Staff and Resource Scheduling at Airports

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1 Introduction

At an airport, a large number of activities required for serving an aircraft while on the ground have to be scheduled. These activities include, for example, passenger and flight crew transportation, check-in and boarding services, various technical services, loading and unloading of cargo and baggage, or catering and cleaning services. With the steady increase of civil air traffic and the corresponding growth of airports over the past decades, the complexity of the task has increased significantly.

The scheduling process is mainly concerned with staff and terminal resources. Due to the very heterogenous qualifications and properties required for performing the various services mentioned above, the scheduling problem is usually handled at the level of individual resources types such as, e.g., cargo and loading staff or aircraft stands. Schedules and corresponding staff and resource requirements are developed at the the strategic, tactical and operational level.

The jobs or tasks to be scheduled depend on the flight schedule, which includes data on aircraft arrival and departure times, carrier, aircraft type, routing, passenger and freight numbers, etc., and on airline service agreements. The tasks have to processed within certain time windows or fixed time intervals that follow from the aircraft arrival and departure times and from constraints within the aircraft turnaround process network. The tasks are obtained by applying a set of rules reflecting the service agreements to the flight schedule. They must be frequently updated on the day of operations: it is quite common that in a peak hour at a busy airport, several updates per second must be processed.

The following sections outline two models and solution approaches for task based staff shift scheduling and for scheduling terminal resources.

2 Task Based Shift Scheduling

Staff shift scheduling models are traditionally based on a demand curve representation of the required workload [5]. If task start and end times are fixed, this curve can be obtained by simply superimposing the tasks. Dantzig [2] has proposed the following model for the problem of covering the demand curve by a set of staff shifts with minimal cost (*demand based shift scheduling*):

$$\min \sum_{k \in K} c^k x^k$$

$$\begin{aligned} \text{s.th.} \ \textstyle\sum_{k \in K} a_t^k x^k &\geq d_t && \forall t \in T \\ x^k &\geq 0 \text{ and integer} && \forall k \in K \end{aligned}$$

The integer decision variables x^k indicate the number of shifts of type k with an associated cost c^k. K denotes the set of shift types, T is the time horizon and d_t denotes the level of the labour demand curve for period t. A coefficient of the incidence matrix (a_t^k) takes the value 1 if period t is covered by shift type k and 0 otherwise.

Demand based shift scheduling works on the aggregated demand curve and ignores the aspect of assigning tasks to shifts. In many application areas, the demand curve is a natural representation of workloads, e.g. when the demand results from (random) customer arrivals and when the work force is homogeneous. In contrast to demand based shift scheduling, the following column generation model for *task based shift scheduling* simultaneously considers the allocation of tasks to shifts and the selection of an optimal number of shifts of each type:

$$\min \sum_{k \in K} c^k \sum_{p \in \Omega^k} \lambda_p^k$$

$$\begin{aligned} \text{s.th.} \ \textstyle\sum_{k \in K} \sum_{p \in \Omega^k} a_{ip}^k \lambda_p^k &= 1 && \forall i \in I \\ \lambda_p^k &\in \{0,1\} && \forall k \in K, \forall p \in \Omega^k \end{aligned}$$

Here, the binary decision variables λ_p^k indicate whether a shift p of type k is part of the solution. An element of the incidence matrix (a_{ip}^k) takes the value 1 if shift p of type k covers work task i and 0 otherwise. I is the set of all work tasks and Ω^k denotes the index set for shifts of type k.

The task based shift scheduling model is similar to column generation models for vehicle routing, with a shift corresponding to a tour. In the model, an index $p \in \Omega^k$ describes a particular shift that contains a sequence of tasks. A shift is constructed in such a way that tasks do not overlap and are not preempted, and that it additionally contains relief breaks and respects other relevant constraints, e.g. sequence dependent setup times such as travel durations, or the qualifications required by the tasks within a shift. In an airport environment, these aspects make the model much more suitable for tactical and operational planning than the demand curved based model which does generally not directly lead to a workable plan.