Demand Uncertainty in Ground Delay Programs

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Introduction

- Models to support GDP decision-making have been studied extensively
  - Richetta & Odoni (1993,1994)
  - Hoffman (1997)
  - Ball et al. (2003)
  - Mukherjee (2003)

- General Approach
  - Determine optimal planned arrival rates in the presence of *stochastic* capacities

Motivation

- But what about *Demand* Uncertainty?

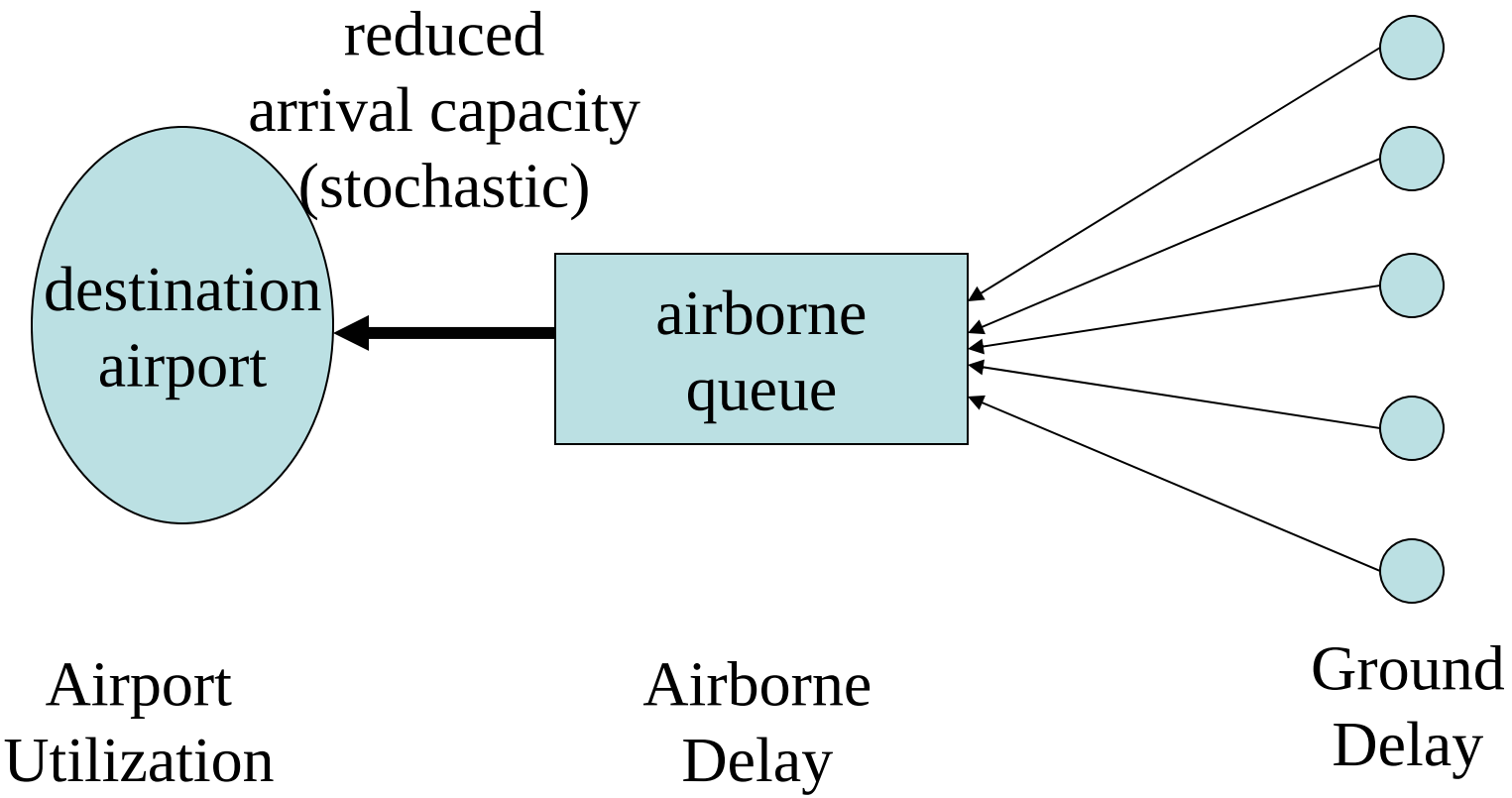
- Considering Demand Uncertainty
  - *May indicate alternate approaches to GDP planning*
  - *May be used to measure the "value of information-sharing"*
    - Alternate approach to measuring CDM benefits

Research Questions

- How to plan GDPs in the presence of Demand Uncertainty?
  - How does it compare with current approaches?
- What is the cost of uncertainty and what is the value of reducing that uncertainty?
  - What is extent/nature of CDM benefits?

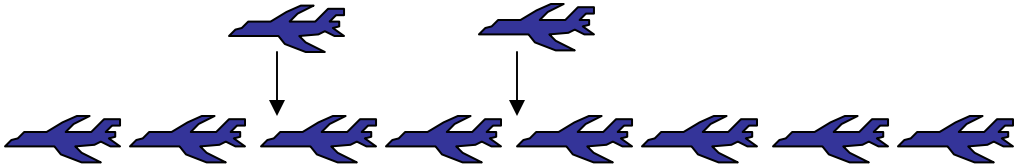
Modeling Demand Uncertainty

- Measuring Quality of GDP Planning and Execution

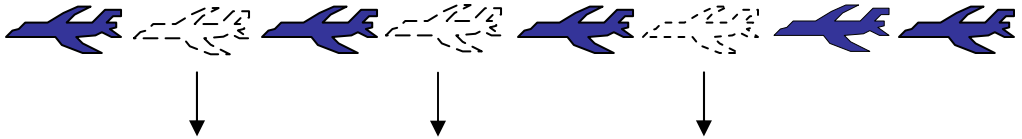


Sources of Demand Uncertainty

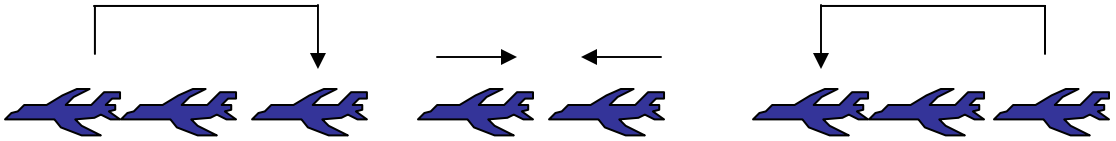
Popups



Cancellations

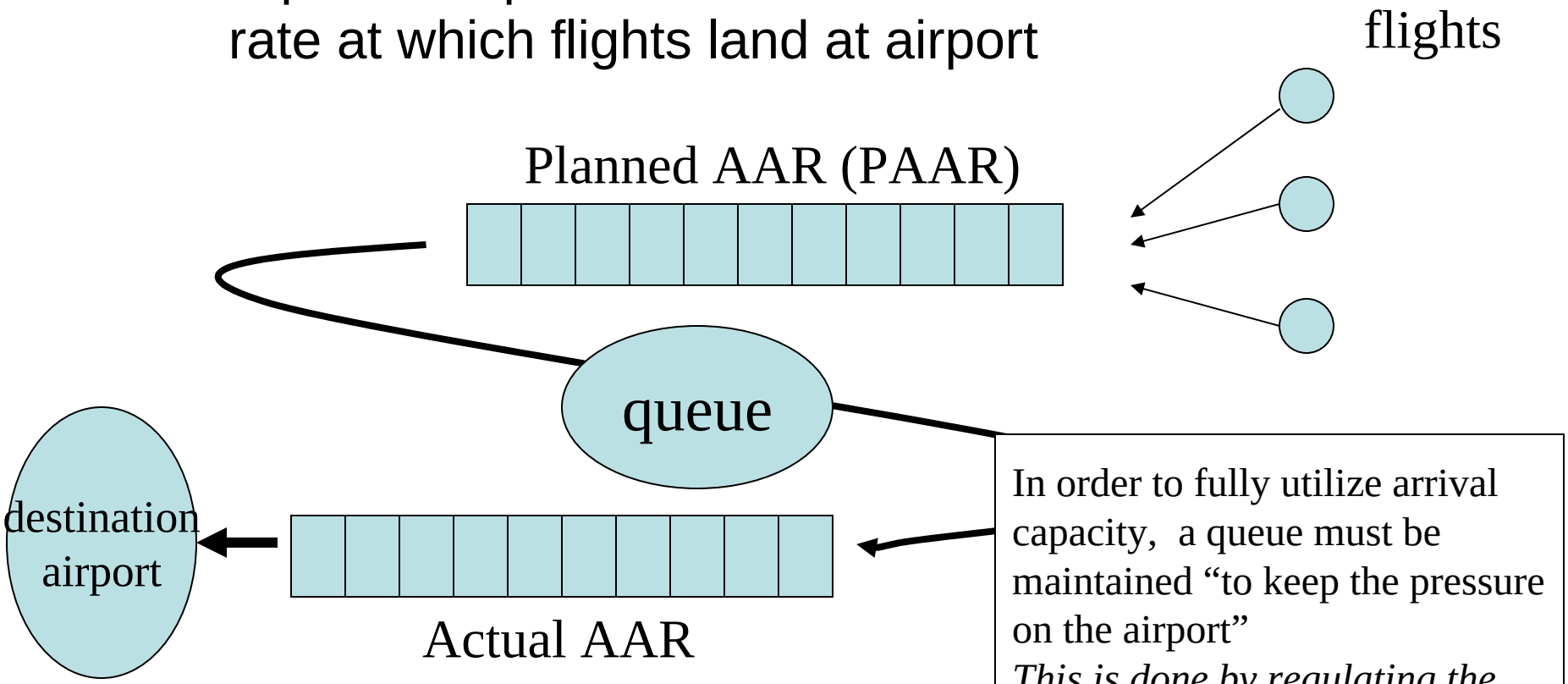


Drift



Planned vs. Actual Airport Acceptance Rate

AAR: airport acceptance rate
rate at which flights land at airport



In order to fully utilize arrival capacity, a queue must be maintained "to keep the pressure on the airport"
This is done by regulating the value of the PAAR

Model Alternatives

1. Minimize $E[\text{Airborne Holding}|\ \vec{n}]$
   subject to

$$E[\text{Unutilized slots}|\ \vec{n}] \ \leq\ \varepsilon$$

or

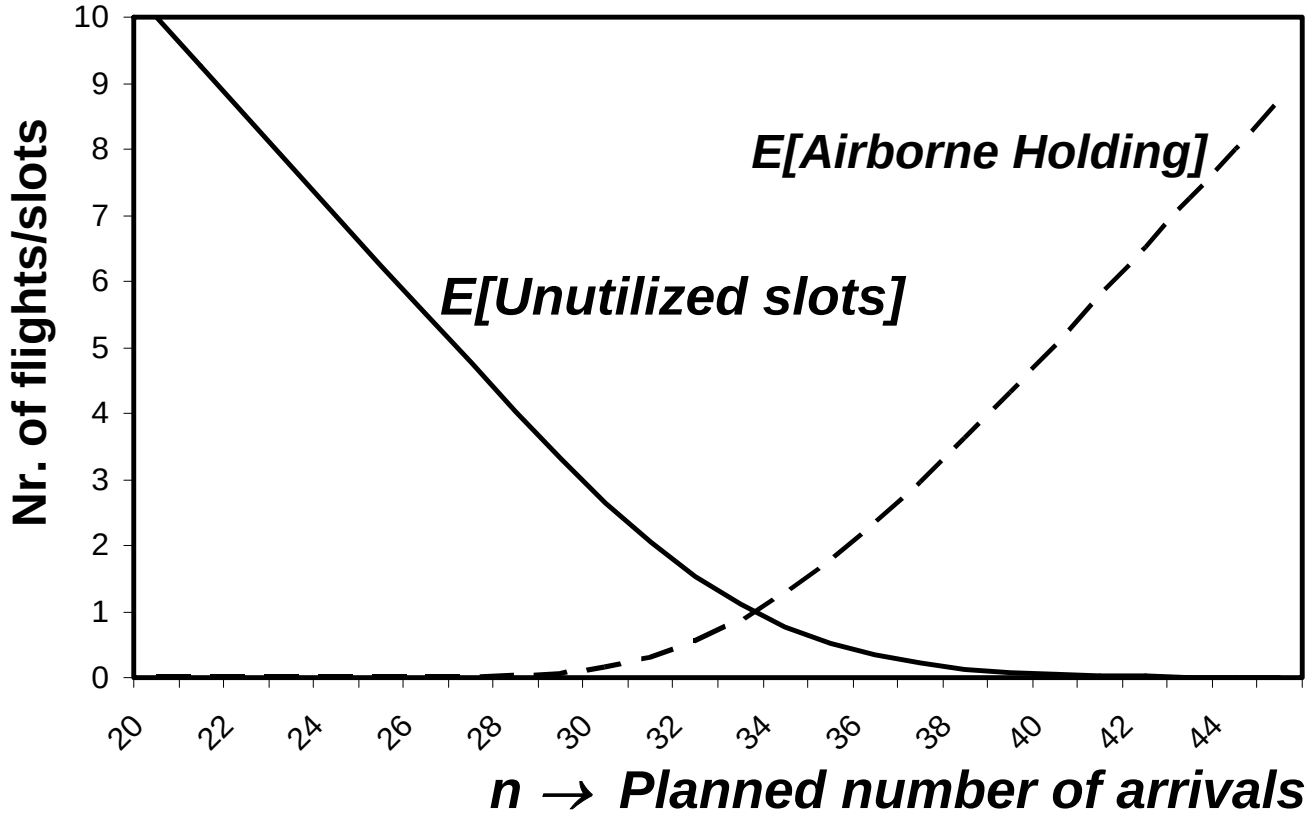
$$Pr\{\text{Unutilized slots}|\ \vec{n}\} \ \leq\ \varepsilon$$

2. Minimize $w_A E[\text{Airborne Holding}|\ \vec{n}] + w_U E[\text{Unutilized slots}|\ \vec{n}]$

Where

- $\vec{n}$: vector of planned arrival rates
- Given capacities, pop-up/cancelation probabilities (*no drift*)

Example: Single Period GDPs



Multiple Period GDPs

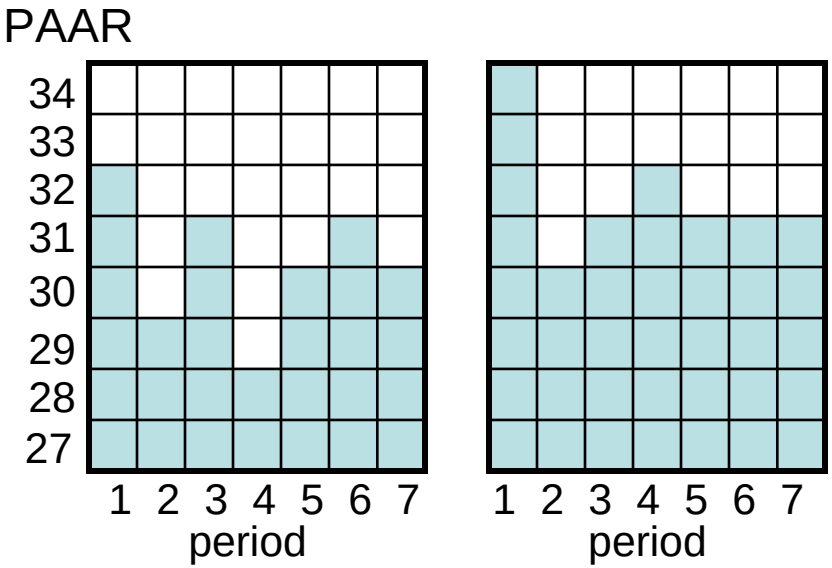
An efficient heuristic:

- **Period 1:**
  - Schedule smallest number of flights such that utilization requirement is met
- **Period 2:**
  - Schedule smallest number of flights such that utilization requirement is met, given the current distribution of flights in queue
- **Etc.**

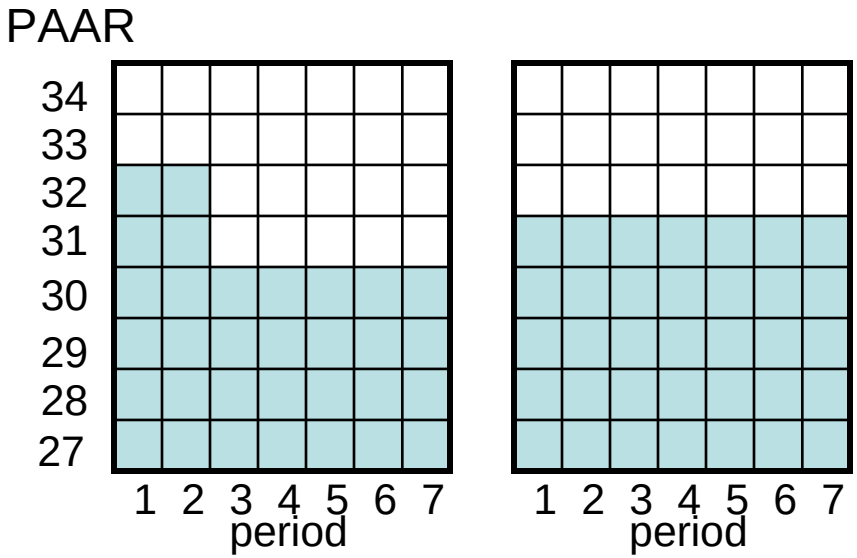
→ *In fact, optimal for all instances considered*

Results

- Model suggest more staggered PAAR patterns



Sample PAARs
suggested by Model



Typical PAARs
used today

The Value of Information-Sharing

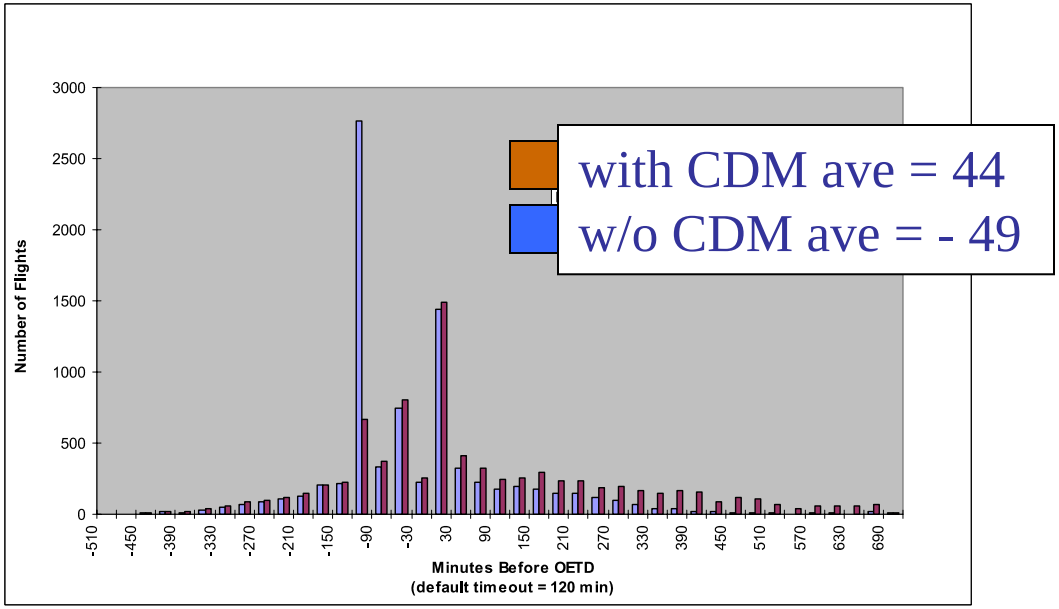
Concepts

- Information-sharing has led to reduction in demand uncertainty
- Reduction in demand uncertainty allows for lower PAARs
  - Lower levels of airborne holding while maintaining utilization
  - Higher utilization while maintaining airborne holding levels

Information Improvements under CDM

- CDM has improved information quality
  - CDMnet
  - Resource Allocation Procedures:
    - Compression eliminates “holes” in arrival stream

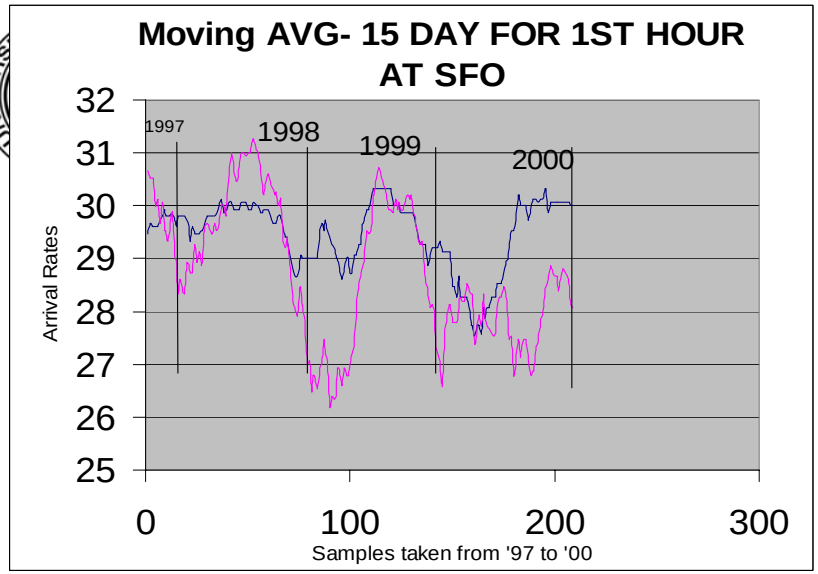
Shift in Distribution of Cancellation Notification Time (minutes before OETD)

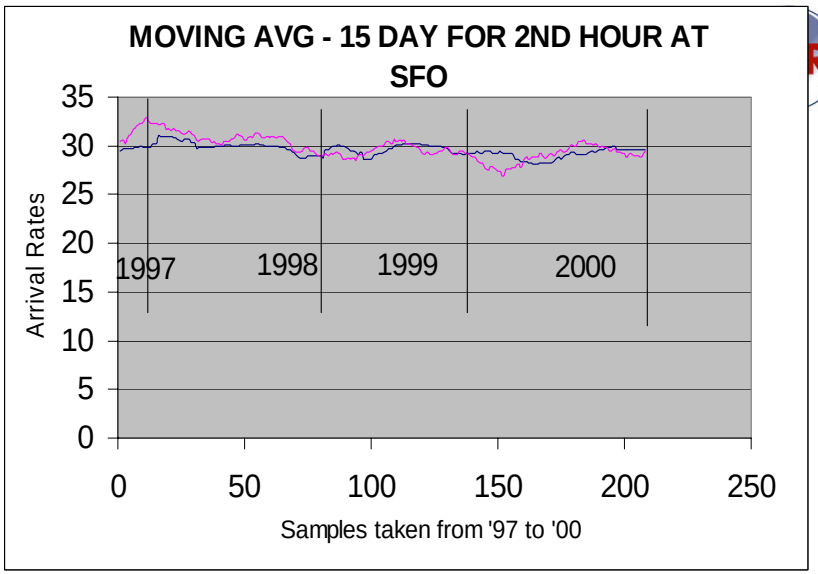


Analysis

- Considered PAAR vs Actual AAR (arrivals) for by hour for two airports;
  - Tried to group GDPs, e.g. only morning GDPs at SFO
  - ATL: used command center logs for PAAR and AAR
  - SFO: used logs for PAAR, tower counts for AAR.

- Key Questions:
  - Is PAAR or AAR increasing or decreasing (improvement = increase in AAR)
  - Is deviation of PAAR from AAR changing (improvement: PAAR and AAR closer together)

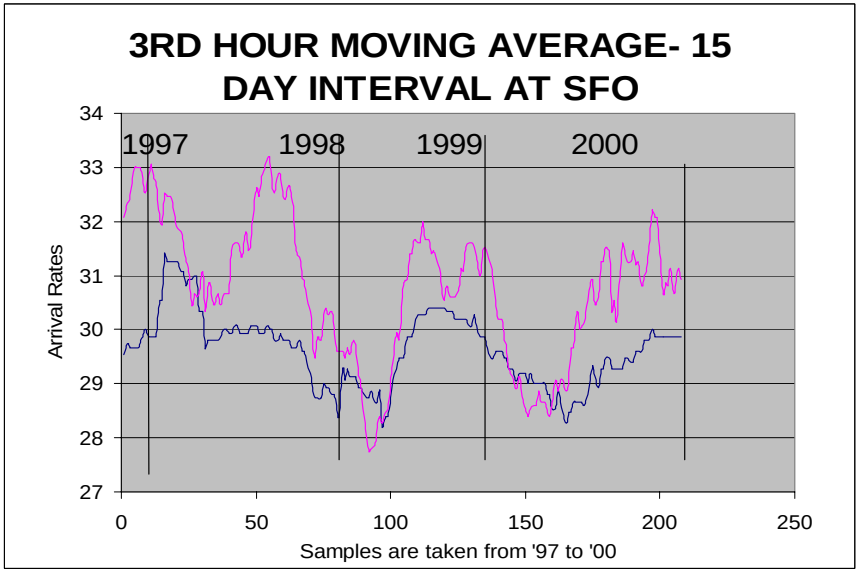


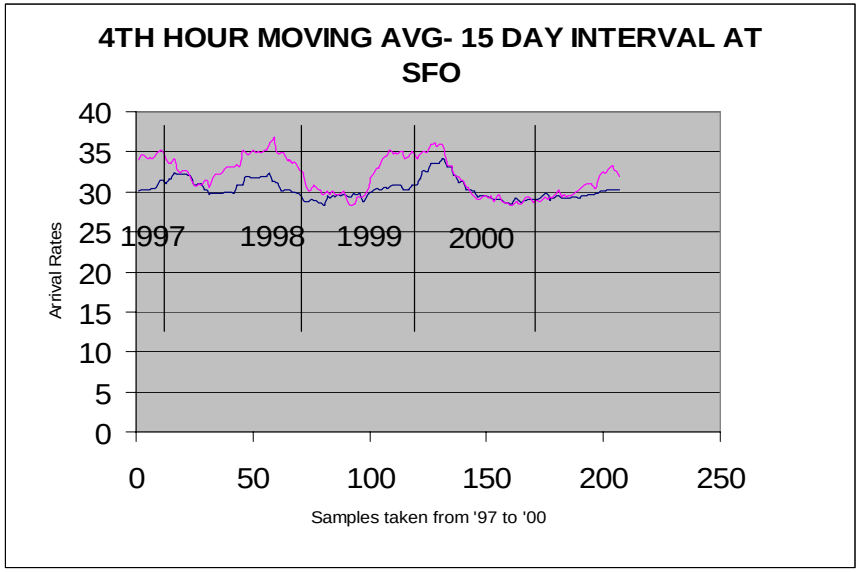


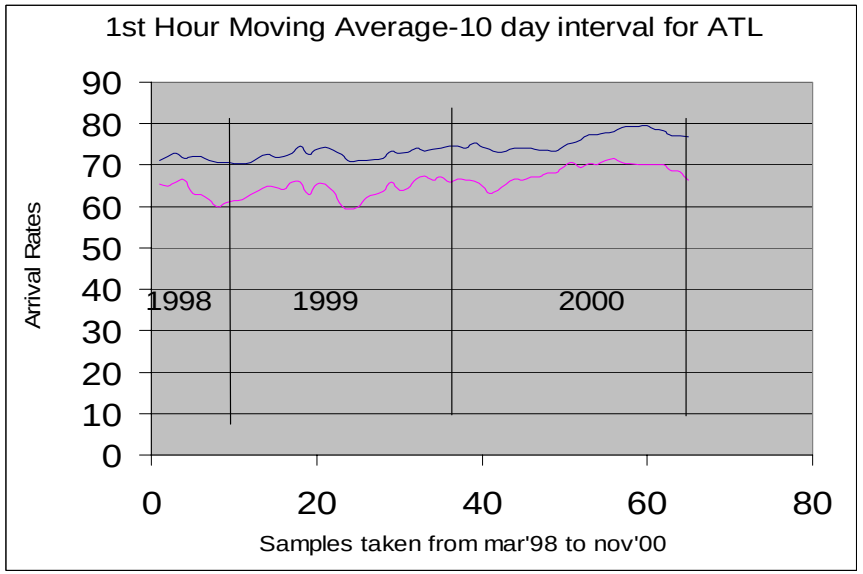
PAAR

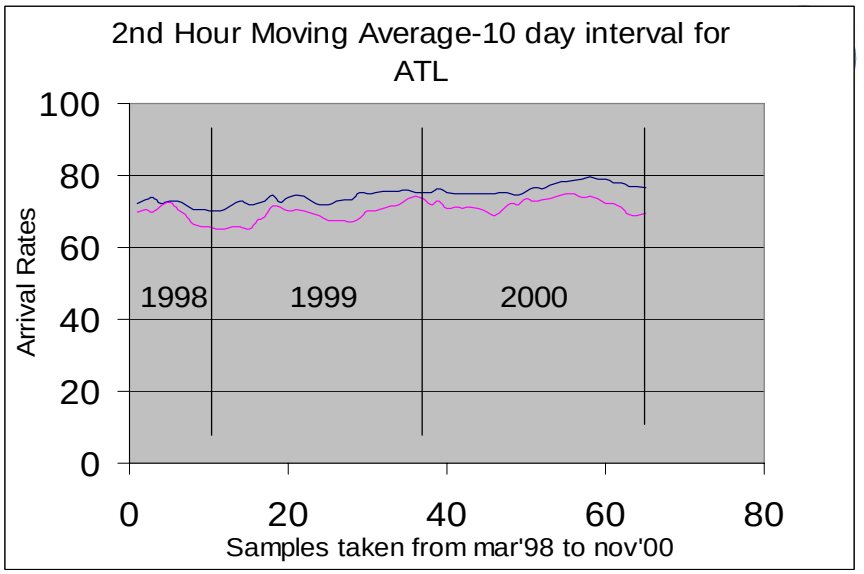
SFO

Actual AAR

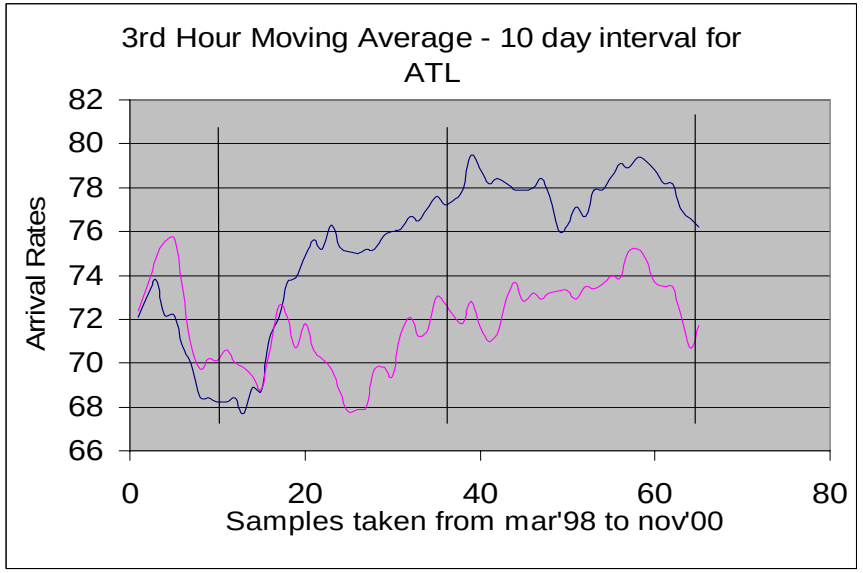


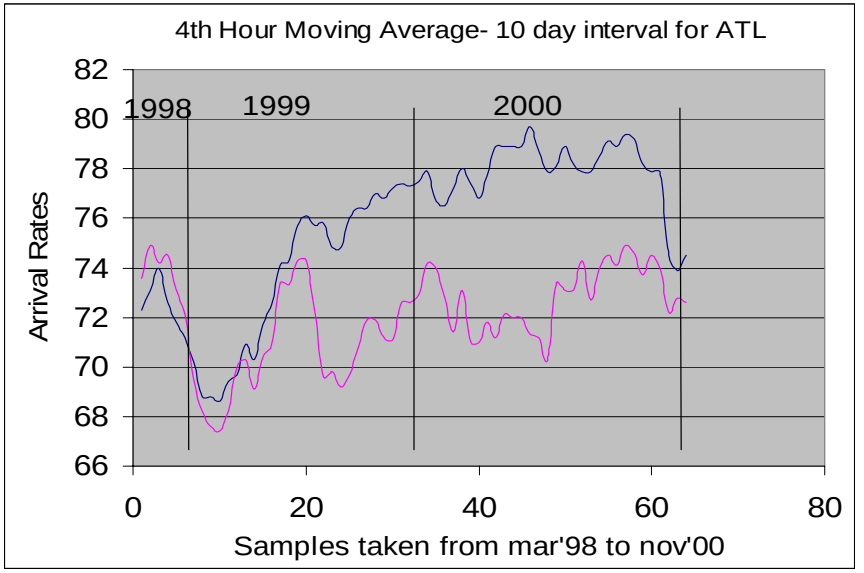






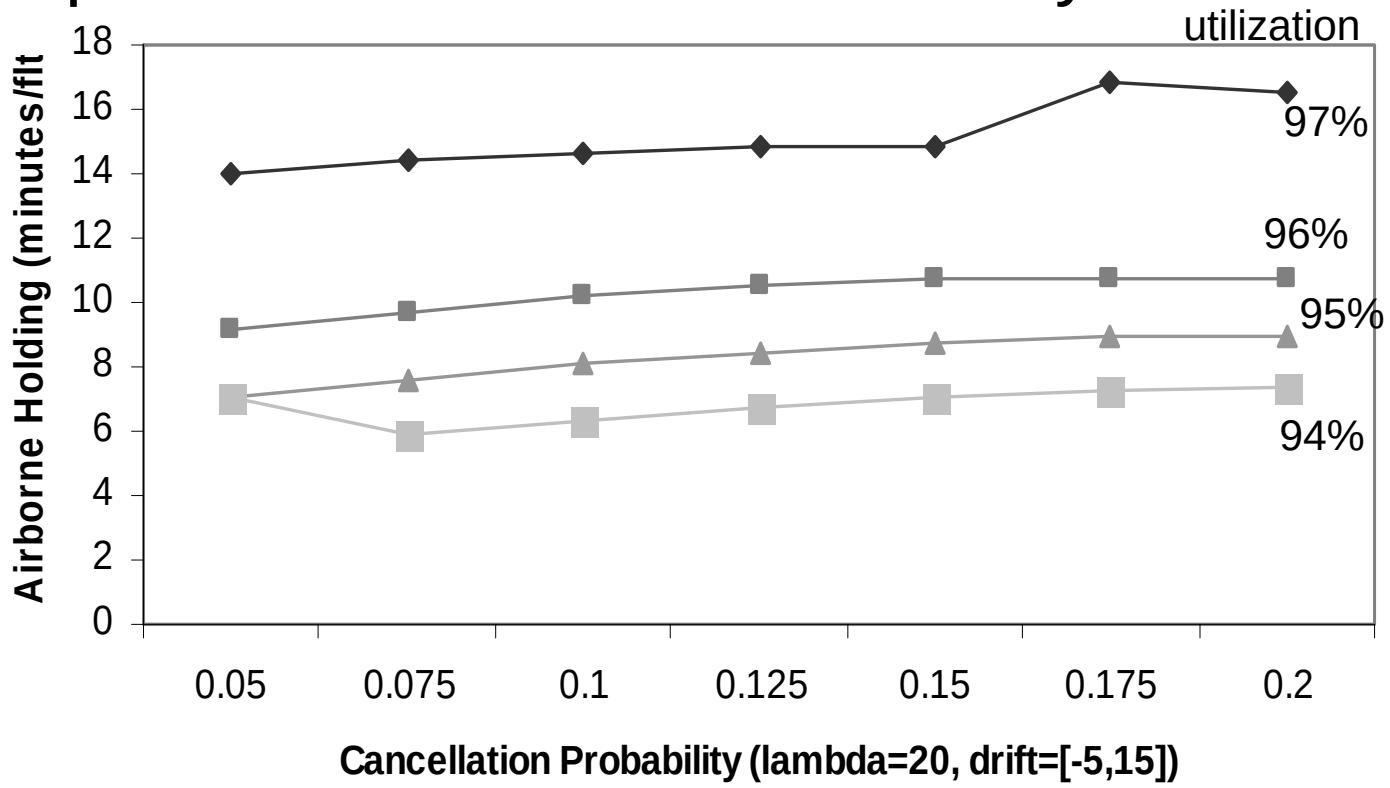
PAAR **ATL** Actual AAR





“Marginal” Effects of Demand Uncertainty

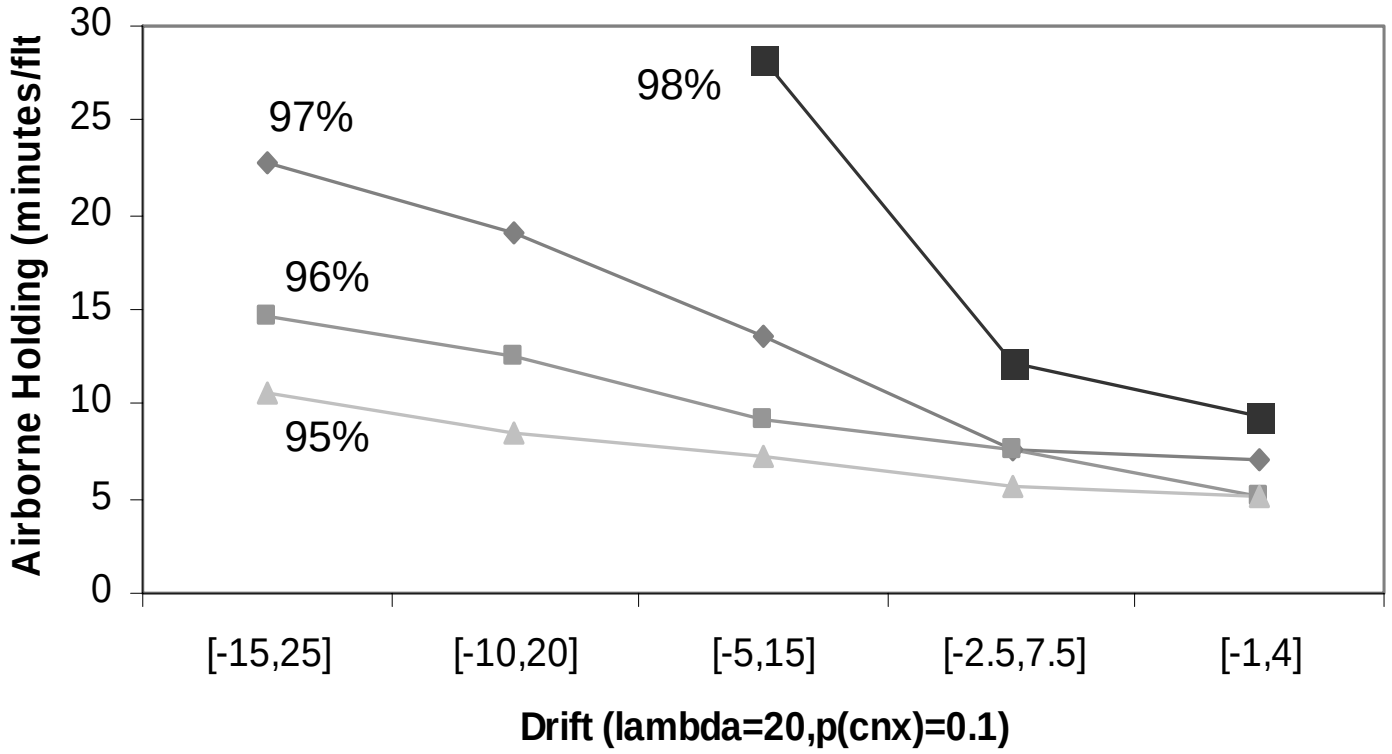
- Impact of Cancellation Probability



Simulation Model used to obtain results

“Marginal” Effects of Demand Uncertainty

- Impact of Drift



Simulation Model used to obtain results

Summary & Conclusions

- Demand Uncertainty can have significant impact on GDP performance
  - Drift may be most important
- No clear evidence (yet) that information improvements have led to actual uncertainty reduction benefits
  - Further analysis necessary
  - Impact of recent initiatives: *SCS, pop-up policy, etc.*
- Alternative PAAR-setting policies may prove beneficial
  - Further Analysis of optimization models