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The impact of cyclic versus non-cyclic scheduling on the project staffing cost

Broos Maenhout · Mario Vanhoucke

1 Introduction

In project scheduling assumptions are made with respect to the availability of resources. In case resources are scarce and/or costly, the scheduling of resources becomes increasingly important. Despite the fact that projects are typically very labour intensive, little attention in the literature is given to the underlying personnel scheduling problem. In the project staffing problem under study we integrate the personnel scheduling problem and the project planning problem. This encompasses that we have to decide on the project schedule that leads to the optimal staffing plan by simultaneously determining the starting times of the activities, the project duration and the best mix of resources in terms of cost. In order to come up with a staffing plan, a baseline schedule is composed for the regular and temporary crew members that takes into account all the scheduling policies and practices.
In this paper we give insight in the parameters of the integrated staffing problem with personnel calendar constraints. More precisely, we investigate the conditions (i.e. problem characteristics and parameter settings) under which a personnel schedule can be constructed in a cyclical or non-cyclical way. In this way, the project planner will learn about the impact of specific problem characteristics and policies on the integrated project staffing outcome.

Broos Maenhout
Faculty of Economics and Business Administration, Ghent University, Belgium
E-mail: Broos.Maenhout@Ugent.be

Mario Vanhoucke
Faculty of Economics and Business Administration, Ghent University, Belgium
Vlerick Business School, Belgium
University College London, United Kingdom
E-mail: Mario.Vanhoucke@Ugent.be

2 Problem description

Project planning and personnel scheduling are two different problems that are separately studied in the literature in various guises and formulations ([6]; [10]. The relevant literature on the integrated project staffing and personnel scheduling problem is on the other hand limited. The problem was introduced by [1] and [2]. In that papers the authors proposed a mathematical problem formulation for composing a cyclic personnel schedule. The objective is to minimize the project makespan and the personnel costs. Maenhout and Vanhoucke [7] extended their problem definition by incorporating temporary personnel members and allowing the regular workers to work overtime. In that paper, a dedicated solution procedure is used to come up with non-cyclical personnel schedules. Other papers on project staffing do not construct a personnel schedule explicitly. [3] discuss an exact optimization method for a multi-skill project scheduling problem. The problem is then to schedule the project activities given the personnel schedule such that the scheduled personnel is able to carry out the different project activities. [5] presents a model for the simultaneous scheduling and staffing of multiple projects with multiple resources. Several other related papers involve the audit scheduling problem where tasks have to be assigned to a set of workers that have an overall capacity for the entire planning horizon (cfr. [4] for an overview).

In this paper, we study a strategic budgeting problem that decides on the project staffing plan and corresponding personnel schedule for a single project. The activity and project scheduling characteristics are defined as follows. There is a project network that consists of a set of activities and a set of direct precedence relations. The pre-emption of activities is not allowed. Each activity has a deterministic duration and requires a number of resource units per time unit. We assume that there is a prescribed maximum project duration. A project schedule is said to be feasible if it is non-preemptive and if the project duration, precedence and resource constraints are satisfied. The activities are executed by different renewable personnel resource types, i.e. regular personnel time units, overtime units and temporal personnel time units. The availability of these resources, and hence, the resource constraints for each time unit of the project horizon are determined in the personnel scheduling step. The personnel scheduling problem is a manpower day-off scheduling problem where the total number of regular crew members, the budget for overtime and temporary help are determined. All personnel members are indistinguishable, as they all possess the same skills to carry out the activities. The schedule of the regular crew members can be conceived *cyclically*, where the same periodic pattern of days on and days off is repeated for each crew member (e.g. a (5,2) pattern that stipulates that the personnel has to work five days followed by two days off)or *non-cyclically*, where an 'ad hoc' schedule is constructed for each crew member and each period. The objective of this strategic budgeting problem is to minimize the overall staffing cost and activity execution cost.

3 Computational experiments

In this research we investigate the effect of the problem characteristics on the staffing budget and the computational performance. The computational experiments are performed using the branch-and-price procedure of [7]. We did our experiments on a randomly generated dataset under a controlled design consisting up to 30 activities. Based on these project instances, we determined the optimal staffing budget for each project duration between the critical path length and the project deadline. The critical path length averages 30 days and in the optimal crew rosters there are 16 regular workers on the average.

We explore the impact of different project and personnel staffing characteristics on the staffing budget and on the possibility to compose a cyclical and/or non-cyclical personnel schedule. More precisely, for the activity and project characteristics we analyse the impact of the serial and parallel complexity indicator and the activity distribution indicator of [8,9], the impact of release and due times and the impact of the resource profile of the activities. Last, we examine the non-linear relationship of the staffing cost as a function of the project duration. The number of regular personnel members shows an inverse relationship with the planning period, i.e. as the planning period is increased, the number of regular personnel members decreases. On the other hand, the required CPU time shows an increasing exponential behaviour when the planning period is extended and the degree of freedom for scheduling the activities increases.

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