USING RATION-BY-DISTANCE TO HANDLE GROUND DELAY PROGRAMS

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Ground Delay Programs

Solving the GDP Planning Problem

What should the overall objective of a GDP be?
- Minimize total delay
- Minimize the number of flights delayed
- Minimize the number of flight sectors delayed

Slot Times:
- 6:00
- 6:15
- 6:30
- 6:45
- 7:00
- 7:15
- 7:30
- 7:45
- 8:00
- 8:15

Many Delay Minimizing Solutions

\[ d(f,s) = \text{delay of assigning flight } f \text{ to slot } s = \text{time}(s) - \text{sched}_\text{time}(f) \]
If \( x(f,s) \) is assignment variable then:
\[ \text{Total delay} = \sum_{s} d(f,s) x(f,s) = \sum_{s} \text{time}(s) - \sum_{s} \text{sched}_\text{time}(f) \]
- total delay only depends on the flights involved and the slots used
- usually all slots are used but in general there is a unique delay-minimizing set of slots
- there are many delay-minimizing solutions

Equity Considerations: Ration-by-Schedule (RBS)

For each slot in order of increasing slot time:
- of all eligible flights that have not yet been assigned
- choose flight with earliest scheduled arrival time

Slot Times:
- 6:00
- 6:15
- 6:30
- 6:45
- 7:00
- 7:15
- 7:30
- 7:45
- 8:00
- 8:15

RBS can be viewed as a priority-based method where priority is based on the published schedule; it was developed and accepted by the FAA and airlines after many "war-gaming" exercises; it has many desirable properties from an equity perspective.

The Good and Bad of Today’s Rationing Method (RBS)

Viewed from a deterministic perspective, the overall process achieves three key objectives:
- Efficiency: solution used maximizes throughput; minimizes total delay.
- Equity: schedule-based fair-assignment mechanism used; accepted by all parties.
- CMDI: airlines provided with ability to internally reallocate slots among their own flights.

But... things are not quite so rosy when one considers the uncertainties associated with weather.

Distance Based Exemption

Figure 35: United States National Airspace System

Intuition: assigning delay to short haul flights allows for quicker reaction to changing events
- GDP planners hate to give delay to long-haul (3 1/2 to 5 hr) flights
  - must ground delay these flights 4 to 6 hours in advance of their arrival
  - much uncertainty regarding weather so far in advance
- Practical approach:
  - assign as little delay as possible to long-haul flights if necessary
  - can always assign delay (or extra delay) to close-to-short haul flights.
- Another point of view: if short haul flight is assigned a delay and the weather clears then it can launch and quickly get to the airport to take advantage of released capacity.

A "blind" application of RBS does not take these considerations into account and it can be shown that "pure" RBS does not in general minimize expected delay.

Impact of long-haul priority

Two flights have same scheduled arrival time; order GDP one must be delayed

A: short haul has priority
- GDP is cancelled
- Flight B is cancelled
- Flight A is cancelled

B: long haul has priority
- Flight A is cancelled
- Flight B is cancelled
- Flight A is cancelled

Typical Weather Events

... with uncertainty

Ration-by-Distance (RBD)

Flight lengths
- 1 hr
- 1.5 hr
- 2 hrs

For each slot in order of increasing slot time:
- of all eligible flights that have not yet been assigned, choose flight with longest distance from departure airport

RBD minimizes total expected delay

SFO Experiment: RBS vs RBD — Total Delay for Various GDP cancellation times

An Integer Programming Formulation of Stochastic Ground Delay Programs

\[ \text{Minimize } \sum_{i,j} c_{ij} x_{ij} \]
subject to:
- Each flight gets one slot
- Each slot gets one flight
- Each flight must be reassigned once in each scenario
- Each reassignment slot can be used once in each scenario.

Minimize the total delay when the RBD algorithm is used instead of the RBS algorithm.

Notice how the total delay is decreased when the RBD algorithm is used instead of the RBS algorithm.