USING RATION-BY-DISTANCE TO HANDLE GROUND DELAY PROGRAMS

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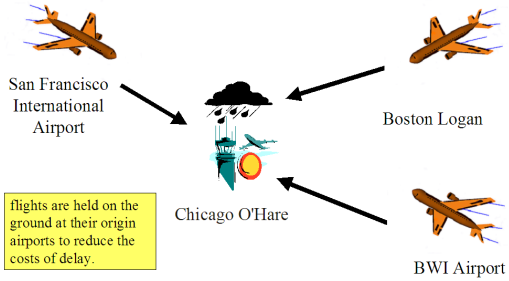
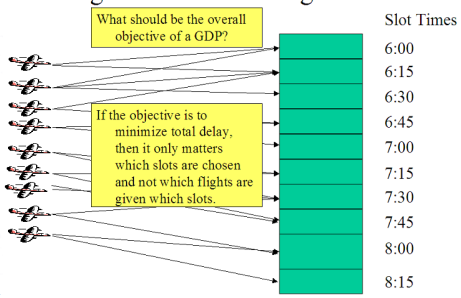
NEXTOR

Ground Delay Programs



flights are held on the ground at their origin airports to reduce the costs of delay.

Solving the GDP Planning Problem



Many Delay Minimizing Solutions

d(f,s) = delay of assigning flight f to slot s
= time(s) – sched_time(f)

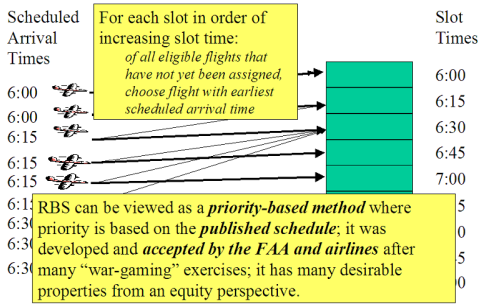
If x(f,s) is assignment variable then:

Tot delay $= \sum_{s,f} d(f,s)\, x(f,s)$
$= \sum_{s} time(s) - \sum_{f} sched\_time(f)$

➔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

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.

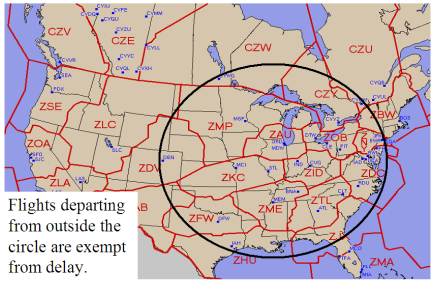
The Good and Bad of Today's Rationing Method (RBS)

Viewed from a ***deterministic perspective*** the overall process achieves three key objectives:

- **Efficiency:** solution used maximizes thru-put/minimizes total delay.
- **Equity:** schedule-based fair-allocation mechanism used; accepted by all parties.
- **CDM:** 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



Flights departing from outside the circle are exempt from delay.

Figure 10: United States National Airspace System

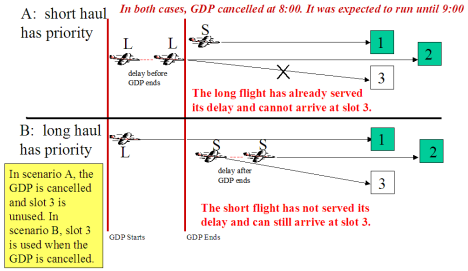
Intuition: assigning delay to short haul flights allows for quicker reaction to changing events

- GDP planners hate to give delay to long-haul (3 ½ 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-in/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.

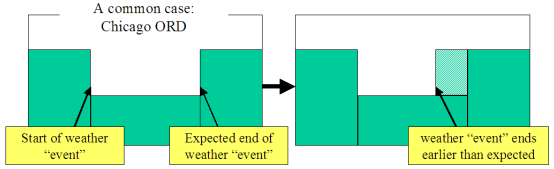
Impact of long-haul priority

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



In scenario A, the GDP is cancelled and slot 3 is unused. In scenario B, slot 3 is used when the GDP is cancelled.

Typical Weather Events … with uncertainty

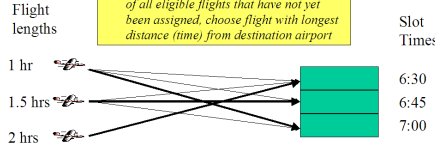


If delay was given to long haul flights instead of short haul flights, there may be no flights available to take off and land in the shaded region.

But since the airport can now handle more capacity, it is being under-utilized, and flights are being given UNNECESSARY DELAY!!!!!!!! GDPs are generally cancelled about 2 hours early.

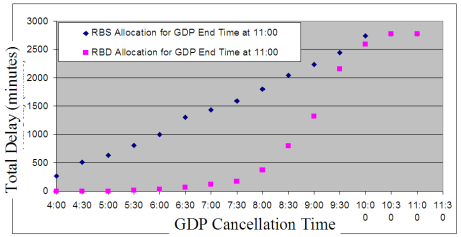
Ration-by-Distance (RBD)

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



Thm: *For each possible program cancellation time, RBD minimizes total delay.*
➔ ***RBD minimizes total expected delay***

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



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

An Integer Programming Formulation of Stochastic Ground Delay Programs

- Min $\sum_t \sum_j \sum_i (p_t(d(f,j) - d(f,i))w(f,i,j,t))$ subject to

These are the delay reductions if the GDP ends in scenario t and the associated probability.

- 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.