A Flexible Model and a Hybrid Exact Method for Integrated Employee Timetabling and Production Scheduling

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Abstract. We propose a flexible model and several integer linear programming and constraint programming formulations for integrated employee timetabling and production scheduling problems. A hybrid constraint and linear programming exact method is designed to solve a basic integrated employee timetabling and job-shop scheduling problem for lexicographic minimization of makespan and labor costs. Preliminary computational experiments show the potential of hybrid methods.

1 Introduction

In production systems, the decisions related to scheduling jobs on the machines and the decisions related to employee timetabling are often made in a sequential process. The objective of job scheduling is to minimize the production costs whereas the objective of employee timetabling is to maximize employee satisfaction (or to minimize labor costs). Either the employee timetabling is first established and then the scheduling of jobs must take employee availability constraints into account or the scheduling of jobs is done first and the employees must then adapt to cover the machine loads. It is well known that optimizing efficiently an integrated process would both improve production costs and employee satisfaction. However, the resulting problem has generally been considered as too complex to be used in practical situations. Some attempts have been made [1,3,7,9,10,11,21] but mostly considering an oversimplified version of the employee timetabling problem. Nevertheless the integration of task scheduling and employee timetabling has been successfully developed in complex transportation systems [6,8,13,17,19,22,23]. In this paper we propose a model of integrated production and employee scheduling that takes account of the following possible specific characteristics of the production context:

A) An employee that has started a task may be replaced at any moment by another employee (of the same skill) with no notable effect nor interruption of the processed task.

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B) An employee is not necessarily needed during all the processing time of a task but only at some time periods that can occur before, during and after the processed task (setups, removals, transportation).
C) Because of the automated production process, or the nature of the tasks performed by the employee (e.g. supervision), an employee may perform several tasks simultaneously during a shift.
D) The production process can be quasi-continuous (on a 24-hour basis) whereas the employee timetabling has to be discretized in periods (on an 8-hour basis for instance).
E) The duration of a task may change depending on the number or on the skill of the assigned workers.

In Section 2, we review the related work dealing with the integration of task and employee scheduling and we give the position of the considered problem among the various production scheduling and employee timetabling problems. In Section 3, we propose different ILP formulations of the considered problem. A constraint programming formulation is proposed in Section 4. In Section 5, we propose a hybrid framework to solve the lexicographic minimization of makespan and labor costs. In Section 6, we provide the results of a preliminary computational experiment carried out on a set of employee timetabling and job-shop scheduling instances. Concluding remarks are drawn in Section 7.

2 Literature Review and Position of the Considered Problem

We review some of the integrated vehicle and crew scheduling methods in Section 2.1 and the previous work on integrated production scheduling and employee timetabling in Section 2.2. We give the position of the considered problem in Section 2.3.

2.1 Vehicle and Crew Scheduling

Integrated vehicle and crew scheduling is an active research area in transportation systems, see [6,8,13,17,19,22,23,28] among others.

We focus hereafter on some recent papers presenting different models and solution methods. Cordeau et al. [8] propose a Benders decomposition scheme to solve aircraft routing and crew scheduling problems. They use a set partitioning formulation for both the aircraft routing and the crew scheduling. In the first scheme, the primal subproblem involves only crew scheduling variables and the master problem involves only aircraft routing variables. Both the primal subproblem and master problem relaxation are solved by column generation. Integer solutions are found by a three-phase method, adding progressively the integrity constraints. More recently, Mercier et al. [23] have improved the robustness of the proposed model. Their method reverses the Benders decomposition proposed in [8] by considering the crew scheduling problem as the master problem.