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FOCUSED FLEXIBILITY IN WORKFORCE SCHEDULING

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ABSTRACT

In many industries, work schedules often go through lengthy approval processes. Once approved, schedules may be locked in for long time horizons (e.g., months). Working regulations allow for partial changes (re-rostering) in a small number of extreme cases. Most other disruptions (staff absenteeism, change in demand pattern, etc.) will be dealt with only at huge costs. Injecting flexibility (affordable, case-specific re-rostering options) from the very outset (schedule approval stage) can foster schedule robustness at lower costs. This work shows how to jointly adopt simulation and Adaptive Large Neighborhood Search to do just that. At each iteration of the proposed Sim-ALNS algorithm, ALNS selects a combination of levels of flexibility (within guidelines set by the organization), while a Monte-Carlo simulation scheme evaluates the performance of the solution. Experiments in an airport security setting show that the method can lead to a 38% decrease in average weekly re-rostering cost.

1 INTRODUCTION

Staff scheduling, in particular staff rostering, is a highly complex problem that is covered by a wide range of research (Ernst et al. 2004; Van Den Bergh et al. 2013). In many unionized settings (for example airports) rostering becomes not only a complex but also a lengthy process due to the approval process of all stakeholders. This means that many day-to-day disruptions such as staff absences and demand pattern changes can only be estimated. Even then, the estimates cannot be allocated to specific members of staff or particular hours of the day. Instead, the scheduler has to make last-minute changes to the schedule as these disruptions come to light – a very costly and complicated process due to workforce regulations.

Fine-tuned design of flexibility options into the roster may help to combat this issue. These measures ensure that the schedule can be adjusted with relative ease, in order to counter some of the most recurring disruptions. Re-rostering cost is reduced, as a result. In this study, two flexibility measures are considered. Firstly, the ratio of buffer & reserve shifts (Wickert et al. 2021) to regular shifts. Secondly, a new measure is introduced: *slack potential* (difference between scheduled work time and maximum allowed work time).

2 FINE-TUNING FLEXIBLITIES – A SIMHEURISTIC APPROACH

A Simheuristic approach (Sim-ALNS) is proposed. This has recently featured quite frequently in the literature (not necessarily going by this name), as a way to improve the effectiveness of ALNS for solving stochastic combinatorial problems. Within the same scheme, different simulation methods have been used: fuzzy simulation (Zhou et al. 2020), discrete-event simulation (Dang and Pham 2016; Keskin et al. 2021; Kisialiou et al. 2018, 2019), and Monte-Carlo (Nasri et al. 2020). However, in all of these cases the ALNS portion of the algorithm is applied directly to the solution of the problem –the roster, in this case. Here instead, ALNS selects the combination of flexibility levels, which are dynamically added as constraints for the rostering problem.

Algorithm 1 gives an overview of how Sim-ALNS can be used to fine-tune flexibility metrics for a rostering problem under uncertainty. Once, the initial set of flexibility levels is decided, the initial roster s^* is created. The roster is then tested by running N Simulations. During each simulation, staff absences are generated based on past data and paired with demand patterns for several weeks. Then the re-rostering cost (c^*) for obtaining feasible schedules is evaluated.

Once the initial parameters and the associated cost are obtained, the algorithm runs through a set number (MAX_{iter}) of iterations during which ALNS is used to obtain a new set of parameters (m') which are used to create a new schedule (s') and obtain a re-rostering cost (c'). If the new parameters lead to an improvement of the re-rostering cost, the algorithm will continue to use them ($m^*, s^*, c^* = m', s', c'$) otherwise, the original parameters will be used again.

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Algorithm 1: SimALNS for parameter tuning
Procedure SimALNS
    m* = select initial levels of flexibility metrics
    s* = create roster using m′ as input
            parameters for black-box roster tool
    For N Simulations
        simulate Absences
        sample demand pattern
        c* = calculate re-rostering cost
    iteration = 1
    While iteration ≤ MAX_iter
        m′ = apply ALNS operators to m*
        s′ = create roster using m′ as input
                parameters for black-box roster tool
        For N Simulations
            simulate Absences
            sample demand pattern
            c′ = calculate re-rostering cost
        IF c′ ≤ c*:
            m*, s*, c* = m′, s′, c′
        iteration = iteration + 1
Return m*, s*, c*
End
```

3 EXPERIMENTAL RESULTS

The method was tested on a realistic airport security rostering problem with a workforce size of 268 employees, a seasonal demand forecast of 29 weeks and an estimated 10% staff absences over the season. The results showed a reduction of 38% in average weekly re-rostering cost. This accounts for approximately £3,000 saved per week compared to a roster without fine-tuned metrics.

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