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Modeling and Solving a Real-Life Multi-Skill Shift Design Problem

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1 Introduction

Shift design is an important phase within the workforce management process (see, e.g., [2]). According to labor regulations, in all industrial sectors, shifts must include breaks for employees for both resting and eating. Therefore, breaks must be taken into account when designing shifts, in order to be able to meet precisely the staffing requirements and thus ensure the desired service level. For this reason, we address the *shift and break* design problem, rather than shift design only.

In this work, we propose a novel multi-skill formulation of the problem arising from a few practical cases. In addition, we propose a new search method based on Simulated Annealing (SA), that, differently from previous approaches (see [3]), solves the overall problem as a single-stage procedure. The core of the method is a composite neighborhood that includes at the same time changes in the staffing of shifts, the shape of the shifts, and the position of the breaks.

The experimentation, which is still on going, makes use of statistically-principled techniques for the tuning of the numerous control knobs. Indeed, they include both the standard parameters of SA and the distributions for the selection of the candidate moves out of the composite neighborhood.

2 Problem formulation

The problem formulation includes the following main entities:

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Planning Granularity: The length of the indivisible step for the planning (typically 10' or 15'), used to divide the planning period into discrete *timeslots*.

Planning Horizon: Number of days of planning (typically 7 or 14). The schedule is assumed cyclic, so that the shifts that cross the midnight of the last day contribute to fulfill the requirements of the morning of the first day.

Requirements: The requirements specify for each skill, for each timeslot of each day of the planning horizon, the number of required workers. This number is not strict, so that overstaffing and understaffing is allowed, but penalized in the objective function.

Shift types: Each shift belongs to a shift type, which sets several constraints on the shape of the shift:
- Minimum and maximum length
- Minimum and maximum start time
- Granularity of the shift length (a multiple of the Planning Granularity)
- Break presence (Boolean-valued)

For shift types with break, the following additional data is included:
- Break length
- Minimum distance of the break from the beginning of the shift
- Minimum distance of the break from the end of the shift
- Minimum start time of the break
- Maximum end time of the break

In our setting, we consider only the break for the meals (that normally last 1 hour), therefore there is at most one break for each shift. Shorter breaks for resting are not planned, but rather assumed to be taken deliberately by the operator according to the current situation.

The problem consists in selecting a set of shifts (belonging to the given types), and the corresponding staffing level for each skill, so as to minimize the cost of the following objectives:

1. understaffing and overstaffing for each timeslot;
2. number of different shifts;
3. average length of shifts.

For the third objective, for each skill we average the length of the shifts (multiplied by the number of operators) and we penalize the discrepancy with respect to a given range (see [4] for the details).

Our current problem is an extension of the shift design problem solved in [4] and [2]. In the current formulation employees can have different qualifications and the workforce requirements for each skill should be fulfilled. Additionally, the scheduling of lunch break has not been considered in [2, 4].

The skills of employees have been considered in shift scheduling by several researchers. Bhulai *et al.* [1] for example investigate scheduling of shifts in multi-skill call centers by an approach that is based on a heuristic method and an integer programming model. Quimper and Rousseau [5] investigate modeling of the regulations for the multiple activity shift scheduling problem by using regular and context-free languages and solved the overall problem with Large Neighborhood Search. Generation of large number of breaks per shifts has been also recently considered in the literature. We refer the reader to [3] for a review of previous work on this problem.

3 Search method

We propose a simulated annealing approach that uses a neighborhood relation that extends and adapts to the case with breaks the one proposed in [2] for simple shift design. In details, we consider the union of the following basic neighborhoods:

1. Shrink or enlarge a shift by one timeslot.
2. Add, remove, or transfer to another shift a worker from a shift.
3. Move the break forward or backward by one timeslot.

For neighborhoods 1 and 3, the move can be selected only if it lead to a shift that is still compliant with its given type.

4 Current and future work

The current work involves the collection of a set of real case instances, and an experimentation on these instances, with the following objectives:

- Define the suitable weights of the objectives in order to obtain the results that better fit with costumers' needs.
- Set the parameters to their best values (with the given statistical confidence) of the search method to obtain good results of the available instances and robust performances for future unforeseen instances.

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