Analysis of Demand Uncertainty Effects in Ground Delay Programs

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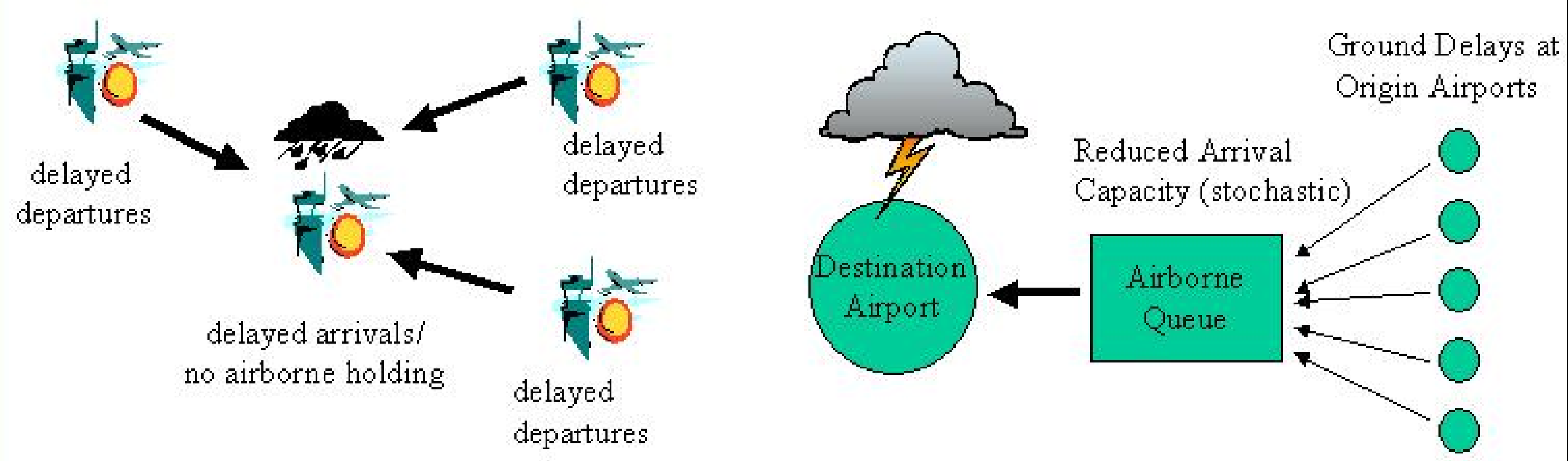
Introduction

The Federal Aviation Administration (FAA) and the aviation community within the U.S have recently adopted new operational procedures and decision support tools for implementing and managing Ground Delay Programs (GDPs) based on the Collaborative Decision Making paradigm. This study considers the effects of these procedures on uncertainty in demand, that is, the unpredictability of the arrival sequence during a GDP. More generally, our study considers the overall effects of demand uncertainty on GDP performance.

What is a GDP?

A GDP is a control action taken by the FAA to reduce arrival flow into an airport suffering from degraded arrival capacity or excess demand. Typically, capacity reductions are caused by bad weather. The implementation of GDPs consists of the assignment of ground delays to individual flights in accordance with a temporarily reduced airport arrival capacity (airport acceptance rate - AAR).



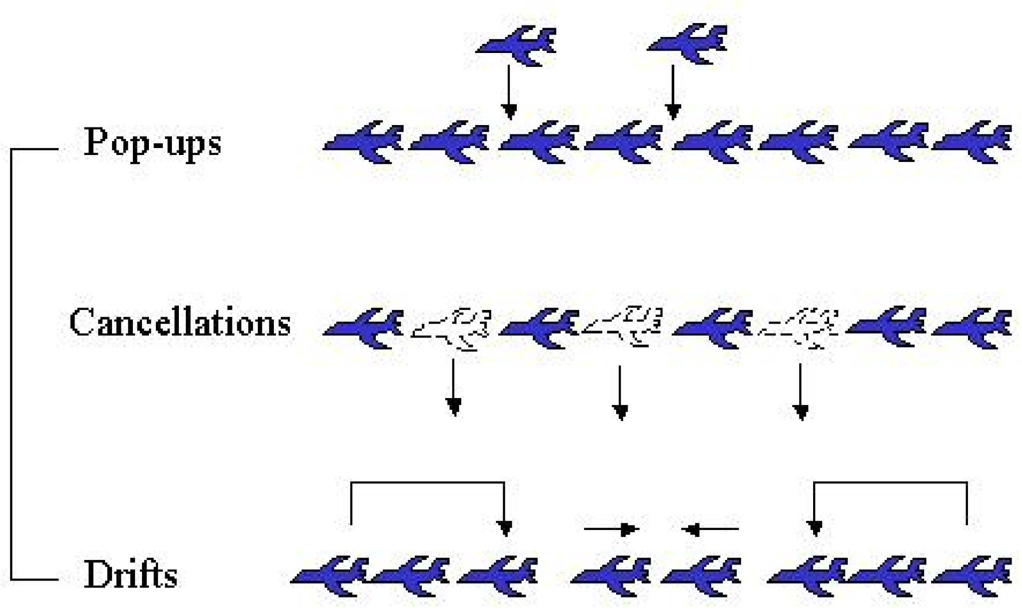
Demand Uncertainty during GDPs

Each GDP produces a *planned* arrival sequence based on controlled times of arrival, which take into account the ground delays that have been assigned. The actual arrival sequence, however, may differ substantially due to the uncertainty associated with flights. Historical analyses of GDPs indicate that the primary sources of demand uncertainty are flight cancellations, pop-ups and drifts.

Pop-up flights are unexpected flights that arrive during the GDP

Cancellations cause unexpected gaps in the arrival sequence

Drifts are flights that deviate from their assigned arrival times



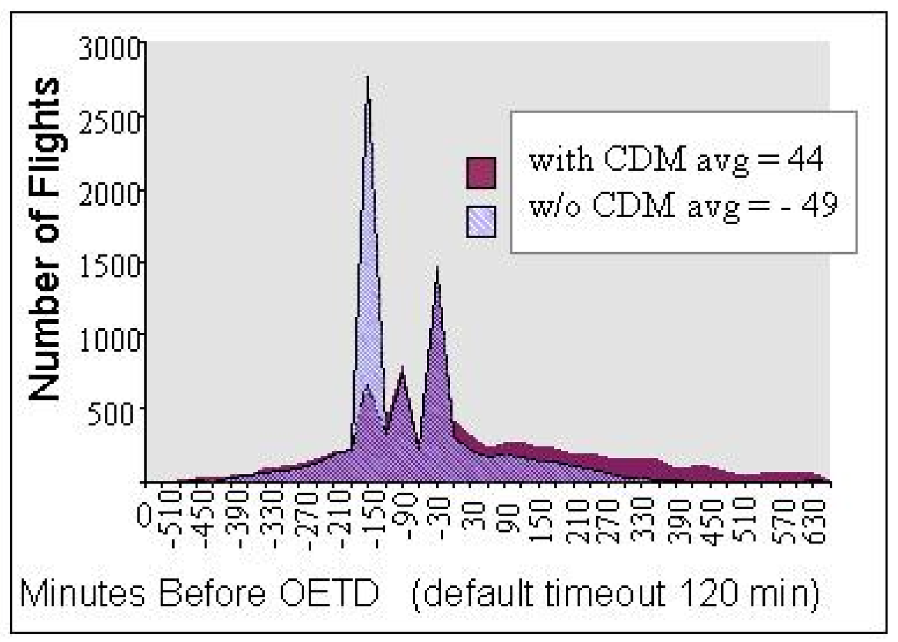
Research Questions

- What is the cost of the three forms of uncertainty, and what is value of reducing those uncertainties?
- Can changes be made to GDP planning or execution to better mitigate demand uncertainties?

Uncertainty and Collaborative Decision Making (CDM)

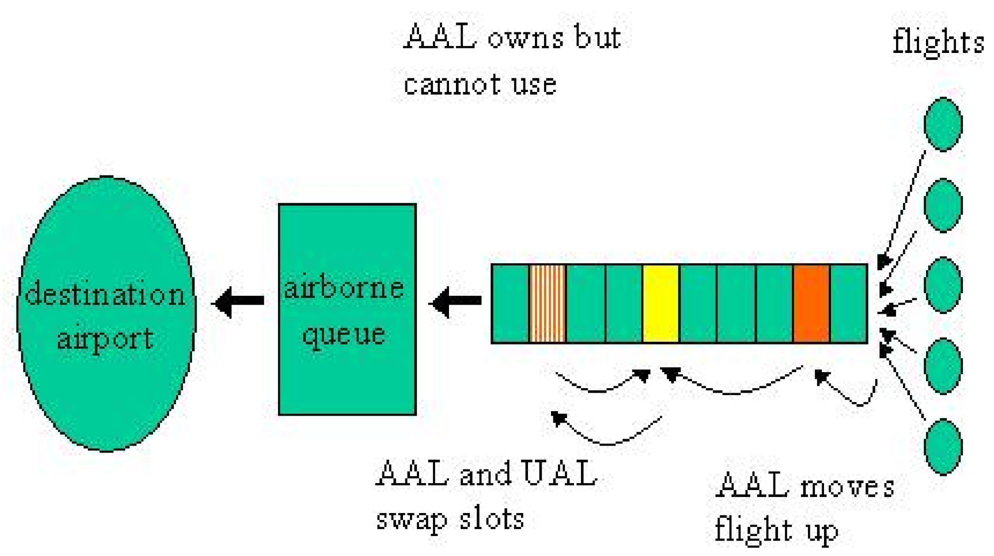
- CDM has improved information quality
  - CDMNet allows airlines and FAA to exchange operational information
  - new resource allocation mechanisms have removed disincentive for airlines to provide most up-to-date intent and status information
- CDM has introduced a dynamic reallocation procedure, Compression, that fills holes in arrival stream caused by flight delays and cancellations

Shift in Distribution of Cancellation Notification Times at SFO, Jan - May 1998



Under CDM, notices of flight cancellation are being received 93 minutes earlier (on average) than prior to CDM (*an improvement under CDM*)

Effects of Compression Algorithm



Net effect of compression:

- *win - win* for airlines because when compression fills open slots, it always gives preference to airlines that owned those slots in the first place
- slots that may have gone unfilled are used

Models to study the effects of Demand Uncertainty during GDPs

- An *Integer Programming model* that determines `optimal' plans in the presence of demand uncertainty. This model considers only flight cancellations and pop-ups as sources of uncertainty.
- A *simulation model* that measures the effects of demand uncertainty for a given plan. The simulation model considers all three sources of uncertainty.

Details on IP Model

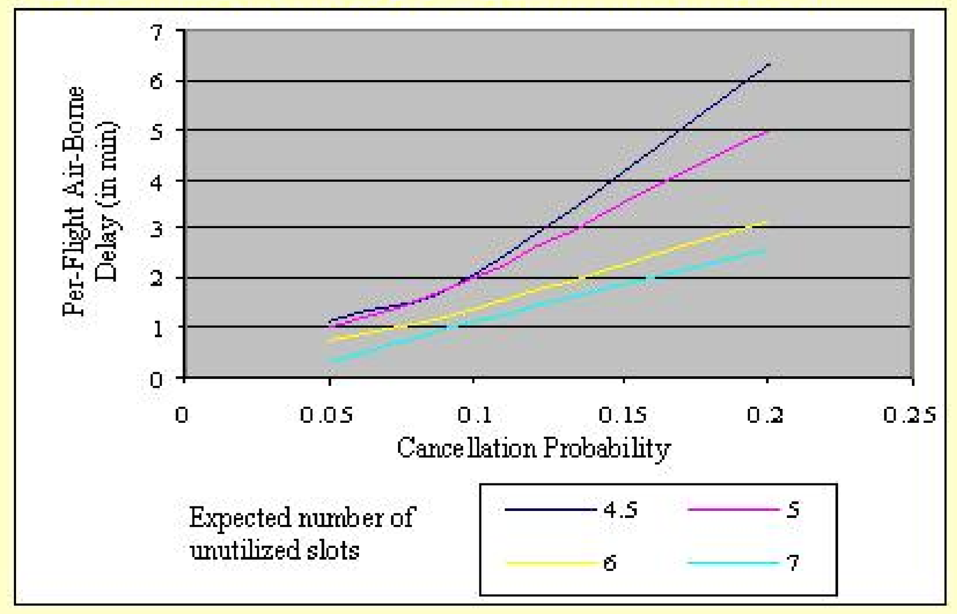
Objective Function : Minimize expected number of flights in airborne queue during GDP

Variables : $X_{paar}(t,k) = 1$ if PAAR in period t is k; 0 Otherwise.
$p(i,t)$ = probability that there are i flights in airborne queue at the end of period t.

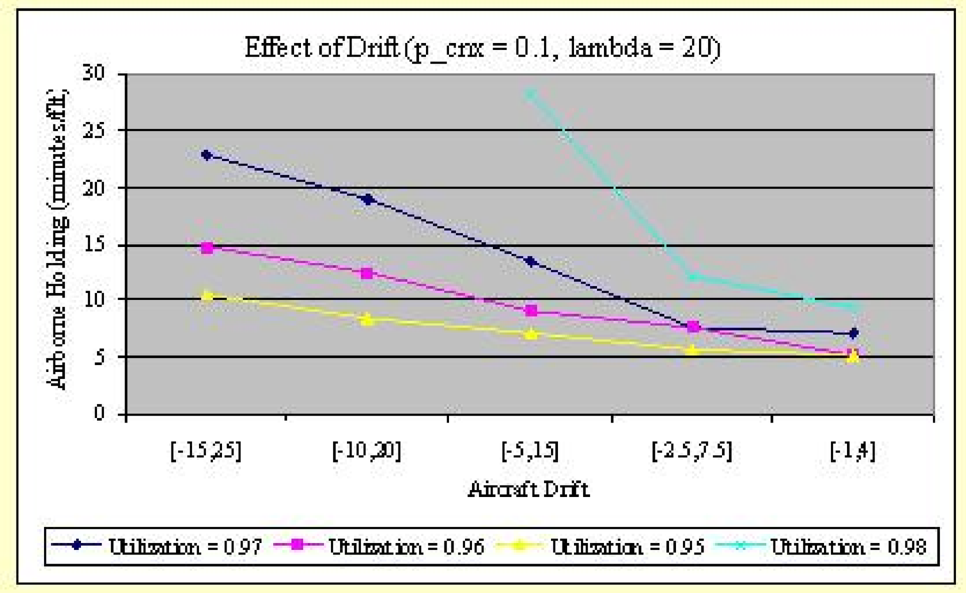
Main constraints : $p(j,t) = \sum_i q(i,j,t)\, p(i,t-1)$, where $q(i,j,t) = \text{Prob}\{i + \text{actual arrivals in } t - aar(t) = j\}$
Expected number of unutilized slots $\leq$ unutilization parameter " ε "

Conclusions

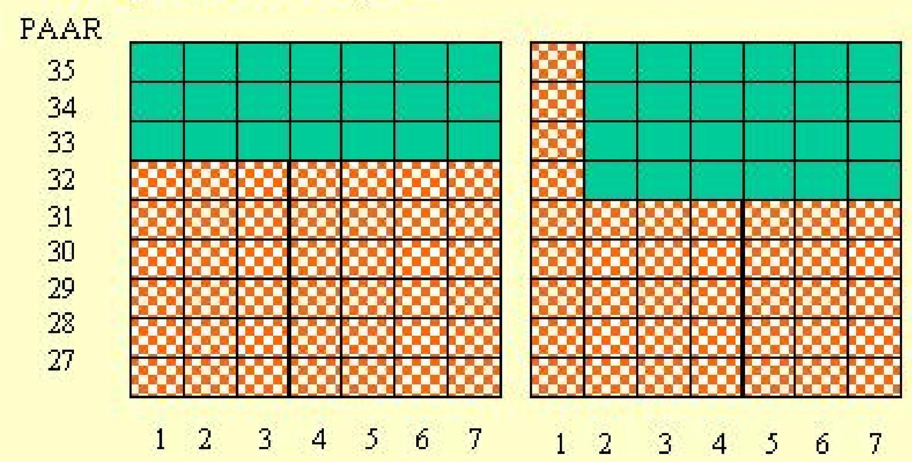
- Airborne Delay increases with Cancellation Probability (Integer Programming Model)



- Airborne Delay can be reduced by decreasing the window of drift (Simulation Model)



- Planned Arrival Rate (PAAR) patterns used today tend to be *flat*



- Optimization model suggests that uncertainty effects can be better mitigated by "stair stepping" arrivals