View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Ghent University Academic Bibliography

The use of overtime to limit the impact of demand variability in personnel scheduling

Jonas Ingels · Broos Maenhout

1 Introduction

Organisations that wish to ensure their desired service level at a maximal employee satisfaction and minimal cost, need to consider uncertainty in their personnel planning process. The satisfaction of employee preferences is an important objective in personnel scheduling [4,9,10] and a large portion of the operating costs of organisations comprises the cost related to the personnel planning process [6,11]. This process consists of three hierarchical phases, i.e. the strategic staffing phase, the tactical scheduling phase and the operational allocation phase [2,5].
In the strategic staffing phase, decisions are taken such that the organisation can satisfy the service demand for a long-term period. These decisions include the provision of a budget and a strategy to distribute this budget over personnel, overtime and temporary resources. This strategy impacts the need for and the availability of overtime in the lower level phases [8].
Based on predictions and assumptions about the service demand, a baseline personnel roster is constructed for a medium-term period in the tactical scheduling phase. In this phase, overtime can be introduced to increase the number of working duties per employee.
Operational variability arises in the operational allocation phase where the assumptions and predictions, utilised in the previous phase, may differ from reality. This variability results in schedule disruptions in the baseline personnel roster, which need to be corrected by reassigning employees and allocating

J. Ingels
Faculty of Economics and Business Administration, Ghent University
Tweekerkenstraat 2, 9000 Gent (Belgium)
Tel.: +32-9-264 42 28
Fax: +32-9-264 42 86
E-mail: Jonas.Ingels@Ugent.be

B. Maenhout
Faculty of Economics and Business Administration, Ghent University
Tweekerkenstraat 2, 9000 Gent (Belgium)

overtime in a short-term period. Van den Bergh et al. [11] distinguish three sources of variability including uncertainty of demand. This uncertainty may result in an actual service demand that differs from the assumed demand.

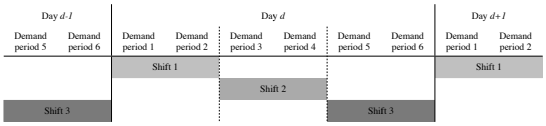
In this paper, we use overtime to improve the stability and flexibility of personnel shift rosters under different degrees of demand variability. We introduce overtime in the tactical scheduling phase and the operational allocation phase to extend the working time. In the tactical scheduling phase, overtime is scheduled for two reasons. First, scheduled overtime may be required to satisfy the service demand. Second, scheduled overtime may be applied as a proactive strategy to anticipate operational variability. The application of a proactive strategy needs to be complemented with a reactive strategy to ensure an appropriate recovery when schedule disruptions occur in the short-term operational allocation phase. We reactively allocate overtime to complement the scheduled overtime, i.e. we allocate unscheduled overtime. However, the number of overtime hours that may be allocated reactively, depends on the maximum number of overtime hours and the number of overtime hours that have already been proactively scheduled. We investigate this trade-off by varying the distribution of the available overtime hours over the tactical scheduling phase and the operational allocation phase.

2 Methodology

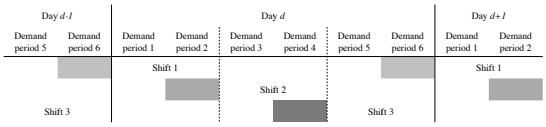
We evaluate the trade-off between proactively assigning scheduled overtime and reactively allocating unscheduled overtime by using a three-step methodology. This methodology is similar to the approaches of Abdelghany et al. [1], Bard and Purnomo [3] and Ingels and Maenhout [7] and includes a tactical scheduling phase, an operational allocation phase and a robustness evaluation. In order to obtain meaningful results, we repeat the operational allocation phase and the robustness evaluation multiple times.

In the tactical scheduling phase, a baseline personnel shift roster is constructed for a pre-determined number of employees and a medium-term period. During this phase, each employee is assigned to a working shift or a day off for each day in the planning period. We consider three non-overlapping shifts of a fixed duration that all comprise two demand periods (cf. figure 1). Moreover, we allow the extension of the working time, i.e.

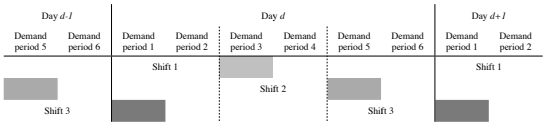
- *Total working time extension*: The assignment of an employee to overtime during a complete shift may extend the working time over the complete planning period (cf. figure 1(a)).
- *Daily working time extension*: The assignment of an employee to overtime during a prior shift extension (cf. figure 1(b)) or a subsequent shift extension (cf. figure 1(c)) extends the daily working time. Note that this assignment may also extend the total working time.



(a) Overtime during complete shifts



(b) Overtime during prior shift extensions



(c) Overtime during subsequent shift extensions

Fig. 1: An overview of overtime duties

In the second step, we imitate the operational allocation phase on a day-by-day basis for the baseline personnel shift roster. This phase consists of a simulation and adjustment component. Each day, the simulation component simulates the operational demand, which may differ from the assumed demand in the tactical scheduling phase. This may result in schedule disruptions, which need to be resolved by adapting the baseline personnel shift roster for the day under consideration. The potential adaptations include *reassignments* of the regular and overtime working duties, *conversions* of a day off to a working duty, the allocation of *unscheduled overtime* and the *cancellation* of regular or overtime duties that contribute to overstaffing.
In the last step, we evaluate the robustness of the baseline personnel shift roster through an assessment of the planned and actual performance. The planned and actual performance respectively reflect the quality of the personnel shift roster in the tactical scheduling phase and the operational allocation phase.

3 Computational experiments

We generate test instances for a planning period of 7 days and varying levels of hired employees. The total number of overtime hours that can be distributed over the tactical scheduling and operational allocation phase is determined by the number of hired employees and the maximum number of overtime hours per employee. We investigate the trade-off between scheduled and unscheduled overtime by varying the limitations on the number of overtime hours that may respectively be used in the tactical scheduling phase and the operational allocation phase.
In order to show the impact of scheduled versus unscheduled overtime for

different degrees of operational variability, we distinguish and compare three types of baseline personnel shift rosters, i.e.

- The *basic personnel roster* does not include (un)scheduled overtime.
- The *minimum cost baseline roster* may include (un)scheduled overtime.
- The *time buffer baseline roster* may include (un)scheduled overtime. Moreover, capacity buffers are installed through the definition of service demand for extra working duties.

References

1. Abdelghany, K., Abdelghany, A., Ekollu, G.: An integrated decision support tool for airlines schedule recovery during irregular operations. European Journal of Operational Research **185**(2), 825 – 848 (2008)
2. Abernathy, W., Baloff, N., Hershey, J.: A three-stage manpower planning and scheduling model - a service sector example. Operations Research **21**, 693–711 (1973)
3. Bard, J., Purnomo, H.: Hospital-wide reactive scheduling of nurses with preference considerations. IIE Transactions **37**, 589–608 (2005)
4. Bard, J., Purnomo, H.: Short-term nurse scheduling in response to daily fluctuations in supply and demand. Health Care Management Science **8**, 315–324 (2005)
5. Burke, E., De Causmaecker, P., Vanden Berghe, G., Van Landeghem, H.: The state of the art of nurse rostering. Journal of Scheduling **7**, 441–499 (2004)
6. Ernst, A., Jiang, H., Krishnamoorthy, M., Sier, D.: Staff scheduling and rostering: A review of applications, methods and models. European Journal of Operational Research **153**, 3–27 (2004)
7. Ingels, J., Maenhout, B.: The impact of reserve duties on the robustness of a personnel shift roster: An empirical investigation. Computers & Operations Research **61**(0), 153–169 (2015). DOI 10.1016/j.cor.2015.03.010. URL http://www.sciencedirect.com/science/article/pii/S0305054815000684
8. Li, N., Li, L.X.: Modeling staffing flexibility: A case of china. European Journal of Operational Research **124**(2), 255–266 (2000). DOI 10.1016/S0377-2217(99)00379-3. URL http://www.sciencedirect.com/science/article/pii/S0377221799003793
9. Pato, M., Moz, M.: Solving a bi-objective nurse rerostering problem by using a utopic Pareto genetic heuristic. Journal of Heuristics **14**, 359–374 (2008)
10. Topaloglu, S., Selim, H.: Nurse scheduling using fuzzy modelling approach. Fuzzy Sets and Systems **161**, 1543–1563 (2010)
11. Van den Bergh, J., Beliën, J., De Bruecker, P., Demeulemeester, E., De Boeck, L.: Personnel scheduling: A literature review. European Journal of Operational Research **226**, 367–385 (2013)