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The Impact of Reserve Duties on Personnel Roster Robustness: An Empirical Investigation

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1 Introduction

Robustness in personnel scheduling is an important aspect in organisations for a variety of reasons, among which service level objectives, cost minimisation [6] and an increasing focus on satisfying individual employee preferences [2]. First, every organisation wants to sustain a certain *service level* towards its customers. This service level objective requires organisational flexibility to deal with unexpected events, which can be caused by uncertainty of capacity, demand and arrival [3]. Unexpected events that require roster changes are called disruptions, with which organisations can cope through a variety of policies, including reserve duty conversion, overtime, assignment of employees with a day off and acceptance that customer demand cannot be fully met [10]. Reserve duty conversion is the conversion of a reserve duty into a working duty. Second, *personnel costs* represent a large portion of the operating costs of an organisation and even a small percentage-decrease can result in a significant

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cost reduction [3]. However, disruptions can cause important deviations between the planned and actual costs of the personnel roster. Planned costs are the estimated costs when the personnel roster is composed, while the actual costs are the costs incurred during the execution of the roster. If we make abstraction of uncertainty and variability during the construction of the personnel roster, the planned costs are minimal but this may lead to significantly higher actual costs.
Third, the adaptations to the original personnel roster, which are required by disruptions in order to restore feasibility, potentially lead to a lower *personnel satisfaction*. This objective is an important objective in the personnel scheduling literature [2, 11, 6] and should therefore be taken into account.
Hence, it is important for organisations to consider uncertainty, which helps them to construct rosters that are more robust. These rosters enable organisations to better achieve their desired service level objectives, cost objectives and employee satisfaction objectives.
In this paper, we evaluate the impact of reserve duties on the robustness of personnel rosters through discrete-event simulation and aim to derive insight into how reserve duties help organisations construct robust rosters.

2 Problem Definition

Personnel scheduling consists of three phases [9]: the strategic, tactical and operational phase. The strategic phase focuses on the long term, during which the personnel mix is determined through hiring, firing and training. The decisions made during this phase serve as input to the tactical phase. This medium-term phase encompasses the construction of a personnel roster for a mid-term period, which, in turn, serves as input to the operational phase. In this phase allocations are made for the next 24-hour period.
Since robustness has both a proactive and a reactive component [8], we examine the relationship between the tactical and operational phase. Thus, the goal is to construct a tactical roster that can absorb disruptions during the operational phase. Nevertheless, a roster that fully absorbs all disruptions is costly, which is why an efficient reactive mechanism is crucial to overcome disruptions with as few changes to the original roster as possible. In order to achieve this, we focus on the assignment of reserve duties during the tactical phase and the conversion of these reserve duties during the operational phase.

2.1 Tactical phase

In the tactical phase, we assume that all input is known and deterministic. Given the estimated daily shift requirements, we create individual personnel schedules, which consist of a collection of 3 possible assignments: a working duty, a reserve duty and a day off.
In order to obtain general results, this paper investigates a general personnel

scheduling problem. Therefore, the personnel information, objectives and constraints are all general and common in literature [4]. Our tactical model can be classified as $ASB\ N|RV\ 3|LRG$ [5].

2.2 Operational phase

In the operational phase, the allocations for the next 24 hours are performed. Due to uncertainty, these allocations may differ from the original assignments made in the tactical roster. Since our focus is to study the impact of reserve duties on the robustness of personnel rosters, we only explore the conversion of reserve duties into working duties to adhere to the original roster while trying to maintain the service level at minimal cost and minimal preference violations.

3 Methodology

Our research methodology is composed out of three different steps, which are explained below. Figure 1 gives an overview of this methodology.

3.1 Tactical phase: Construction of the optimal personnel roster with reserve duty assignments

The tactical roster is constructed using a branch-and-price algorithm. We test instances with a planning period of at least 7 and at most 28 days. The number of employees varies but is limited to 20.
The set of constraints that we consider can be classified into coverage constraints and time-related constraints [4]. Both these constraints include constraints for working duties and reserve duties.
The objectives used are related to the minimisation of assignment costs, preference violations, shortages and surpluses in working and reserve duties.

3.2 Operational phase: Simulation and adjustment of the personnel roster

In the operational phase, we use a 24-hour rolling horizon framework [1] that consists of two iterative steps: simulation and adjustment. During the simulation step, the uncertainty of demand and capacity are simulated, potentially causing understaffing and overstaffing. In the adjustment step, we evaluate if changes are necessary and possible through reserve duty conversion. The decisions for the next 8 hours are executed and we proceed 8 hours to perform the same steps for the following 24 hours. This process is repeated until the last 8 hours of the tactical roster are simulated and adjusted.

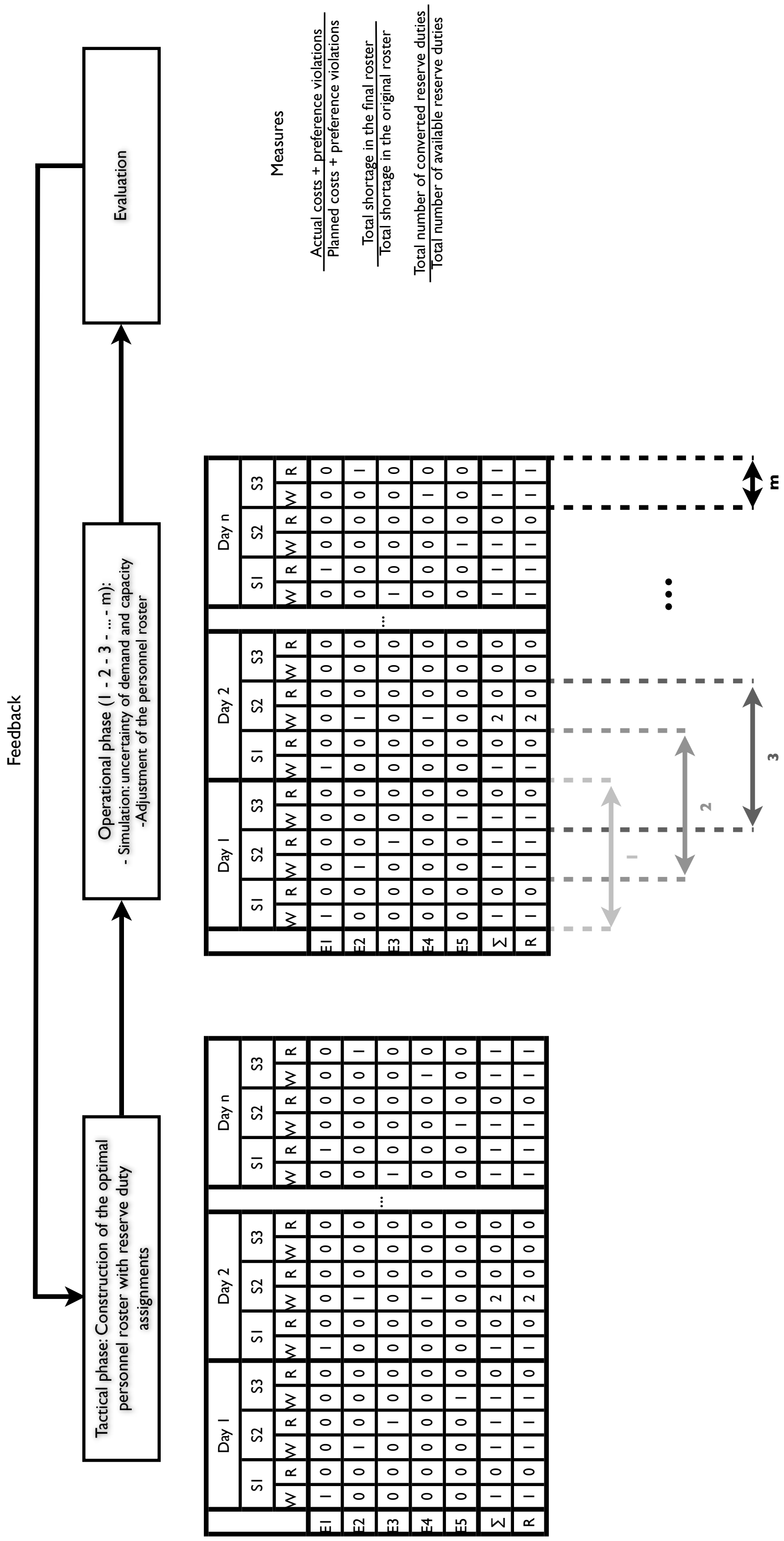

Fig. 1 Methodology

3.3 Evaluation and feedback

A first important measure for robustness is based on the planned/actual costs and preference violations.

$$RM_1 = \frac{Actual\ costs\ +\ preference\ violations}{Planned\ costs\ +\ preference\ violations} \tag{1}$$

A second important measure is the service level the organisation can offer to its customers and is based on the solution quality evaluation in [7]. Therefore, we compare the shortages in the original roster to the shortages in the final roster.

$$RM_2 = \frac{Total\ shortage\ in\ the\ final\ roster}{Total\ shortage\ in\ the\ original\ roster} \tag{2}$$

A third measure is related to the conversion of reserve duties into working duties at the time of execution.

$$RM_3 = \frac{Total\ number\ of\ converted\ reserve\ duties}{Total\ number\ of\ available\ reserve\ duties} \tag{3}$$

These measures indicate the robustness of our original roster and we can determine them for each day or even each shift. Furthermore, it is possible to split the third measure up per employee. This indicates to what extent an employee is efficiently used. This information is then used to change the objective function coefficients and the constraint parameter values of the related reserve variables and reserve constraints in the tactical phase, after which the process is repeated.

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