Transportation Research Part E 99 (2017) 34–53

Contents lists available at ScienceDirect

Transportation Research Part E

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

SOSTA: An effective model for the Simultaneous Optimisation of airport SloT Allocation

Paola Pellegrini [a,*], Tatjana Bolić [b], Lorenzo Castelli [b], Raffaele Pesenti [c]

[a] Univ. Lille Nord de France – IFSTTAR, COSYS, LEOST, Villeneuve d'Ascq, France
[b] Dipartimento di Ingegneria e Architettura, Università degli Studi di Trieste, Trieste, Italy
[c] Dipartimento di Mangement, Università Ca' Foscari di Venezia, Venezia, Italy

ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form 10 November 2016
Accepted 12 December 2016
Available online 21 January 2017

Keywords:
Airport slot allocation
Air transport
Integer linear programming
Grandfather rights
Case-study
Capacity-demand imbalances

ABSTRACT

In this paper, we propose SOSTA, an integer linear programming model for optimisation of the airport slot allocation process on the European scale. The main contribution of SOSTA is the simultaneous allocation of slots at all Europan airports, while applying the existing regulation and practices. Additionally, SOSTA considers aircraft rotations through the turnaround time constraints, which is another novel contribution. In an experimental analysis based on real data, we show the benefits of the simultaneous allocation, and the flexibility and capabilities of SOSTA, along with the extremely good computational performance.

1. Introduction

The continuous growth of air traffic combined with the constrained airport capacity increase generates imbalances between traffic demand and available capacity, leading to significant delays and associated costs. For instance, in Europe in 2014 the traffic has increased by 2.5% in terms of flight hours controlled with respect to 2013, but the estimated cost of en-route and airport Air Traffic Flow Management delay has increased by 7.6% (EUROCONTROL. PRR 2014, 2015). Since airports often represent bottlenecks in the air transport network, initiatives to increase their capacity are always sought. Infrastructural interventions (such as building new runways) are rarely possible, mainly for economic and environmental concerns. Currently, each major airport may consider the following options to mitigate its congestion: either managing the demand at the strategic level or adjusting the allocation of airport resources to flights at the tactical level. The rationale of the former choice is to smooth peaks of traffic demand by moving arrival and/or departure requests to times of the day with a lower demand for the use of the airport infrastructure. Demand management is usually achieved either through the enforcement of administrative measures or through the use of economic instruments such as congestion pricing or auction mechanisms (see, e.g., Perret, 2015). The rationale of the latter choice is to adapt the use of the infrastructure to improve the utilisation of the airport capacity. For example, dynamic change of runway configurations or the selection of the arrival and departure service rates can be used to that end (Jacquillat and Odoni, 2015). This paper focuses on the administrative-based demand management procedure at the strategic level. It proposes Simultaneous Optimisation of the airport SloT Allocation (SOSTA), a decision support tool capable of optimally coordinating the airports' capacity management at the European level.

* Corresponding author.
E-mail addresses: paola.pellegrini@ifsttar.fr (P. Pellegrini), tbolic@units.it (T. Bolić), castelli@units.it (L. Castelli), pesenti@unive.it (R. Pesenti).

http://dx.doi.org/10.1016/j.tre.2016.12.006

Nowadays the capacity of many airports worldwide is managed though *airport slots*, in accordance with IATA's (International Air Transport Association) Worldwide Slot Guidelines (IATA, 2015). A slot is defined as "a permission given by a coordinator for a planned operation to use the full range of airport infrastructure necessary to arrive or depart at a Level 3 airport on a specific date and time". A *Level 3* (or *coordinated*) airport is an airport "where capacity providers have not developed sufficient infrastructure, or where governments have imposed conditions that make it impossible to meet demand. A *coordinator* is appointed to allocate slots to airspace users and other aircraft operators using or planning to use the airport as a means of managing the declared capacity." In addition to Level 3 airports, flight schedules are facilitated at *Level 2* (or *facilitated*) airports, which are those "where there is potential for congestion during some periods of the day, week, or season which can be resolved by schedule adjustments mutually agreed between the airspace users and facilitators. A *facilitator* is appointed to facilitate the planned operations of airlines using or planning to use the airport" (IATA, 2015). In Europe, there is one coordinator per country, meaning that a unique national authority manages the primary slot allocation of each Level 3, and schedule facilitation at Level 2 airports of this country (see, http://www.euaca.org). The allocation and schedule facilitation is always performed on an airport by airport basis, though. In Europe there are as many as 107 airports designated as Level 3 and another 79 as Level 2, representing 60% and 61% of all Level 3 and Level 2 airports in the world, respectively (see the Appendix 11.2 of IATA (2015)).

In the European Union, the IATA's Worldwide Slot Guidelines are implemented by Council Regulation (EEC) No 95/93 "on common rules for the allocation of slots at Community airport" and its subsequent amendments: EC Regulations No 894/2002, No 1554/2003, No 793/2004, and No 545/2009. The slot allocation process in Europe consists of two main steps: primary slot allocation, and slot exchanges and transfers. The primary slot allocation begins about five months before the start of the season (the winter season starts on the last Sunday of October, the summer season on the last Sunday of March), when the airspace users (e.g., airlines) submit formal requests for slots (and schedule facilitation) to airport coordinators. The requests are submitted in a standardised format, the Standard Schedule Information Manual (SSIM) format (IATA, 2015), containing the flight number, time period of operations (from-to within a season), day of the week, route and arrival or departure time. Airspace users can also indicate the acceptable displacement around the requested slot time. However, "Airport slots are not route, aircraft or flight number specific and may be changed by an airline from one route or type of service to another. Such changes are subject to final confirmation by the coordinator" (IATA, 2015).

At Level 2 airports, when mismatches between capacity and demand exist, an airspace user might be asked to move the scheduled time of an operation, for the minimum necessary amount of time, on a voluntary basis. At the Level 3 airports, the coordinators endeavour to satisfy the requests, under the existing capacity constraints, respecting historical precedence, the so-called *grandfather rights*. An airspace user obtains the grandfather right on a slot, if it operated the corresponding slot at least 80% of the times in the preceding equivalent season. In such a case we refer to this airspace user as an *incumbent*. In addition, the incumbent is allowed to slightly modify the time (w.r.t. the preceding equivalent season) of any of its grandfather slots.

Once all grandfather rights from incumbent airspace users are granted, fifty percent of the remaining slots are allocated to *new entrant* airspace users, and the rest to other airspace users. A new entrant is defined as: "an airline requesting a series of slots[1] at an airport on any day where, if the airline's request were accepted it would hold fewer than five slots at the airport on that day" (IATA, 2015). IATA slot conference takes place after the primary allocations are established, to facilitate negotiations of slot exchanges between airspace users. The aim of the conference is to diminish as much as possible, through negotiations, the difference between the requested and assigned slot times, which is referred to as *schedule displacement* (see, e.g., Pyrgiotis and Odoni, 2014). For example, from the conversations with a coordinator of one of the congested airports, at the beginning of the process, about 40% of requests could be granted as requested, while other requests had an average of 25 min of difference. The subsequent IATA conference negotiations brought the satisfied requests to about 85% with six minutes of average difference for non-satisfied requests. By the start of the season, 97% of requests were satisfied. This shows how the definition of airspace users' schedules is a non-trivial exercise at global level. In fact, the slots an airspace user receives are the outcome of several local allocations and may include different schedule displacements. As such, the received slots may be impracticable with respect to, say, the fleet rotation constraints, or undesirable in terms of departing/arriving times for business purposes. Decisions on which schedule displacements to accept, and their magnitude, may not be straightforward as airspace users may have to deal with many coordinators at the same time, and this may require a significant effort especially from airspace users that fly to/from many Level 3 airports.

The European Commission has financed several studies in the last years to assess the implementation of EC Regulation 95/93 and its amendments (Coopers and Lybrand, 1995; NERA, 2004; Mott MacDonald, 2006; SDG, 2011). These studies acknowledge the inefficient use of capacity at some airports, highlight difficulties that new entrants face to obtain slots, and identify significant differences in coordinators' operations. In this context, Madas and Zografos (2013) propose possible changes in the slot allocation process, including the introduction of economic instruments (e.g., congestion pricing, secondary trading, and auctioning). The design of economic instruments to enhance the efficiency of the slot allocation process has been under investigation for decades as in Rassenti et al. (1982) who proposed to allocate airport slots through a sealed-bid combinatorial auction. Several other auction-based models have been designed and evaluated as in Maldom (2003), Li

[1] Slots are allocated in series, which is a sequence of at "least five slots, requested for the same time on the same day-of-the-week, distributed regularly in the same season." (IATA, 2015). For example, a request for departures from an airport at 10 : 30 for at least five Wednesdays during a season is considered a series of slots.