Pushing the Envelope: the role of slot scheduling in optimising the use of scarce airport resources

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The rapid growth of demand for air transport services coupled with political, physical and institutional constraints for building new airport capacity has resulted in acute airport congestion in UK and across Europe. Demand is expected to exceed capacity by as much as 2.3 million flights (or 11%) in the most-likely growth forecast scenario by 2030 at 138 Eurocontrol airports[1]. Imbalances between traffic and capacity generate serious undesirable externalities for air transport and the society at large. Almost one third of flights delayed in ECAC area in 2013, with the average delay per delayed flight exceeding 26 minutes[2]. Similarly, ATM inefficiencies in EU[3] were estimated to result in 10.8 million minutes of ATFM delays in 2012, costing around €11.2 billion to airspace users and passengers and producing 7.8 million tonnes of wasted CO2. Increasing complications for expanding capacity render a pure supply-side solution both expensive and practically difficult to implement. In effect, a more sustainable approach being able to better cope with the congestion problem with existing resources is called for.

Solutions aiming to manage congestion through the optimum allocation of scarce airport capacity have received a great deal of consideration from the airport community, policy makers, and researchers. Capacity at schedule coordinated airports is expressed in slots and allocated within the framework of

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[1] Eurocontrol, 2008. Long-Term Forecast: IFR Flight Movements 2008-2030. Forecast prepared as part of the Challenges of Growth 2008 project, Brussels, Belgium.

[2] Eurocontrol, 2014. CODA Digest: Delays to Air Transport in Europe Annual 2013. Report prepared by Eurocontrol's Central Office for Delay Analysis (CODA), Brussels, Belgium.

[3] International Air Transport Association (IATA), 2014. Fact Sheet: Single European Sky (SES). Available online at: `http://www.iata.org/pressroom/facts_figures/fact_sheets/pages/ses.aspx` (accessed May 20, 2014).

voluntary guidelines developed and evolved over the years under the auspices of IATA. A slot identifies a time interval, specific date and time, during which a carrier is permitted to use the airport infrastructure for landing or take-off at a slot-controlled airport. A fundamental concept in the slot allocation process is declared capacity and particularly its rationing and allocation on the basis of a complicated set of administrative rules, criteria, and priorities. Declared capacity represents an "artificial" measure of capacity specifying and controlling the number of slots available per unit of time. Therefore, slot scheduling and the setting of optimum declared capacity levels are closely interdependent and both lie at the heart of optimising the allocation and use of scarce airport resources.

The objective of this presentation is to provide an overview of the evolution of slot scheduling and declared capacity modelling, identify open research issues, and underline the potential of slot scheduling in optimising the allocation and use of scarce airport resources.

The existing slot allocation process produces poor outcomes in that it fails to properly match requested slots with those allocated to airlines. On top of that, slot misuse sharpens the capacity shortage due to poor use of scarce capacity. Even at airports where slot demand exceeds capacity, over 10% of the allocated slots go unused[4]. ACI Europe[5] estimated that slots unused due to their late return account for losses of around €20 million per season at large, congested European airports.

In order to deal with inefficiencies and limitations of the existing allocation practice, the policy and research community has placed the focus on two alternative (and potentially complementary to each other) directions: i) approaches introducing alternative, market-driven mechanisms aiming to allocate capacity among competing users by considering real market (or approximations of) valuations of access to congested airport facilities (e.g., congestion-based pricing schemes, primary/secondary trading, auctioning of part of or the entire slot pool) and ii) efforts aiming to improve the allocation efficiency of the IATA-based allocation mechanism from a slot scheduling point of view.

Slot scheduling signifies a challenging stream of research due to its potential to generate quick and drastic capacity utilisation improvements and the complexity and size of the resulting mathematical problems. The slot scheduling procedures currently in use suffer from a number of limitations such as the following: i) they are very simplistic in modelling the objectives, as well as the operational and regulatory constraints of the stakeholders involved in and affected by the slot allocation process, ii) they fail to consider the inherent dependency and complementarity of slots allocated to a network of airports, iii) they do not sufficiently capture the dynamic nature and uncertainty as-

[4] Steer Davies Gleave, 2011. Impact Assessment of Revisions to Regulation 95/93. Study prepared for the European Commission (DG MOVE), London, UK.

[5] Airport Council International (ACI) Europe, 2009. ACI Europe position on the proposed revision of the Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports. Presentation at the TRAN Meeting at the European Parliament, March 25, Strasbourg, France.

sociated with airport capacity, iv) they employ empirical or ad hoc processes for determining (rather than assessing/computing) declared capacity, and v) they hardly address strong interdependencies among various resource allocation problems at strategic, (pre)tactical, and operational level. In addition, difficulties and inefficiencies in current allocation practice at a single airport feed into the hugely complex network-wide slot allocation problem for which there is no available decision support to authorities responsible for slot allocation. As a result, existing slot scheduling procedures do not realistically address the complexities of the real-world problem and apply an oversimplified approach that is eventually in the expense of allocation efficiency and utilisation of scarce airport resources.

Existing research has mainly focused on the tactical, ground holding problem, while more recently simplified modelling approaches of the strategic, single-airport, single-objective slot allocation problem were examined in the literature. The latter considered replacing the current allocation mechanism by mathematical models focusing mostly on the strategic (2-12 months before operation) allocation of slots at single-airport level. A common objective for the single-airport slot allocation problem is the minimisation of a delay-based cost function such as the so-called "schedule delay". Schedule delay is a distance-based measure expressing the difference between requested and allocated slot times (often modelled as linear cost functions) subject to declared (mainly runway) capacity, turnaround, and slot/flight assignment constraints.

Future research towards the next generation of slot scheduling models should capitalise on existing models and expand their capabilities in several directions such as: i) new, realistic modelling representations of the strategic slot allocation problem taking into account various operational and regulatory constraints, the dynamic nature of both demand and capacity, the uncertainty of air transport operations, and, most importantly, the inherent interaction and complementarity of slots at the airport network level, ii) simultaneous consideration of multiple objectives (e.g., schedule delay, operational/queuing delay, resource utilisation, fairness and equity, environmental externalities), iii) alternative formulations of the objectives (e.g., non-linear cost functions for delay) and/or the constraints (e.g., rolling capacity, turnaround, flight connectivity) of the allocation problem coping with the trade-off between complexity and accuracy of the solution, and iv) powerful new adaptive search algorithms which can provide high quality solutions to complex, large-scale, real-world problems. Furthermore, despite its utmost importance and substantial influence on the efficiency of the allocation process, the declared capacity determination process has not been sufficiently examined in the literature. In particular, the setting of optimal declared capacity levels with view to the modelling of trade-offs between declared capacity levels, allocation efficiency, service level (e.g., actual operational/queuing delays), and utilisation of scarce airport resources merit further research in the years to come.

Existing research has already demonstrated the large room for improvement of the allocation outcomes. Improvements in slot allocation affect the demand-capacity mismatch and eventually reflect on the efficient use of scarce

airport resources. Due to the intrinsic complexity and large scale of the slot allocation problem, the full potential of such improvements can only be viewed under the prism of airport network synergies. Fundamentally new mathematical structures, solution techniques and methodologies pave the way and bring promises for an enormous economic, environmental and societal impact with clear benefits for airlines, airports, passengers and the society at large.