through the review of various literatures. The following are the main achievements from this research:

- Identification of the resource constrained scheduling features in commercial package that is, Primavera P6.
- Resource constrained project scheduling using Genetic algorithm was also analyzed.
- The results from two methods is analyzed for finding the optimal solution.
- From various literatures, it was found that for a particular problem Primavera P6 is efficient than genetic algorithms.

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