A decision framework for allocating scarce resources at congested airports (OR-MASTER)

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Introduction

Congestion is a major problem at major airports around the world. In 2013, almost one third of flights delayed in ECAC area. These delays have significant financial and environmental costs. In the absence of major expansions to infrastructure in the short-term these issues must be addressed through improvement management of airport resources.

Capacity at busy airports is managed through the allocation of slots. A slot is a time interval during which an airline has the right to use airport infrastructure for take-off or landing.

Objectives of OR-MASTER

OR-MASTER is a research project which aims to address the issue of slot allocation at congested airports. Its objectives are as follows:

- The formulation of mathematical models which take account stakeholder utilities, the interaction of slots at airport-network level, and the feedback loops between the slot allocation and declared capacity problems
- The development of a methodology for determining the airport declared capacity
- The development of exact and heuristic algorithms for solving realistic instances
- A rigorous and wide ranging evaluation of the models and algorithms on real-world instances
- OR-MASTER is led by CENTRAL and has QMUL as a partner

Overall project methodology

The project consists of three interrelated and strongly interacting themes. Theme 1 will address the modelling issues and it will capture the complexities involved in the modelling of the airport slot allocation at a single airport and a network level. Theme 2 will deal with the optimum determination of the declared airport capacity. Theme 3 will mathematically analyse the models and methods to inform the development of effective search methodologies in these complex environments.

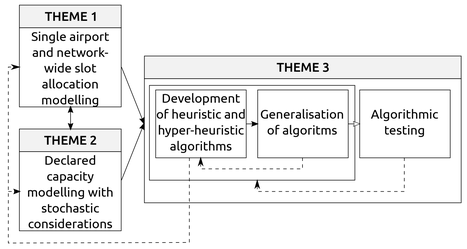
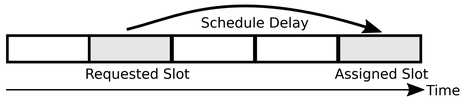


Figure 2: Overall Project Methodology

Schedule delay and fairness

Schedule delay is the time displacement of an allocated slot from the requested slot. One aim of the slot allocation is to minimise the total schedule delay for all requested movements.



However, in order for an allocation of slots to be acceptable, it must also distribute schedule delay fairly across airlines. The following principle can be used for this purpose: the amount of schedule delay allocated to an airline should be proportional to the number of slots requested. Based on this, the following fairness metrics have been proposed for slot allocation [2]:

- Maximum deviation from absolute fairness
- Maximum deviation from average fairness
- Gini index

Delay and capacity management

The schedule delay depends on the capacity parameters at the coordinated airport. The higher the capacity, the more flights that can be scheduled in a slot, and so the lower the schedule delay. However, in the absence of an increase in actual service rates at the airport, an increase in capacity will also lead to increased queuing delays. The capacity parameters at an airport should therefore be chosen to minimise a combination of schedule and queuing delay.

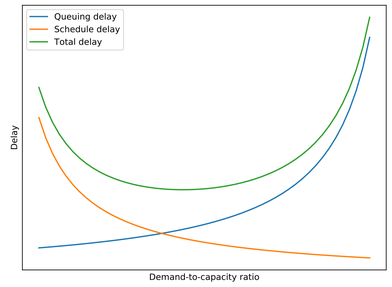


Figure 3: Trade-off between schedule and queuing delay (adapted from [1])

Network-wide slot allocation

The main limitation of using single airport models is that complementary departure and arrival slots at the origin and destination airports may not be assigned compatible slots. This problem can be overcome by assigning *simultaneously* slots at all airports in a network. A network-wide assignment of slots also offers the opportunity to improve the connectivity of a network.

Solving the network-wide slot allocation problem is necessarily much more difficult than solving the single-airport problem, and will require the development of new exact and heuristic solution algorithms.

Preliminary results

The research thus far has been focused on enhancements to the single objective model [3] to include:

- Weighted displacement
- Introduction of fairness as an explicit objective
- Investigation of a variety of fairness metrics for airport slot scheduling
- Development of bi-objective models (efficiency-fairness trade off analysis, mini-sum vs mini-max)

Current work

We are currently working on further refinements to the single-airport slot allocation model and investigating its policy implications, in particular:

- Modification of fairness metrics to differentiate between requests at on-peak and off-peak times
- Sensitivity of schedule displacement and fairness to a range of slot coordination parameters

References

[1] P. Swaroop, B. Zou, M. Ball, and M. Hansen. "Do more {US} airports need slot controls? A welfare based approach to determine slot levels". In: *Transportation Research Part B: Methodological* 46.9 (2012), pp. 1239 –1259.

[2] K. G. Zografos and Y. Jiang. "Modelling and solving the airport slot scheduling problem with efficiency, fairness, and accessibility considerations". In: *TRISTAN Symposium*. 2016.

[3] K. G. Zografos, Y. Salouras, and M. A. Madas. "Dealing with the efficient allocation of scarce resources at congested airports". In: *Transportation Research Part C: Emerging Technologies* 21.1 (2012), pp. 244–256.

Acknowledgements

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