The Planning of Ground Delay Programs Subject to Uncertain Capacity

Michael Hanowsky  October 25, 2007

Advising Committee:
Prof. Cynthia Barnhart (Chair), Prof. Amedeo Odoni (Research Advisor), Prof. Joseph Sussman

Delays occur when arrival demand exceeds capacity

Demand Rate: 60 ac/hour

Arrival Rate: 60 ac/hour

Wind
GDPs create ground delays to avoid those in the air.

Demand Rate: 60 ac/hour

Arrival Rate: 60 ac/hour

Wind
Ground Delay Programs require more advance planning than other ATFM tools.
GDP design considers two key questions

• How much ground delay should be assigned?
  – Too much causes additional, unnecessary delays
  – Too little and expensive airborne delays may occur

• When should the GDP be created?
  – Waiting means that flights depart and cannot be delayed
  – Additional, improved capacity information becomes available over time

GDPs are both stochastic and dynamic
Academic literature highlights the use of optimization techniques

- Uncertain forecast arrival capacities can be quantified
  - MIT Lincoln Laboratory (2004): use airport-specific meteorological data
  - Hansen and Liu (2006): use historical AARs

- Linear programming techniques can model GDPs with uncertain arrival capacities
  - Odoni and Richetta (1993): stochastic and dynamic conditions
  - Mukherjee and Hansen (2004): aircraft based model

- GDPs with uncertain arrival capacities can be analyzed
  - Hanowsky (2006): Analysis of GDPs with uncertain capacity

Existing literature is concerned with system efficiency
Model IV Objective Function

Minimize:

\[
\sum_{q} p_q \times \sum_{f} \left( TDC_{fq} + ADC_{fq} + GDC_{fq} \right)
\]

Minimize the weighted sum of delay costs for all flights

Subject To: DELAY COST

\[
TDC_{fq} = \sum_{t=DT_f}^{T-1} \left( (1 - \lambda_{ftq}) \times \left( \tau_{t-DT_f+1} - \tau_{t-DT_f} \right) \right) \quad \forall \ f \in F; \ q \in Q
\]

\[
GDC_{fq} = \sum_{t=DT_f-ERT_f}^{T-ERT_f-1} \left( (1 - d_{ftq}) \times \left( \gamma_{t-DT_f+ERT_f+1} - \gamma_{t-DT_f+ERT_f} \right) \right) \quad \forall \ f \in F; \ q \in Q
\]

\[
AD_{fq} = \sum_{T} \left( \delta_{ftq} - \lambda_{ftq} \right) \quad \forall \ f \in F; \ q \in Q
\]

\[
ADC_{fq} \geq m_t \times AD_{fq} + b_t \quad \forall \ f \in F; \ t \in T; \ q \in Q
\]

From a system perspective, we seek to minimize the total expected cost
Flight delay by scheduled departure time

Delay Cost by Scheduled Departure Time for FC

[Graph showing delay cost by scheduled departure time]
Flight delay by scheduled arrival time

**Delay Cost by Scheduled Arrival Time for FC**

- **Y-axis:** Delay Cost
- **X-axis:** Time (Z)

The graph shows the relationship between delay cost and scheduled arrival time. The cost decreases as the scheduled arrival time approaches later hours, indicating that delays are more costly as they occur closer to the scheduled time.
The “wait and see” approach avoids uncertainty.

“Wait and see” is reinforced in practice by GDP “scope”
The “wait and see” approach also sets a scope.
Average and StDev of delay by flight distance

Summary of Flight Delay Costs by Distance

Average (Exp) Delay Cost by Flight Distance
Average and StDev of delay by flight carrier

Summary of Flight Delay Costs by carrier

Average (Exp) Delay Cost by Flight
Summary of Flight Delay Costs by type
GDP-TFM Model Results

Summary of Flight Delay Costs by type

Average (Exp) Delay Cost by Flight Type

- RJ
- B777
- B767
- MD
- B757
- B747
- A340
- A330
- A320
- A319
- A318

0 5 10 15 20 25 30 35

160
140
120
100
80
60
40
20
0