“Mathematical Models and Algorithms for Allocating Scarce Airport Resources” (OR-MASTER)

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Presentation Contents

• Problem Definition
• Classification of Slot Allocation Methods
• The OR-MASTER Project
Problem Definition (1/4)
The Good News First

Substantial traffic growth ahead!

- IATA 20-year passenger growth forecast:
  - PAX numbers: 7.3 billion by 2034 (4.1% average annual growth) - more than doubling as compared to 2014!
  - 105 million jobs and $6 trillion in GDP (81% and 150% increase over 2014, respectively).
Problem Definition (2/4)
Then ... The Not So-Good News

**Capacity Shortage**

- 177 Airports around the world are overly congested (coordinated)

Source: [https://www.iata.org/policy/infrastructure/slots/Pages/slot-guidelines.aspx](https://www.iata.org/policy/infrastructure/slots/Pages/slot-guidelines.aspx)
Problem Definition (3/4)
...The Not So-Good News

*Capacity Shortage Implications*

Performance issues:

- **Delays:** Almost one third of flights delayed in ECAC area in 2013
- **Costs:** €4.5 billion to airspace users and €6.7 billion to passengers
- **Environment:** 7.8 million tonnes of wasted CO$_2$
Problem Definition (4/4)

How to deal with supply-demand imbalances?

- By somehow manipulating the demand-to-capacity ratio

Spatial and temporal distribution of demand

Demand

Expand available capacity

Allocation of scarce airport slots (slot scheduling)
Classification of Slot Allocation Methods (1/2)

SLOT ALLOCATION METHODS

ADMINISTRATIVE MEASURES

MARKET-DRIVEN INSTRUMENTS

HYBRID INSTRUMENTS

INTEGRATED STRATEGIES

PURE ADMINISTRATIVE

RULE-BASED SCHEDULING

SCHEDULE OPTIMISATION

CONGESTION PRICING

PURE PRICING

SLOT AUCTIONS

SLOT TRADING

PRIMARY VS. SECONDARY

MONETARY VS. NON-MONETARY

ADMINISTRATIVE

MARKET-DRIVEN
Classification of Slot Allocation Methods (2/2)

Administrative Rule-based Scheduling Approaches

*Historical evolution and geographical coverage*

- **IATA rule-driven allocation approach** based on voluntary guidelines and administrative procedures created since 1947 and evolved over the years.

- Adapted and complemented by EU Regulation 95/93 and its several amendments (2004; 2008; 2009).

- The **dominant access control mechanism** (outside U.S.).

- The **U.S. practice** is based on a largely non-interventionist approach. Exceptions to this regime are the airports governed by the High Density Rule (HDR), for which some scheduling limits are only applied.

The OR-MASTER Project (1/10)

• Modelling the slot scheduling problem taking into account:
  – a range of stakeholder utility functions / objectives
  – various operational and regulatory constraints
  – the dynamic nature of both demand and capacity
  – the weather induced uncertainty and variability of air transport operations
  – the inherent interaction and complementarity of slots at airport network level

• Large-scale, complex, multi-objective scheduling models for the allocation of slots at airport network level.

• Efficient solution algorithms to deal with the network problem size for the entire scheduling season.
The OR-MASTER Project (2/10)

- **Complement** - rather than **substitute** - to existing allocation practice.
- Large room for quick improvements in capacity utilisation with gains increasingly growing at large, severely congested airports.
- **Directly incorporating airlines’ preferences and “utility functions” or tolerances.**
- Introducing fairness and equity objectives.
- Explicitly capturing strong slot complementarity and efficiently dealing with the problem size/complexity at network level.

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Zografos et al., 2016
Overall Program Methodology
The OR-MASTER Project (4/10)

Slot Allocation Modelling Approach (Theme 1)
The OR-MASTER Project (5/10)

Overall Declared Capacity Definition and Assessment Process (Theme 2)
The OR-MASTER Project (6/10)

Schedule vs. Queuing Delay

Adapted from Swaroop et al., 2012
The OR-MASTER Project (7/10)

Weather Dependency

- Declared capacity (10 min. avg. delay)
- Declared capacity (5 min. avg. delay)
- Available capacity during bad weather

Movements/hour vs. Duration of bad weather conditions

Capacity gap 1
Capacity gap 2

Eurocontrol, 2005;
Maximum throughput (DEP): 40 DEPs/hour (MACAD)

Set Declared Capacity: 35 DEPs/hour

... and assess (queuing) delays (MACAD/DELAYS)

Zografos et al., 2016
The OR-MASTER Project (9/10)

Maximum throughput (DEP) : 40 DEPs/hour (MACAD)

(Re)Set Declared Capacity: 30 DEPs/hour

... and (re)assess (queueing) delays (MACAD/ DELAYS)

Zografos et al., 2016
An increase in declared capacity improves disproportionately the allocation outcome… in the expense of higher “schedule delays” (lower declared capacity results in higher difficulty in matching requested with allocated slots).

Queuing delays are reduced (by controlling demand through lower declared capacity).

Which are the implications of declared capacity levels on the utilisation of scarce airport infrastructure?

Zografos et al., 2016
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Thank you for your attention
References

References

• https://www.iata.org/policy/infrastructure/slots/Pages/slot-guidelines.aspx