Analysis of Demand Uncertainty Effects in Ground Delay Programs

Thomas Vossen, Narender Bhogadi, Michael Ball, Robert Hoffman

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.

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.

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 disincentives 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

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

Effect of Compression Algorithm
- Compression Algorithm reduces airborne delay
  - AAL saves hub capacity
  - AAL uses but cannot see

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

Details on IP Model
Objective Function: Minimize expected number of flights in airborne queue during GDP
Variables: $X_{ij}(t,k) = 1$ if PAAR in period $i$ in state $k$, 0 otherwise.
$p(t)$ = probability that there are $i$ flights in airborne queue at the end of period $t$.
Main constraints:
- $p(t+1) = \sum_j q_{ij}(t+1)$, where $q_{ij}(t) = \text{Prob}(i + \text{actual arrivals in } t - \text{arr}(t) = j)$
- Expected number of unutilized slots $\leq$ unutilization parameter $\epsilon$