Minding the gap: Optimizing airport schedule displacement and acceptability

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\textbf{ABSTRACT}

Serious congestion problems at slot-controlled airports worldwide call for some action. Slot scheduling related research has mainly focused on scheduling models allocating airport capacity by optimising scheduling efficiency. However, existing literature does not capture the effect of slot allocation decisions on the acceptability of slot schedules. The objective of this paper is to investigate the trade-off between scheduling efficiency and the airlines' dis-utility of slot schedules expressed by various metrics of schedule displacement. We develop and solve two bi-objective scheduling models considering different combinations of total and maximum acceptable slot displacement objectives. The proposed models are applied to real-world scheduling data. Substantial improvements in schedule acceptability metrics are achieved without sacrificing a lot in terms of scheduling efficiency. Sacrifices in scheduling efficiency increase the capability of the airport coordinator to allocate slots that are eventually acceptable and hence more intensively used.

1. Introduction

Congested airports constitute a serious bottleneck of the overall efficiency of the air transport system with congestion implications moving from ground to air and vice versa (SESAR JU, 2015). The sustainability of the air transport system closely depends on the evolving relationship between demand and supply of air transport services. Long-term forecasts (Eurocontrol, 2013), adjusted for economic downturn effects, anticipate lower air traffic growth rates, which are however accompanied by reduced airport capacity expansion plans due to weaker economic outlook. According to the same forecast (Eurocontrol, 2013), more than 30 airports are expected to be operating at 80% of capacity or more for 3 or more hours per day by 2035. Intensive use of saturated airport capacity and increasing imbalances between demand and capacity will adversely impact predictability and punctuality of the air transport system (SESAR JU, 2015). Current evidence and forecasting trends discussed above necessitate some form of intervention aiming to better control the so called demand-to-capacity ratio.

Supply-side interventions aiming to build new capacity are capital intensive solutions, require significant implementation time, and are often subject to heated political debates. The need for an immediate relief to seriously congested airports calls for short to medium-term, demand-side solutions that are based on the optimum allocation and use of available airport capacity (Zografos et al., 2016).

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The dominant demand-side mechanism currently applied at about 170 of the busiest and most congested airports worldwide (outside the United States) is driven by a set of rules, priorities, and voluntary guidelines set out by IATA (IATA, 2014); later adapted and further complemented by relevant EU regulation (European Commission, 1993, 2004, 2009).

The IATA-driven mechanism prescribes a strategic, pro-active (few months before operations) schedule coordination process that aims to build a viable flight schedule by controlling (actually limiting) the maximum number of scheduled operations during a unit of time at each airport. A necessary prerequisite of the schedule coordination process is to optimally set its declared capacity, i.e., the capacity that can be made available for allocation and use to airport users (Ball et al., 2007a; Odoni and Morisset, 2010; Jacquillat and Odoni, 2015). The declared capacity of a schedule coordinated airport is assigned by a coordinator to airport users through the allocation of slots, i.e., a time interval during which a flight can use the airport infrastructure for landing or take-off. Declared capacity is rationed according to a set of criteria and rules assigning different priorities to: (i) requests with historical usage rights (“grandfathered slots” – GFR), (ii) requests with new entrant status, and (iii) all remaining requests. Slots are mainly allocated in series (at least five slots for the same time and day of the week regularly) for the entire scheduling season (i.e., winter/summer). In order to cope with strong slot complementarity at the airport network level, the initial slot allocation outcome at each airport is further streamlined by airlines in biannual worldwide scheduling conferences.

One issue that arises frequently at schedule coordinated airports is that the temporal distribution of demand expressed in slots requested by the airport users does not necessarily coincide with the temporal distribution of the available (declared) capacity. Therefore, although the daily available capacity may be sufficient to cover the daily demand, the airport users may not be able to obtain their preferred slots since demand may exceed supply during certain sub-intervals (e.g., hour, 15-min. interval). In this context, the slot scheduling problem seeks to satisfy slot requests by allocating available capacity. This means that a slot request may not be entirely satisfied in terms of the time that will be eventually scheduled. As a result, the flight will experience a displacement (scheduled at an earlier or later slot than the one originally requested). This displacement, also known as “schedule delay”, is expressed by the absolute value of the distance between the requested and allocated slot times (Koesters, 2007; Zografos et al., 2012).

The slot scheduling problem may provide a “solution” to the optimum utilisation of available capacity by displacing flights from time intervals where demand exceeds capacity to time intervals where capacity exceeds demand. However, it may produce solutions that are not acceptable or even practical at all. This is because the displacement of a flight to an undesirable slot may have a detrimental effect on the feasibility of the entire flight schedule of the airline’s network or the commercial viability of the flight. As a result, certain slots may not be attractive enough to be actually operated by the assigned airport users, a fact that may lead to waste of a really scarce resource. Under these circumstances, the capacity shortage problem is further sharpened by low utilisation levels and severe misuse (e.g., late return of unwanted slots, “no shows”) of that scarce capacity (Madas and Zografos, 2010). Studies suggest that even at congested airports, over 10% of the allocated slots go unused (Steer Davies Gleave, 2011) with significant economic consequences reaching €20 million per season at large congested European airports (ACI Europe, 2009).

Schedule optimisation signifies a challenging stream of research dealing effectively with the complexity and size of the resulting airport scheduling problem with a promising potential to deliver quick capacity utilisation improvements (Zografos et al., 2012). The strategic airport slot scheduling problem has been recently addressed in the literature (Zografos et al., 2017). Existing models have basically considered the following objectives: (i) total schedule displacement (Zografos et al., 2012; Castelli et al., 2012), (ii) total and maximum schedule displacement (Pyrgiotis and Odoni, 2015; Jacquillat and Odoni, 2015), (iii) schedule displacement and expected operational (queuing) delays (Corolli et al., 2014), and (iv) fairness and total schedule displacement (Zografos and Jiang, 2016). However, the issue of acceptable schedule displacement and alternative ways of accommodating airlines’ preferences and tolerance levels against schedule displacements have not been sufficiently addressed in existing literature. Most importantly, existing research and practice ignores the effect of slot allocation decisions on the potential acceptability and utilisation of scarce airport resources or the expected number of unused slots as a result of “unacceptable” schedule displacement.

This paper aims to investigate alternative ways of better accommodating airlines’ preferences and tolerance levels in compliance with the existing IATA-based strategic scheduling process. The objective of the paper is to develop and solve two bi-objective single-
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