Project Scheduling and Cost Minimization with Multiple Availability Constrained Resources under Stochastic Conditions

Rui Moutinho, Department of Production and Systems Engineering, University of Minho, Guimarães, Portugal
Anabela Tereso, Department of Production and Systems Engineering, University of Minho, Guimarães, Portugal

ABSTRACT

The authors propose a mathematical model to minimize the project total cost where there are multiple resources constrained by maximum availability. They assume the resources as renewable and the activities can use any subset of resources requiring any quantity from a limited real interval. The stochastic nature is inferred by means of a stochastic work content defined per resource within an activity and following a known distribution and the total cost is the sum of the resource allocation cost with the tardiness cost or earliness bonus in case the project finishes after or before the due date, respectively. The model was computationally implemented relying upon an interchange of two global optimization metaheuristics – the electromagnetism-like mechanism and the evolutionary strategies. Two experiments were conducted testing the implementation to projects with single and multiple resources, and with or without maximum availability constraints. The set of collected results shows good behavior in general and provide a tool to further assist project manager decision making in the planning phase.

Keywords: Availability Constrained Resources, Global Optimization, Multimodal Activities, Multiple Resources, Project Scheduling, Renewable Resources

INTRODUCTION

Uncertainty is one challenge any project manager must cope in practice. Some random events are nearly impossible to predict, even by the most skilled and experienced project managers. Such events include, for example, weather related catastrophes. On the other hand, there are more

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subtle variations in a smaller level that can be anticipated to a certain degree by using estimations rather than strict values to activity durations. Furthermore, those estimations can change according to the allocated amount of resources and this, in turn, may be constrained by total availability.

In our proposal, we use stochastic work contents to describe the uncertainty associated to the use of each resource by each activity and we consider fully renewable resources constrained in total availability. The work content describes the relation between the resource allocated amount and the activity duration. In the deterministic case, the work content is a constant. For example, an activity with one resource having work content of 10 men-days would take 10 days using just 1 man but with 5 men the same activity would reduce its timespan to just 2 days. The work content concept also implies the multimodal aspect of activities. When considering the stochastic case, the work content is a random variable, thus there are, potentially, innumerable execution scenarios depending on the nature of the distribution used and the permissible allocations. Therefore, this approach on uncertainty achieves a wider coverage of the problem and the results from the optimization will provide more control (of the uncertainty) to the project manager.

LITERATURE REVIEW

The study of the Resource-Constrained Project Scheduling Problem (RCPSP) deals with project activity scheduling regarding both precedence relationships and resource constraints. The RCPSP is a vast subject but usually the objective is to minimize the project total cost. Furthermore, when the activity durations are sensitive to the allocated resource amount, then the minimum total execution time is also part of the objective. The literature is rich with several methods solving the many aspects of the RCPSP. Next, we will summarize the most relevant to our research. We refer to Demeulemeester and Herroelen (2002) for a comprehensive overview of this subject.

The scheduling of activities is the process where the starting times for each one of them is determined while respecting any constraints, primarily the activity precedences and the resource constraints. The more commonly precedence type is the finish-to-start (FS) relationship: an activity $a$ precedes $b$, denoted by $a \prec b$, when $b$ must only start after $a$ is finished. The direct application of these relationships among project activities translates the scheduling process as the determination of the earliest possible time when each activity can start. The simplest method is the serial scheduling oriented by a priority list. Priority lists are any ordering of activities respecting the precedencies. Often, different lists result in different schedules due to the effect of resource constraints. Also, each schedule would hold specific total time. Thus, it is crucial to search for the best schedule.

In the classical literature, we find the branch & bound methods (Sprecher, Hartmann, & Drexl, 1994, 1997). These aim to avoid the examination of all the possible schedules by narrowing the enumeration (of cases) through well-defined lower and upper bounds determined from the properties of the problem. Together with dominance rules, the method crawls the tree of enumeration deciding, at each branching point, the best path as returned by the application of the dominance rules. The branch & bound methods are most suitable to the determinist RCPSP and provide the optimal solution.

With the stochastic RCPSP, the durations of the activities are no longer deterministically known. This increases the complexity of the problem. Still, there has been research on implementations with branch & bound to these problems (Stork, 2000). Others use heuristic strategies which rely on greater computational power to approach the problems through convergence over a sequence of iterations approximating the optimal solution (Boctor, 1993, 1996; Tsai & Gemmill,
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