European Journal of Operational Research 246 (2015) 597–608

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Exact and heuristic approaches to the airport stand allocation problem

J. Guépet [a,b], R. Acuna-Agost [b], O. Briant [a], J. P. Gayon [a,*]

[a] Grenoble-INP/UJF-Grenoble 1/CNRS, G-SCOP UMR5272 Grenoble, F-38031, France
[b] Amadeus S.A.S., 485 Route du Pin Montard, Sophia Antipolis 06560, France

ARTICLE INFO

Article history:
Received 3 September 2014
Accepted 21 April 2015
Available online 27 April 2015

Keywords:
Mixed integer programming
Gate assignment problem
Heuristic algorithms

ABSTRACT

The Stand Allocation Problem (SAP) consists in assigning aircraft activities (arrival, departure and intermediate parking) to aircraft stands (parking positions) with the objective of maximizing the number of passengers/aircraft at contact stands and minimizing the number of towing movements, while respecting a set of operational and commercial requirements. We first prove that the problem of assigning each operation to a compatible stand is NP-complete by a reduction from the circular arc graph coloring problem. As a corollary, this implies that the SAP is NP-hard. We then formulate the SAP as a Mixed Integer Program (MIP) and strengthen the formulation in several ways. Additionally, we introduce two heuristic algorithms based on a spatial and time decomposition leading to smaller MIPs. The methods are tested on realistic scenarios based on actual data from two major European airports. We compare the performance and the quality of the solutions with state-of-the-art algorithms. The results show that our MIP-based methods provide significant improvements to the solutions outlined in previously published approaches. Moreover, their low computation makes them very practical.

1. Introduction

Every day, airports deal with different decisions related to aircraft movements. These decisions usually involve the use of fixed and limited resources such as runways, stands (parking positions) and passenger gates. Due to the growing flow of passengers, these resources are falling short of needs while activity planning is increasingly crucial and complex. Consequently, some airports have experienced deterioration in service quality. In one of our partner airports, the number of passengers allocated to remote stands has increased in the last years. This affects passenger connection times, increases bus transfer costs and decreases airport revenue given that airlines usually pay lower fees for flights allocated to remote stands. Since building new terminal gates is expensive and does not provide a short-term solution, value can only be gained from better management of airport resources.

In this paper we deal with the Stand Allocation Problem (SAP). This consists in assigning aircraft operations to available stands in line with operational requirements and different objectives. This problem is closely related to the Gate Allocation Problem (GAP). Our work results from close collaboration between the laboratory G-Scop and the company Amadeus. In what follows, we provide a detailed description of the stands, aircraft operations, operational requirements and the different objectives to be taken into account for solving the SAP.

A stand is an aircraft parking position. Fig. 1 illustrates the two types of possible stands: contact stands (i.e., stands touching an airport terminal gate) and remote stands (i.e., stands where a bus is needed to reach the terminal). Airports and airlines usually prefer contact stands as they are more convenient for passengers and no bus transfer is necessary.

The stand operations of an aircraft turnaround can be roughly divided into three parts: disembarkation of the arrival flight, waiting, and embarkation of the departure flight. Disembarkation concerns passengers and luggage and also involves aircraft ground handling operations (refueling, cabin services, catering, etc.) linked to the aircraft's arrival. Similarly, embarkation concerns passengers and luggage and other related ground handling operations. The waiting period can be null if the turnaround is short. During the waiting period, airport operators may decide to tow (move) aircraft to other stands. This can be for several reasons but usually targets a better utilization of valuable stands (e.g. contact stands). However, these operations require an expensive towing tractor (see Fig. 2) and increase airport congestion. The data provided by our partner airports shows that, at most, two towing operations are performed during a turnaround: one after disembarkation and one before embarkation. Consequently, we assume that turnarounds are split into three operations at most.

* Corresponding author. Tel.: +33 4 76 57 47 46.
E-mail address: jean-philippe.gayon@grenoble-inp.fr, jpgayon@gmail.com (J.P. Gayon).

http://dx.doi.org/10.1016/j.ejor.2015.04.040

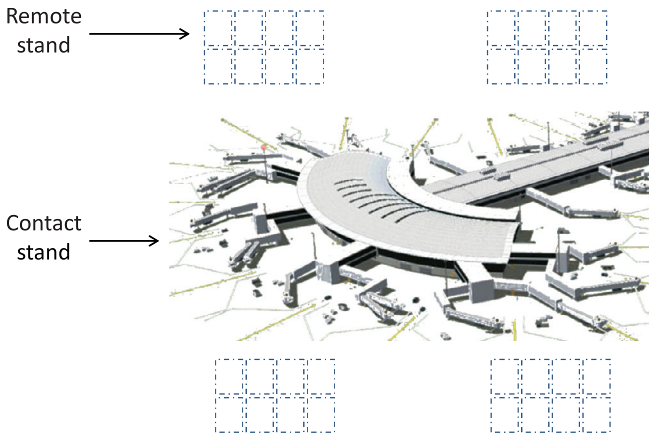

Fig. 1. Airport stands.

Fig. 2. A towing tractor.

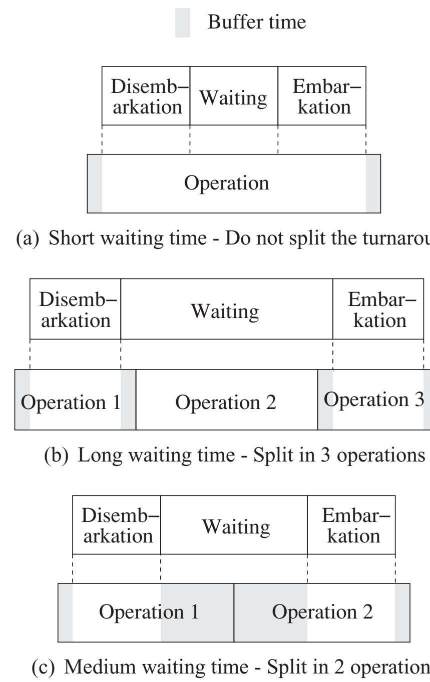

Fig. 3. Splitting turnarounds in operations and adding buffer times.

In order to define operations, we need to distinguish between three situations depending on the waiting period length (see Fig. 3). If the waiting period is too short to move the aircraft (case (a)), then we consider that we only have to schedule a single operation since disembarkation, waiting and embarkation will necessarily take place at the same stand. In order to make the assignment plan robust in the face of small disruptions such as short delays or early arrivals, we add a buffer time at the beginning and end of this single operation. If the waiting period is long enough to move the aircraft twice (case (b)), then we split the turnaround into three operations since an aircraft can potentially disembark at one stand, wait at a second stand and embark at a third stand. We add a buffer time before and after embarkation and disembarkation operations. If the duration of the waiting period is only long enough to move the aircraft once but not twice (case (c)), then the turnaround is split into two operations with the waiting time equally distributed between both operations and providing of a buffer time. Note that a different distribution of the waiting time is possible, but the one described above seems to be the most natural. We also add a buffer time before the embarkation operation and after the disembarkation operation. When towing is allowed (cases (b) and (c)), the towing time is much shorter than the disembarkation and embarkation times. Hence these can be included in the operations, which simplifies modeling even if it results in a slight overestimation of processing times. Indeed, this approach gives flexibility for actually performing the towing during the operations. In what follows, the set of operations, with fixed start and end time, is considered an input of the problem and is given by the airport.

The assignment of aircraft operations to stands must take into account aircraft-stand compatibility. Indeed, not all aircraft can be assigned to all the stands because of size compatibility but also because of aircraft flight requirements. For example, some stands are forbidden to international flights because they do not offer access to governmental inspection facilities. Furthermore, two overlapping operations must not be assigned to the same stand. Finally, adjacency conflicts, also called shadow restrictions, must be taken into account, e.g. two large aircraft cannot be assigned to adjacent stands simultaneously.

The quality of an assignment plan can be defined using several, often competing criteria, such as the number of unassigned operations, the number of passengers at contact stands, compliance with airline preferences, passenger connection convenience or the number of towing operations. In practice, an unassigned operation has to be handled manually, either overstepping certain requirements or delaying a flight. One option is to assign an operation to a non compatible stand and to transfer passengers to a compatible terminal area by bus. Another option is to keep the aircraft waiting on the tarmac.

In the literature, several authors consider the objective of minimizing passengers' walking distance or connection time (see Section 2). However, this is not always a suitable approach for airports since a large share of their revenue comes from the shops hosted in the terminal. The more passengers walk, the more likely they are to go into a shop and buy something thus boosting the airport's revenue.

For our partner airports, the assignment of aircraft activities is generally decided, at the latest, the day before the operations. In this phase, computation time is not overly problematic. However, on the day the operations are scheduled, disruptions can happen. Many random events may occur, leading to delays and flight cancellations. New flights (e.g. general aviation) and diversions can also impact planning. Hence, the assignment must be robust in the sense that small disruptions must not oblige airport authorities to change the whole assignment plan. Bigger disruption may oblige the airport to reassign aircraft. In this case, computation times need to be very short.

The Stand Allocation Problem (SAP) is closely related to the Gate Allocation Problem (GAP). A gate is the boarding desk where passengers' tickets are checked by the airline and a stand is the position where the aircraft is parked. In many US airports, embarking and disembarking passengers at remote stands is forbidden. Consequently, there is a perfect match between stands and gates, and therefore