Resource Rationing and Exchange Methods in Air Traffic Management
Part II

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Resource Allocation Process:

• FAA: *initial “fair” slot allocation*  
  [Ration-by-schedule]

• Airlines: *flight-slot assignments/reassignments*  
  [Cancellations and substitutions]

• FAA: *periodic reallocation to maximize slot utilization*  

  [Compression]
Compression Example

Earliest time of arrival = 4:20

4:05

4:50  AAL 672

5:10  AAL 95

Slot made available by canceled or delayed flight
Compression Example

Earliest time of arrival = 4:20
Slot Exchange Alternatives

• Compression as Reallocation
  – Dynamic changes to airline “demand profiles” necessitate (re)rationing

• Compression as Slot Trading
  – e.g., Slot Credit Substitutions:
    “I am willing to cancel flight $f_1$ if I can move up flight $f_2$.”
Slot Trading Opportunities

Airline Substitution/Cancellation Patterns

Consider potential benefits of extending slot trading framework

– e.g., Increase offers submitted by airlines
Mediated Slot Trading

General Framework:
• Each airline submits a set of offers
• Offer:
  – $O_{a,t}$ : slots willing to give up
  – $R_{a,t}$ : slots required in return
• Mediator (FAA) determines which offers to select and execute
  – Alternate interpretation of Compression Procedure
Approach:

From 1-for-1 trades to 2-for-2 trades

• Compression
  – 1-for-1 trading system, i.e. offers involve giving up one slot and getting one in return (many offers processed simultaneously)

• What about k-for-k or k-for-n offers, e.g. 2-for-2:
Possible 2-for-2 trades:

1 up for 1 down: reduce delay on 1 flight/increase delay on another; Model as reduce delay at least $d^-$ on f1 in exchange for increasing delay at most $d^+$ on f2.

2 down: reduce delay on two flights; handled by 2 “reduce delay” single flight trades.

2 down: increase delay on two flights; not reasonable.
Motivation

• Operationally significant delay levels often follow a “staircase” pattern

- On-time performance
- Bags misconnect (1-15 minutes)
- Passengers misconnect (15 minutes and more)
- Crews misconnect (25 minutes and more)
- 45 Minutes and more
Formulation of 2-for-2 trading problem as network flow problem w side constraints:
Case Studies

Different Airline Objectives:

1. Maximize On-Time Performance
2. Minimize Passenger Delay Costs
Airline Objective: On-time Performance

• Offers proposed:
  “I am willing to delay flight $f_1$, in return for a delay reduction that will let flight $f_2$ arrive on time” (< 15 minutes delay)
  – Additional use of “aspiration levels” to limit additional delay

• Mediation Problem:
  – Maximize number of offers executed
Airline Objective: On-time Performance

Compression Benefits
- compression executed after flts with excessive delay (>2hrs) are canceled

2-for-2 Trading Model
- proposed offers: all at-least, at-most pairs that improve on-time perf.
Airline Objective: On-time Performance

- Impact of limiting offers proposed:
  - Use of “aspiration levels” to restrict willingness to delay flights
Airline Objective:  
On-time Performance  

Summary  

• 2-for-2 trading offers significant improvement over Compression  
  – Approximates “global” optimum  

• 2-for-2 trading improvements are “robust”  
  – Gradual performance degradation as offers are restricted
Airline Objective: Passenger Delay

• Offers proposed:
  “I am willing to delay flight $f_1$, in return for a delay reduction on flight $f_2$ that will reduce net passenger delay by at least $D$ minutes”
  – Additionally, use of “staircase” pattern to represent passenger delays

• Mediation Problem
  – Maximize number of offers executed
Airline Objective: Passenger Delay

- Two passenger delay minimization objectives

Maximum achievable improvement:

Improvement from slot trading model:
Airline Objective: Passenger Delay

Summary:

• Trading benefits rely on “staircase” structure of airline preferences
• Trading benefits limited by carriers which operate smaller aircraft
  – Potential benefits of allowing side payments to compensate carriers for delay