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Operational workforce planning for check-in counters at airports

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ABSTRACT

This paper addresses operation models for workforce planning for check-in systems at airports. We characterize different tasks of the hierarchical workforce planning problem with time-dependent demand. A binary linear programming formulation is developed for the fortnightly tour scheduling problem with flexible employee contracts. This binary programming model is solved for optimality by CPLEX for real-world demand scenarios with different workforce sizes. The numerical study analyzes the impact of the degree of flexibility and economies of scale. The model formulation is extended to generate convenient tours with regard to employee preferences.

1. Introduction

Workforce planning involves matching the supply of and demand for employees from a strategic level up to an operational level. Strategic workforce planning suggests the determination of the workforce size over a long period of time (see Koutsopoulos and Wilson (1987)). Tactical and operational workforce planning, or rostering, is the process of constructing work timetables. According to Ernst et al. (2004b), it is common to decompose rostering problems into the following separate modules: (i) demand modeling, (ii) days-off scheduling, (iii) shift scheduling, (iv) line of work construction, (v) task assignment, and (vi) staff assignment. The first module determines how many staff are needed at different times. Days-off scheduling determines the days off for each employee. Shift scheduling is the assignment of employees to work in hours of the day (shifts). Line of work construction, or tour scheduling, combines both tasks of modules (ii) and (iii), i.e., the employees are assigned to shifts or days-off for each day of a planning horizon from one week up to several months. One or more tasks should be assigned to a shift in the task assignment module. If an individual staff has not been assigned to tours in previous modules, these assignments must be performed last.

This paper addresses the analysis of workforce staffing for check-in systems, one of the subsystems of the complex passenger service system available at airports. The personnel planning of a ground handling company providing check-in services for different airlines is analyzed. In this case, contracts with airlines determine the number of check-in agents required per flight. A time-varying overall demand for check-in operators, dependent on the flight time table, can be observed. With regard to the time before departure, the workforce planning process for check-in counters is divided into four main planning tasks. On the strategic level, the head count and the required qualifications of the operators are planned for a whole flight-plan season. The rostering process is divided into three main tasks. Fortnightly tours for individual employees are constructed first, covering the modules (ii), (iii), and (iv) of the general classification above. Second, individual flights are assigned to operators for each day (task assignment). Third, due to unforeseen delays or cancellations of flights, a

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replanning may be necessary during the day of operation. The task assignment and the replanning tasks cover just a single day, which reduces the planning complexity in comparison to the fortnightly tour scheduling problem. For approaches to the task assignment and the replanning problem; see, for example, Fischetti et al. (1992), Dowling et al. (1997), Ernst et al. (2004a), Moz and Pato (2007), and Abdelghany et al. (2008). The assignment and reassignment of check-in counters to flights are analyzed with respect to archiving service levels (see Tosic (1992), Park and Ahn (2003), Parlar and Sharafali (2008), Duin and Van der Sluis (2006), and Yan et al. (2008)).

This paper focuses on the first operational planning task of scheduling fortnightly tours. In the considered case of a ground handler at a German airport, there are very flexible restrictions for shift building and combining shifts into tours, i.e., making a valid duty roster. Such flexible employee contracts are often found in this kind of service industry. The flexible lengths and positions of the working periods make it possible to set up workforce schedules that cover the dynamic demand very closely. Labor scheduling efficiency could be improved through this scheduling flexibility, but such a change may result in a large number of variables in traditional mathematical programming formulations of shift or tour scheduling problems (see Alfares (2004)). Comprehensive literature surveys of tour scheduling problems are provided by Ernst et al. (2004a) and Alfares (2004). Typical mathematical programming formulations of the tour scheduling problem are based on the set-covering formulation of Dantzig (1954) or on implicit formulations (see Alfares (2004)). Especially for systems with a high scheduling flexibility, the number of possible tours becomes very large. As the traditional set-covering approach requires a complete tour matrix, it cannot be applied to the tour scheduling problem presented in this paper. Column generation approaches could overcome this explosion in size, but the subproblem of pricing often must be solved heuristically; see, for example, Easton and Rossin (1991) and Ernst et al. (2004b). In implicit formulations, the rules for building shifts and tours are modeled as constraints within the mathematical program. Such formulations are analyzed for several applications; see, for example, Thompson (1992), Thompson (1995), Jarrah et al. (1994), Jacobs and Brusco (1996), Aykin (1996), Isken (2004), Brusco and Jacobs (2000), and Brunner et al. (2009). These formulations result in a large number of constraints and often cannot be solved for optimality for real-world tour scheduling problems; see, for example, Brunner et al. (2009). Therefore, tour scheduling problems are often decomposed into subproblems; for example, into assignments of days-off, shift scheduling, and construction of weekly tours (see Jarrah et al. (1994) and Alfares (2004)). Other heuristic solution approaches for tour scheduling problems are discussed in Morris and Showalter (1983), Li et al. (1991), Easton and Mansour (1993), Brusco and Jacobs (1993), and Brusco and Jacobs (1995). The literature regarding personnel scheduling at airport stations is limited. Schindler and Semmel (1993) analyze a shift scheduling problem for airport stations of Pan Am. Alfares (1999) analyzes a days-off scheduling problem for aircraft maintenance workers. Decomposition approaches to tour scheduling problems at airports are analyzed in Brusco et al. (1995), Dowling et al. (1997), Mason et al. (1998), and Alvarez-Valdes et al. (1999).

The main contributions of this paper are the following:

- the description of the hierarchical workforce planning for check-in counters with flexible employee contracts,
- the development of a new binary linear programming formulation for the underlying tour scheduling problem, and
- testing the new formulation for real-world demand data.

To the best of our knowledge, no tour scheduling model in the literature treats all the features of flexible employee contracts and individual employee preferences. In contrast to the above-mentioned set-covering formulation and implicit models, this new formulation is based on given daily shift types. It will thus allow for the optimization of tour schedules within acceptable computation times.

The remainder of the paper is organized as follows: Section 2.1 characterizes the hierarchical workforce planning process with respect to the objectives and constraints of different planning tasks. A detailed description of the analyzed tour scheduling problem with flexible contracts is provided in Section 2.2. We develop a new mathematical programming formulation for this tour scheduling problem in Section 3.1. The numerical study in Section 3.2 shows the applicability to real-world demand scenarios. The impact of the number of employees and the number of workdays on the objective function is shown in the sensitivity analysis presented in Section 3.3. In Section 4, additional restrictions on the scheduling of convenient tours based on the individual preferences of the employees are presented. Section 5 concludes with suggestions for further research.

2. Characterization of the workforce planning process and problem description

2.1. Structure of the workforce planning process

The airline-specific demand for a certain number of check-in operators per flight is given by contracts between the airline and the ground handler. It depends on the time before departure and the number of passengers per flight and may also depend on the destination of the flight. The flight schedule and these specific contracts with airlines result in overall personnel requirements per short time period; for example, 5 or 15 min. The level of this demand typically varies over the day and from day to day. Hence, the main task of operational workforce planning is to assign a given amount of check-in agents to different shifts to meet this time-varying demand. Fig. 1 shows the hierarchical planning system with four subproblems, as mentioned in Section 1. These subproblems have different planning horizons, objectives, and constraints.