1 Introduction

Human resources are one of the main causes for schedule disruptions in all kinds of companies and organizations. In the health sector, schedule disruptions caused by unplanned personnel absences have a dramatic effect on the budget for workforce staffing. In total 4% of the total resources spent on staffing are lost to schedule disruptions [1]. Since uncertainty is considerable in healthcare applications and these disruptions cannot be eliminated, decision support systems should be developed that adequately react to unexpected events or that workforce schedules are improved to be more responsive to disruptions. The adopted personnel policies and practices are important determinants for the motivation and work quality of employees [2]. Hence, in this context, constructing an appropriate nurse roster and/or being responsive to changes is essential for the delivery of care to patients.

2 Problem Description

Basically there are two different approaches to cope with disruptions in the personnel schedule such that the schedule remains valid in accordance with the schedule requirements (e.g. industry regulations, local laws), i.e. a reactive and a proactive scheduling approach. In reactive scheduling, a roster is revised and re-optimized after unexpected events have occurred. Hence, the scheduler waits for a disruption that renders the current optimal schedule invalid (i.e., tasks cannot be operated below a minimum number of required staff) and then applies a re-rostering method to rebuild the schedule. Often
times, the goal of re-rostering is to rebuild a new optimal schedule while minimizing the number of deviations to the original schedule. Applying traditional rostering methods produce new optimal schedules but often result in schedules that deviate considerably from the current schedules, which may not be very well accepted by the workforce.

In the proactive scheduling approach, uncertainty in the scheduling environment is tackled by constructing a predictive schedule that accounts for statistical distributions to deal with uncertainty. The consideration of uncertainty information ahead of time is used to make the predictive schedule more robust. The degree to which schedules are made insensitive to disruptions can vary and different approaches can be adopted. However, a proactive technique will always require a reactive component to deal with schedule disruptions that cannot be absorbed by the baseline schedule. The number of interventions of the reactive component is typically inversely proportional to the robustness of the predictive baseline schedule.

Due to the importance of reactive scheduling in personnel rostering, we propose an optimization tool for the nurse re-rostering problem in which the current roster must be reconstructed with as few changes as possible. The scheduler must reassign other employees to cover the shift, while continuing to meet current demand and staffing requirements and time-related constraints guaranteeing the roster quality of the single personnel members.

3 Solution Procedure

In the literature, many successful exact and heuristic procedures were developed for the traditional nurse rostering problem that generates a workable baseline schedule, assuming complete information and a static and deterministic environment. An extensive overview of personnel shift scheduling problems can be found in [3] and [4] and for the nurse scheduling problem specifically in [5] and [6]. In contrast to the nurse rostering problem, the nurse re-rostering problem has received limited attention in the staff scheduling literature ([7], [8], [9], [10], [11]).

We focus on the application of established nurse rostering techniques to re-rostering problems and adapt these to meet the peculiarities (additional objectives and constraints) of re-rostering. The personnel scheduling optimization methods found in the literature provide excellent solutions to the nurse rostering problem. However, as uncertainty and absenteeism are inherent when dealing with personnel, these roster solutions may no longer be valid at certain point. We discuss how we deal with nurse re-rostering from an algorithmic point-of-view. We developed an exact branch-and-price procedure and a genetic algorithm, both incorporating problem-specific information concerning the nurse re-rostering problem. The one or the other method is applied to solve nurse re-rostering problem instances depending on the problem characteristics (objectives, constraints, problem size) and possible phase transitions in problem complexity.

4 Experimental Analysis

We provide computational and managerial insights into the nurse re-rostering problem. To provide a realistic environment to test our procedure, we obtained information on a real-life problem setting in a Belgian hospital about the structural organization of the
personnel scheduling process and data related to the required shift duties, staff mix, the nurse preferences, the nurse competencies, the shift scheduling policies and practices, nurse rosters, etc. Based on this roster information we constructed a problem set for the nurse re-rostering problem by specifying the occurrence of disruptions which are systematically varied in a controlled way. We validate the performance of the proposed procedures with respect to other techniques and the existing literature [10] and of the problem-specific operators for the nurse re-rostering problem. Moreover, we utilize the proposed procedure as a simulation tool and investigate the impact of different policy decisions and strategies on the resulting quality of the reconstructed nurse roster.

References