An improved equity criterion formulation for Multi-Activity Tour Scheduling problems

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1 Introduction

The Multi-Activity Tour Scheduling problem is a personnel scheduling problem consisting of constructing feasible shift schedules for company staff, in order to satisfy workload demands. According to the typology of Bergh et al. [1], it is categorized as tour scheduling, beside the shift scheduling and days-off scheduling problems.

Equity is one of the most important criteria for evaluating solutions of resource scheduling problems. It aims at seeking the most balanced solution in the terms of employee's working time. In other words, a planning is called equal if the difference of working time of its resources is minimal. Many studies in the literature have included the equity criterion into their models [2, 3, 4]. Most of them only focus on minimizing the difference between the lowest and the highest resource's gap [3, 4]. In many cases, this formulation cannot ensure the equity of the employees whose working time is between the lowest and the highest.

This paper proposes a new mathematical formulation to optimize the equity of plannings. Instead of shrinking the gap between those who works the most and the least, the proposed formulation minimizes the absolute gap between employee's real working time and their mean working time. In other words, the new method allows finding a solution where the real working time of the resources is not too far from the average.

The experimental results show that the proposed formulation outperformes the benchmark formulation and offers more balanced solutions.

2 Model formulation

In [3], the equity model consists of minimizing the difference between the highest and the lowest employee's working time. It can be modeled as the following mixed integer linear programming model :

$$Minimize: \quad T^{Max} - T^{Min} \tag{1}$$

$$\forall i \in R: \quad T^{Min} \leq \sum_{\substack{a \in A \\ j \in J}} x_{ija} \leq T^{Max} \tag{2}$$

Where the time horizon is devided into a set J of identical time slots, R is the set of resources, and A is the set of activities to be planned. x_{ija} is the binary decision variable indicating whether the employee i performs the activity a on slot j. T^{Min} and T^{Max} are respectively the lowest and highest working time of resources. The constraint (2) represents the relation between T^{Min}, T^{Max} and x_{ija}.

In this work, we propose a new equity formulation which consists to minimize the mean absolute gap between employee's real working time and the average working time. The formulation is as follows :

$$Minimize: \quad \bar{\Delta} = \frac{1}{n} \times \sum_{i \in R} |t_i - \bar{t}| \tag{3}$$

$$\forall i \in R: \quad t_i = \sum_{\substack{a \in A \\ j \in J}} x_{ija} \tag{4}$$

$$\bar{t} = \frac{1}{n} \times \sum_{i \in R} t_i \tag{5}$$

Where $\bar{\Delta}$ is the mean absolute gap between employee's working time (t_i) and the mean working time ($\bar{t}$). The objective function is represented in (3). In the linear programming model, the constraint (3) was linearized by using minimax constraints. The calculation of each resource's working time and the average working time are shown in (4) and (5).

To test the efficiency of the proposed formulation, the two formulations are respectively included into a Multi-Activity Tour Scheduling model [1] where multiple activities must be assigned to multiple employees so that the satisfaction of the given workload demands is maximized. The equity is considered as a secondary objective of the problem. Which mean for two given solutions, if their workload satisfactions are the same, then the solution with better workload sharing equity will be the better one.

3 Experiments and conclusions

To show the efficiency of the new equity formulation, several experiments are done on industrial instances. The benchmark equity formulation is that of [3] represented in Section 2. The proposed model and the benchmark model were both resolved with Cplex 20.1.

The experiment results shown that the newly proposed formulation could offer better solutions in the terms of plan balancing in most of the cases. Especially when a resource has a low availability in their timetable, then they can only work in a few slots. As a consequence, the objective value of the benchmark equity is very high, and the workload sharing of other resources is also not optimal. The proposed formulation, in the other hand, considers the working time of every resource in its objective function, so even when a resource performance is low, the others still get a balanced planning. However, the test results also shown that the proposed formulation, in general, had a lower performance in computational time compared to the benchmark formulation.

As a perspective for the futur works, the proposed formulation can be applied on heuristic methods to evaluate the equity of Multi-Activity Tour Scheduling problems.

Références

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