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A rolling planning horizon heuristic for scheduling agents with different qualifications

Raik Stolletz, Emilio Zamorano *

University of Mannheim, Business School, Chair of Production Management, Schloss SO 229, 68131 Mannheim, Germany

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ABSTRACT

This paper presents an optimization model for the tour scheduling problem for agents with multiple skills and flexible contracts in check-in counters at airports. The objective is to minimize the total assignment costs subject to demand fulfillment and labor regulations. In order to solve this problem we develop a rolling planning horizon-based heuristic. Our heuristic is robust and provides near-optimal schedules within reasonable computation time for real-world cases, although the parameter selection is important to its performance. In addition, we discuss the impact of the skill distribution on the scheduling costs for several instances.

1. Introduction

Third-party ground-handling agencies provide passenger handling services, such as check-in of passengers at airport terminals, to airlines. After the release in 1996 of Directive 96/67/EC on the liberalization of the ground-handling market at European airports, the number of third-party ground handlers increased by 90% in five years (S&HE, 2002), leading to higher competition and price reductions (Airport Research Center, 2009). Because staff costs represent 66% to 75% of ground handlers' operating costs, optimized workforce schedules significantly increase their profitability (Steer Davies Gleave, 2010).

A typical workforce planning process undergone by ground-handling agencies is divided into four sub-stages, each with different planning horizons, objectives, and constraints: (i) head count planning, (ii) tour scheduling, (iii) task assignment, and (iv) replanning (Stolletz, 2010). Our work focuses on the second phase of this process: monthly tour scheduling. This decision problem consists of assigning individual employees to tours (*e.g.*, daily shifts and days off) to satisfy the time-dependent employee requirements for check-in of individual flights. The requirements are driven by the flight schedule and depend on the contract with the airline. Airlines work with different computer systems for their check-in processes, and only qualified agents are allowed to operate them. Agents can specialize on the operation of a single system or can be cross-trained to operate multiple systems, although no downgrading is allowed (agents with higher skill levels cannot be assigned to cover lower skill requirements *i.e.*, agents have non hierarchical skill sets). In addition, agents are allowed to switch between different skills during a working shift. Agent assignment also must satisfy rules based on the contracts and qualifications of the employees. The contracts, however, enforce flexible schedules by a set of tour building rules: variable shift length and starting times, variable tour length, variable number of working hours, or non-consecutive days-off, for example. This leads to a huge amount of possible tours per employee. Such a combination of multiple non-hierarchical skills and highly flexible contracts has not been previously addressed in tour scheduling literature. The objective of this planning task is to minimize operative workforce costs: overall scheduled hours, overtime and outsourcing. The resulting schedules need

* Corresponding author. Tel.: +49 6211811585.
E-mail addresses: stolletz@bwl.uni-mannheim.de (R. Stolletz), ezamoran@mail.uni-mannheim.de (E. Zamorano).

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to respect the given pool of agents and their individual contracts while ensuring that enough qualified employees are assigned to cover the demand over the course of each day.

This paper presents a Mixed Integer Programming (MIP) model for tour scheduling with multiple skills. The consideration of multiple skills prevents a solution for the MIP in short CPU times with standard software. Therefore, this study presents a new heuristic based on a rolling planning horizon approach. The main idea is to decompose the main tour scheduling problem for multiple weeks into smaller but well-connected subproblems that cover only part of the entire planning horizon. That is contrary to the common decomposition into daily shift scheduling and a line of work construction (Ernst et al., 2004b; Alfares, 2004). Such a decomposition approach could lead to infeasibilities in the second step, especially for workforce with heterogeneous skills. Instead of looking at a planning horizon of a single day only, our heuristic extend it to several days. For such a short horizon, the resulting subproblem (which is the tour scheduling problem for a significantly shorter horizon) could be solved exactly.

To the best of our knowledge, no previous efforts have been directed toward applying a rolling planning horizon to the problem at hand.

To summarize, the main contributions of this paper are the following:

- The development of Mixed Integer Programming (MIP) model for the tour scheduling problem of a multiskilled workforce with flexible contracts, and
- the development of a new heuristic based on a rolling planning horizon approach for this problem.

This paper is organized as follows: Section 2 gives an overview of related work. Section 3 presents a description of the problem and the formulation as an MIP. The rolling planning horizon heuristic (RPH) is described in Section 4. The numerical studies described in Section 5 demonstrate the reliability of the solution of the RPH compared to that of the MIP, obtained for data from different ground-handling agencies. A sensitivity analysis shows the impact of the skill distribution on the overall scheduling costs. Concluding remarks and managerial insights are presented in Section 6.

2. Previous research

Reviews of decision models and solution approaches in workforce scheduling and, in particular, tour scheduling are given in Alfares (2004), Ernst et al. (2004b), Ernst et al. (2004a) and Van den Bergh et al. (2013). The types of scheduling flexibility, as defined by Jacobs and Bechtold (1993) and Stolletz (2010), are: (i) shift length flexibility, (ii) tour length flexibility, (iii) meal-break flexibility, (iv) shift-start flexibility, (v) start-time float flexibility, (vi) days-off flexibility, and (vii) overall-hour flexibility. The more of these flexibility types are incorporated into a model, the higher the degree of scheduling flexibility the model has. In contrast to the tour scheduling problem which we consider in this paper, shift scheduling determines shifts and allocates them to agents for a single day. Avramidis et al. (2010) and Helber and Henken (2010) address the shift scheduling problem for multiskilled agents in call centers. They consider, similar to our approach, non-hierarchical skill sets and high degree of shift length and shift-start flexibility. However, this review concentrates on tour scheduling approaches. First, we review tour scheduling approaches considering a high degree flexibility although a homogeneous workforce is assumed. Second, we comment on approaches considering hierarchical skills and discuss on the degree of flexibility they assume. Third, we discuss more general models assuming non-hierarchical skill sets and different degrees of flexibility.

1. Homogeneous workforce

Stolletz (2010) and Brunner and Stolletz (2014) consider the tour scheduling problem for check-in counters at airports with flexible contracts. Stolletz (2010) includes all aforementioned types of scheduling flexibility, except meal-break flexibility, and proposes a MIP model for this problem. Brunner and Stolletz (2014) extend this by including meal-break flexibility and develop a branch-and-price algorithm to solve this problem. In contrast to our approach, they both consider a homogeneous workforce.

2. Heterogeneous workforce with hierarchical skills

Models for tour scheduling with multiple qualified agents often assume hierarchical skill sets. In this case, employees with higher skill levels are allowed to be assigned to jobs that require lower skill levels, *i.e.*, downgrading is allowed. The general non-hierarchical model can solve this as a special case. Billionnet (1999), Bard (2004) and Rong and Grunow (2009) assume hierarchical skills. In addition, they incorporate some scheduling flexibility types into their assumptions. Billionnet (1999) proposes a Integer Programming (IP) model to assign agents with hierarchical skills to work days and flexible days-off on a weekly basis. This models allows downgrading agents and ensures that each agent receives n days-off during a week. Bard (2004) addresses a scheduling problem for postal service personnel. In this model, full- and part-time agents are assigned to daily shifts of and days-off in a weekly basis. Shifts can have variable lengths and meal-breaks are allocated flexibly. Rong and Grunow (2009) consider full- and part-time employees in an air cargo terminal scheduling problem. They propose a MIP to assign full- and part-time workers to weekly schedules where the shift length and shift start times are flexible. These approaches differ to ours on their lower degree of scheduling flexibility and on the hierarchical skills assumption.