

# *Demand* Uncertainty in Ground Delay Programs

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# Introduction

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- 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

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- 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

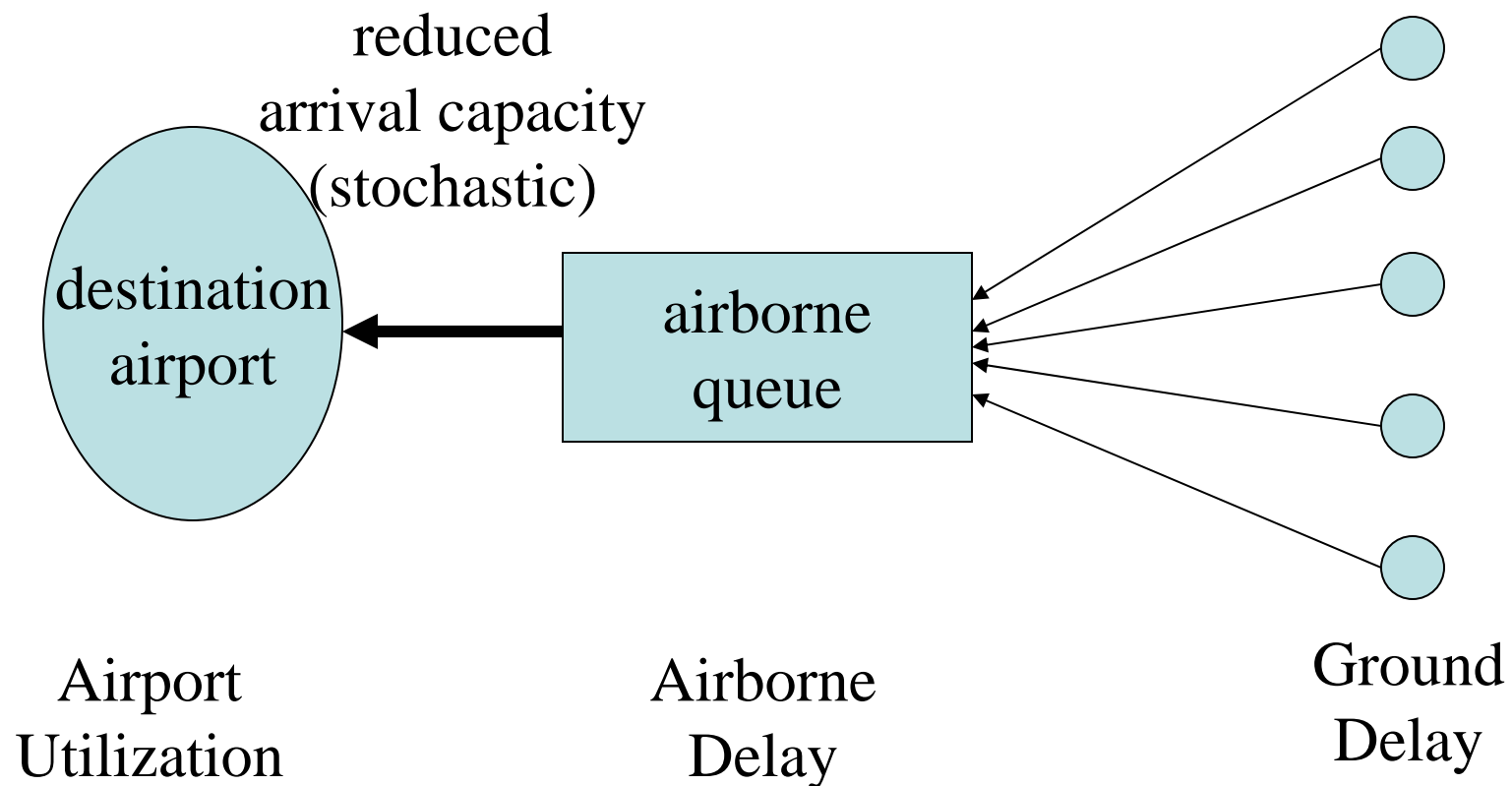
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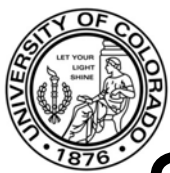
- How to plan GDPs in the presence of Demand Uncertainty?
  - How does it compare with current approaches?
- What is the cost of uncertainty and what is the value of reducing that uncertainty?
  - What is extent/nature of CDM benefits?



# Modeling Demand Uncertainty

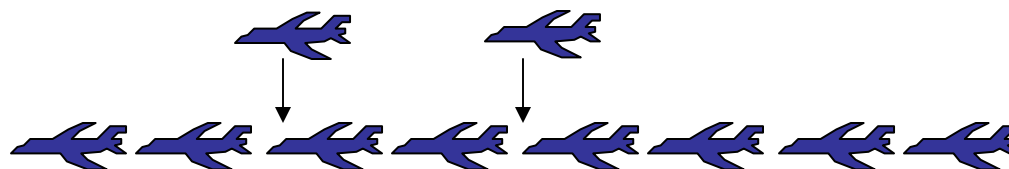
- Measuring Quality of GDP Planning and Execution



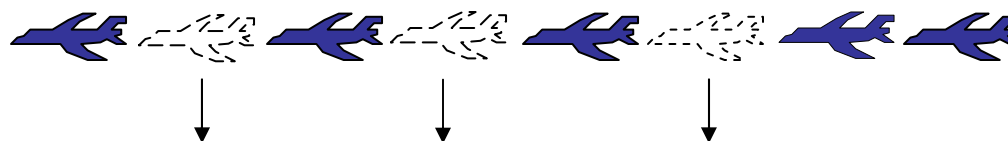


# Sources of Demand Uncertainty

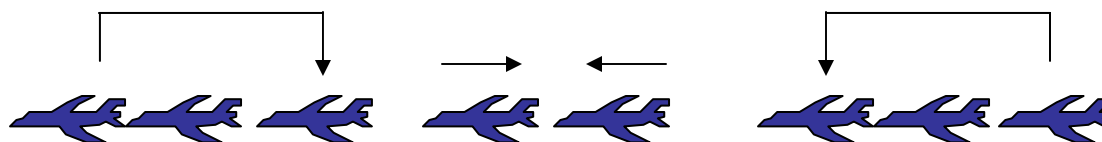
Popups



Cancellations



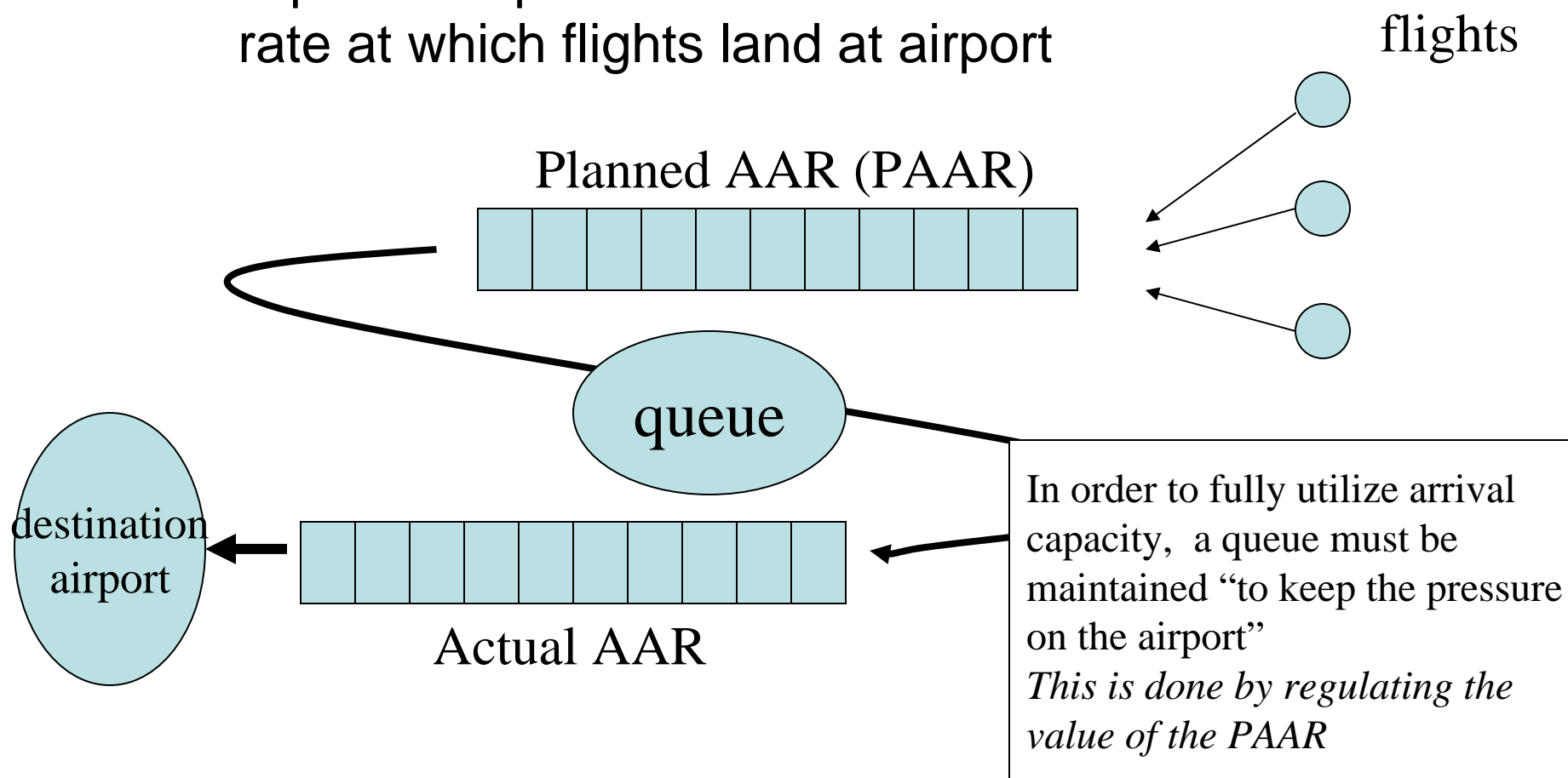
Drift





# Planned vs. Actual Airport Acceptance Rate

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





# Model Alternatives

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

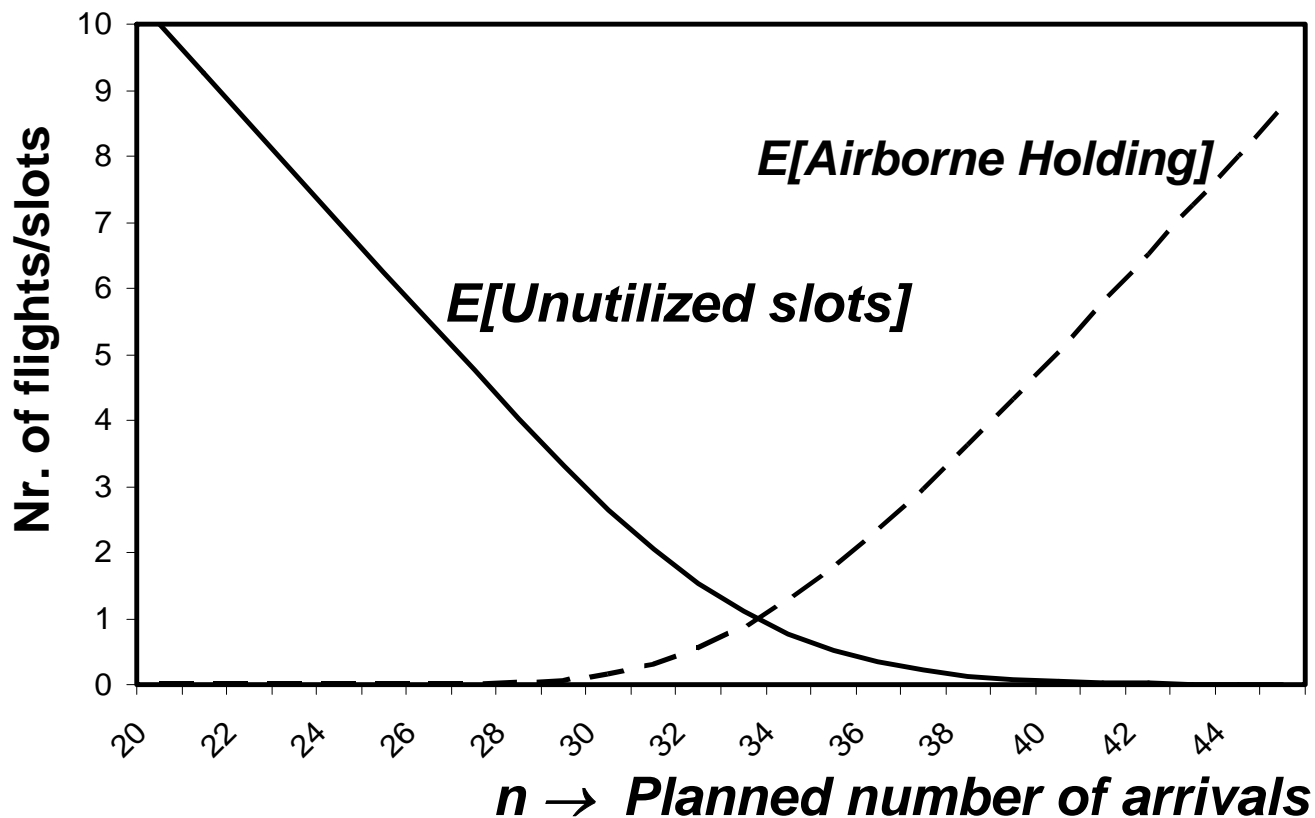
Where

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





# Example: Single Period GDPs





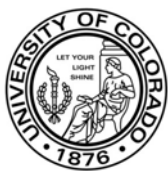
# Multiple Period GDPs

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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.**

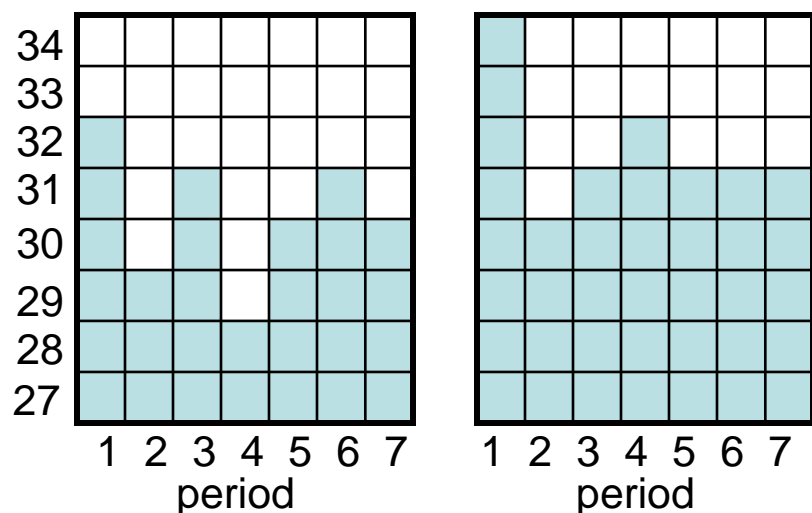
→ *In fact, optimal for all instances considered*



# Results

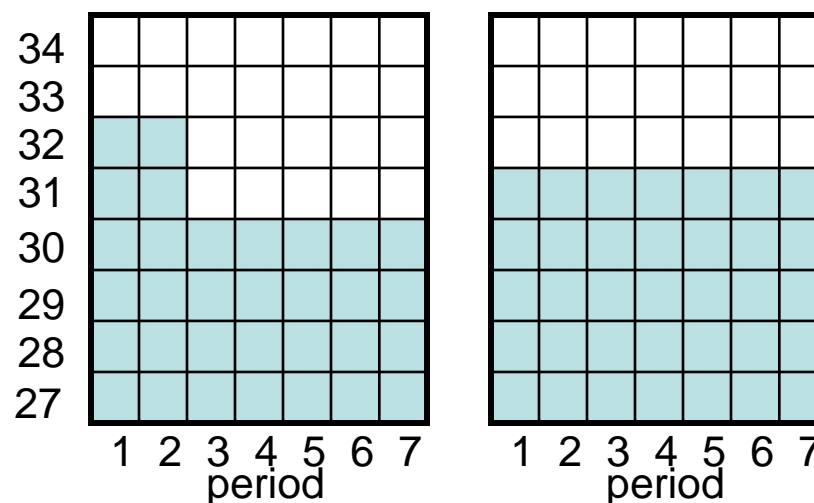
- Model suggest more staggered PAAR patterns

PAAR



Sample PAARs  
suggested by Model

PAAR



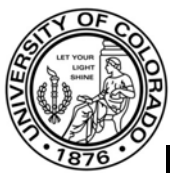
Typical PAARs  
used today



# The Value of Information-Sharing

## Concepts

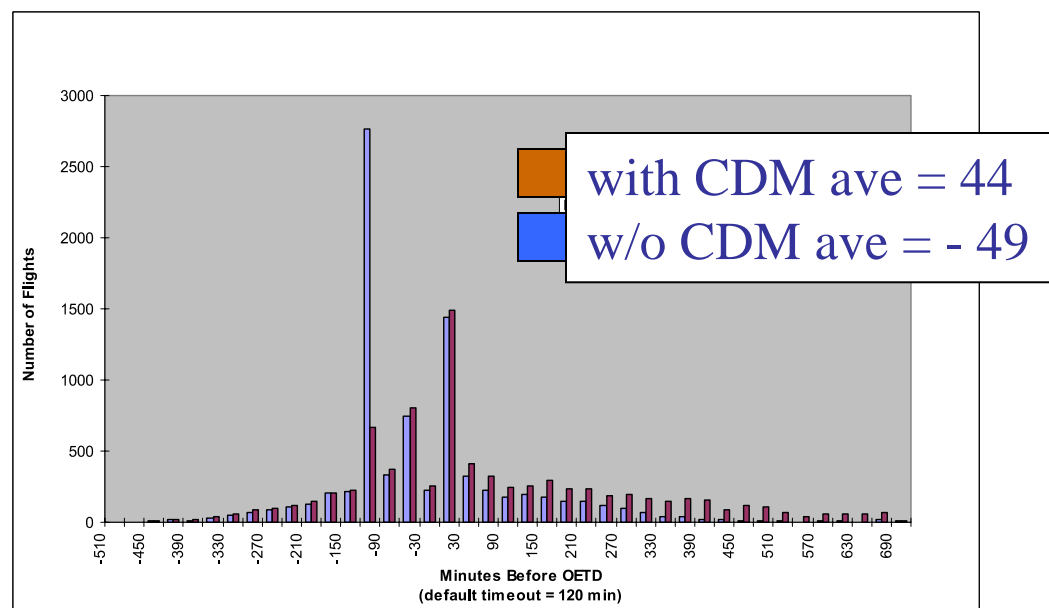
- Information-sharing has led to reduction in demand uncertainty
- Reduction in demand uncertainty allows for lower PAARs
  - Lower levels of airborne holding while maintaining utilization
  - Higher utilization while maintaining airborne holding levels



# 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)

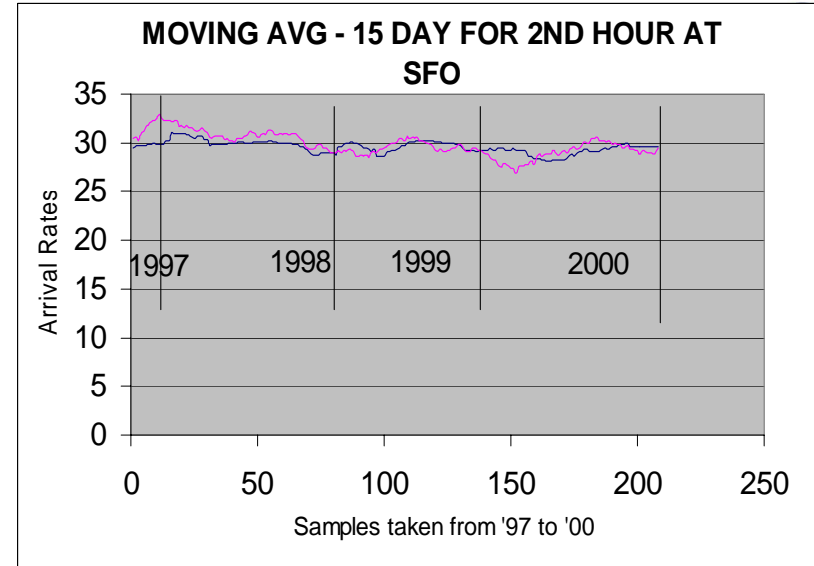
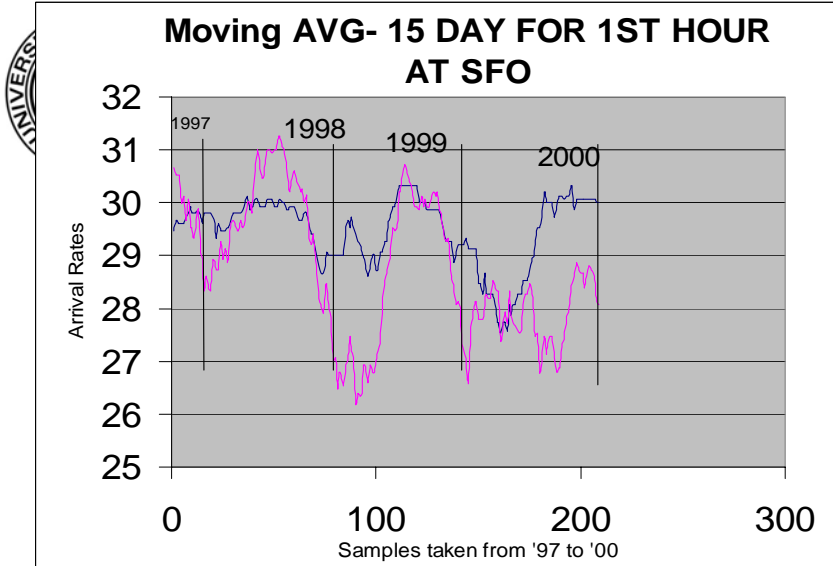




# Analysis

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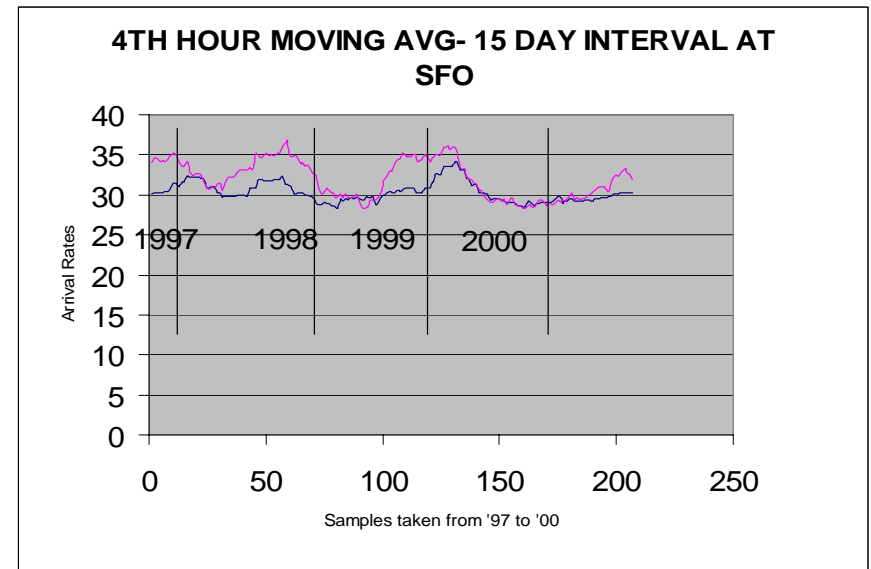
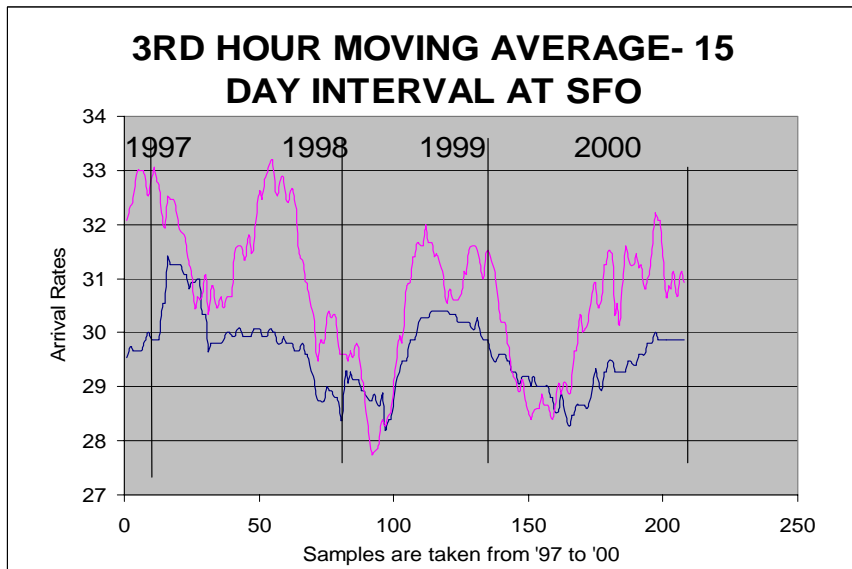
- Considered PAAR vs Actual AAR (arrivals) for by hour for two airports;
  - Tried to group GDPs, e.g. only morning GDPs at SFO
  - ATL: used command center logs for PAAR and AAR
  - SFO: used logs for PAAR, tower counts for AAR.
- Key Questions:
  - Is PAAR or AAR increasing or decreasing (improvement = increase in AAR)
  - Is deviation of PAAR from AAR changing (improvement: PAAR and AAR closer together)

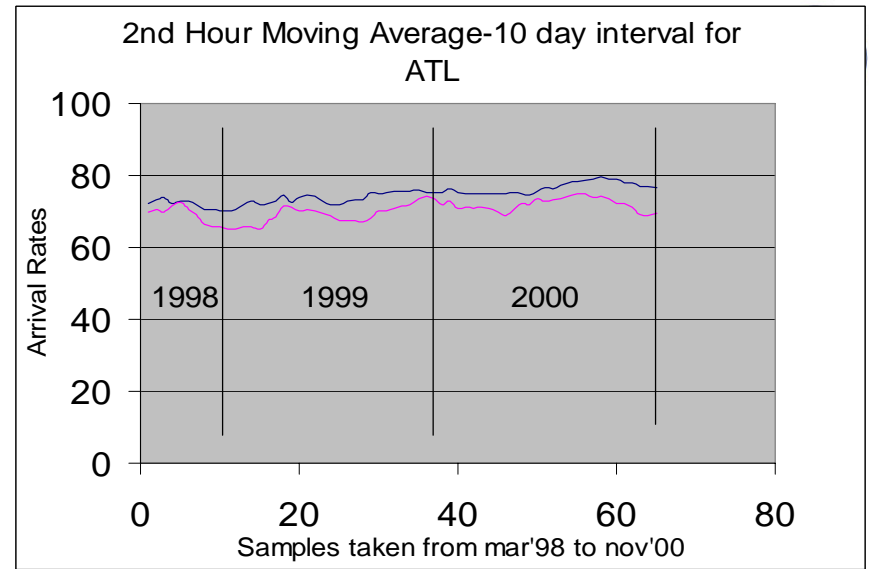
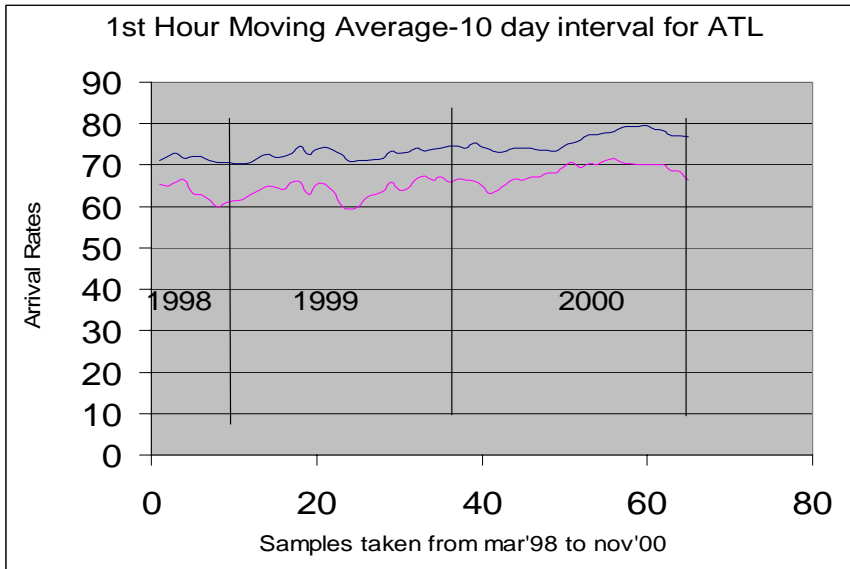


— PAAR

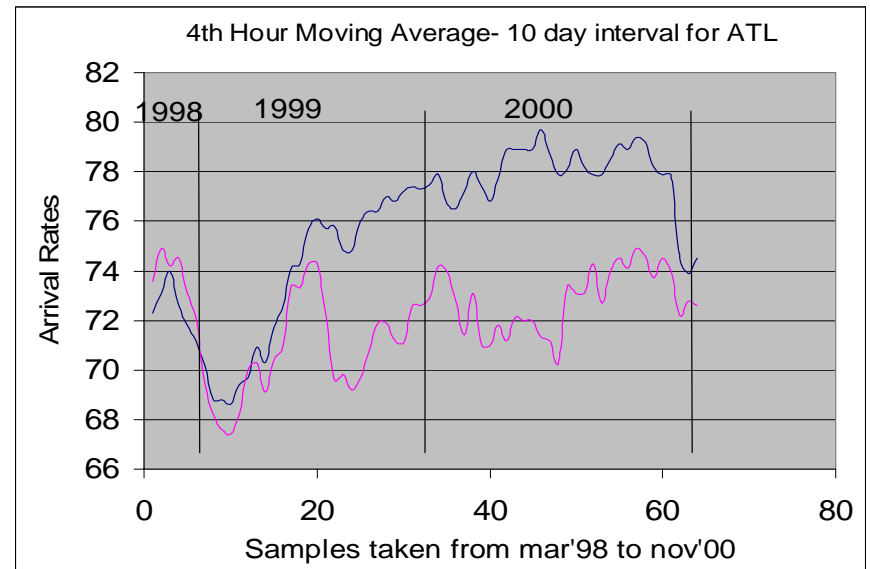
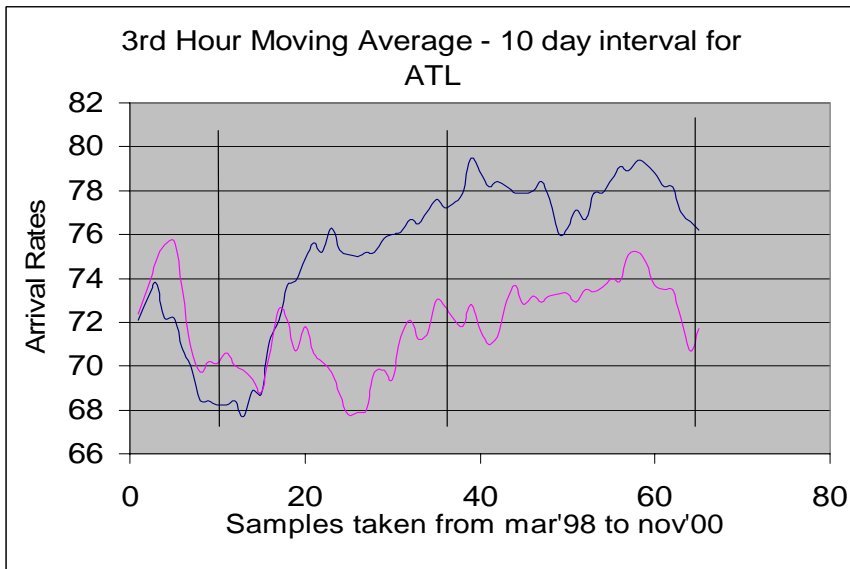
**SFO**

— Actual AAR





— PAAR ATL — Actual AAR

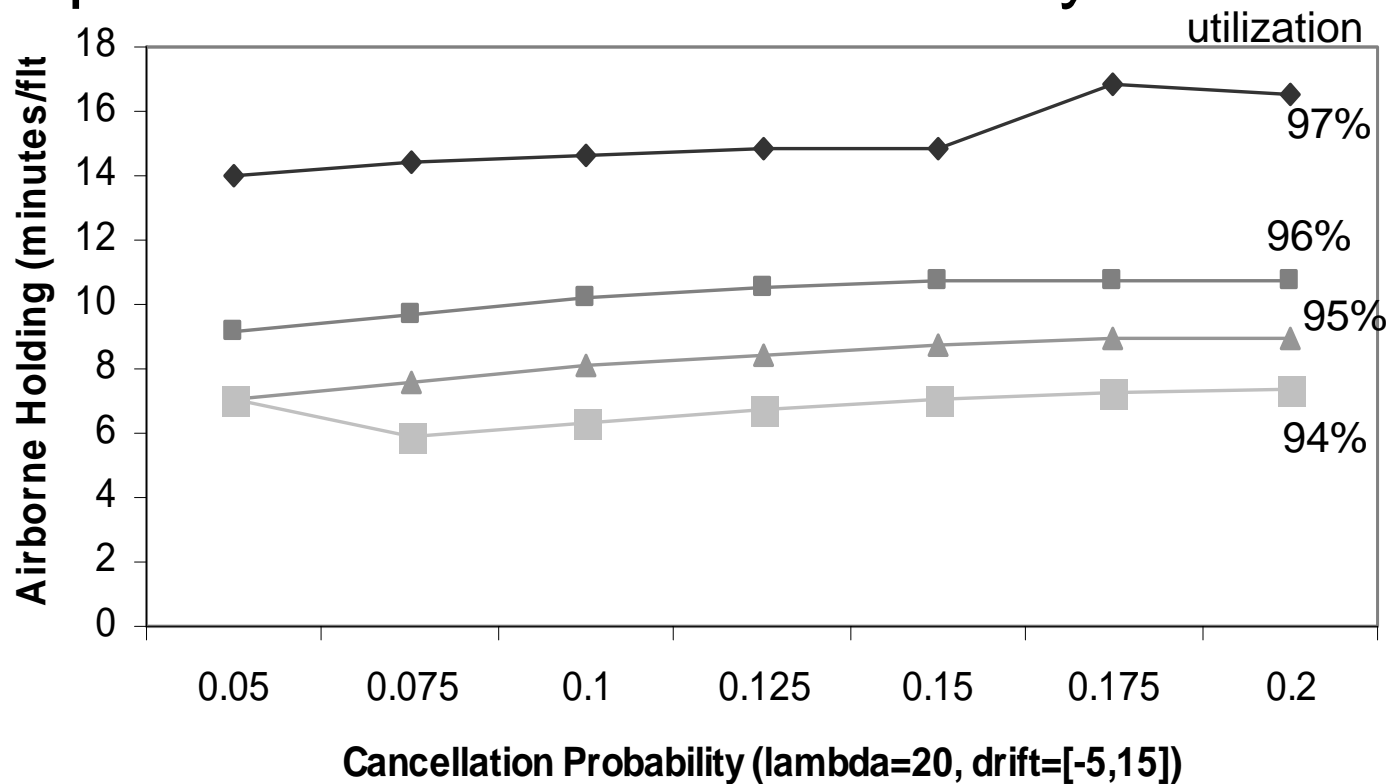






# “Marginal” Effects of Demand Uncertainty

- Impact of Cancellation Probability

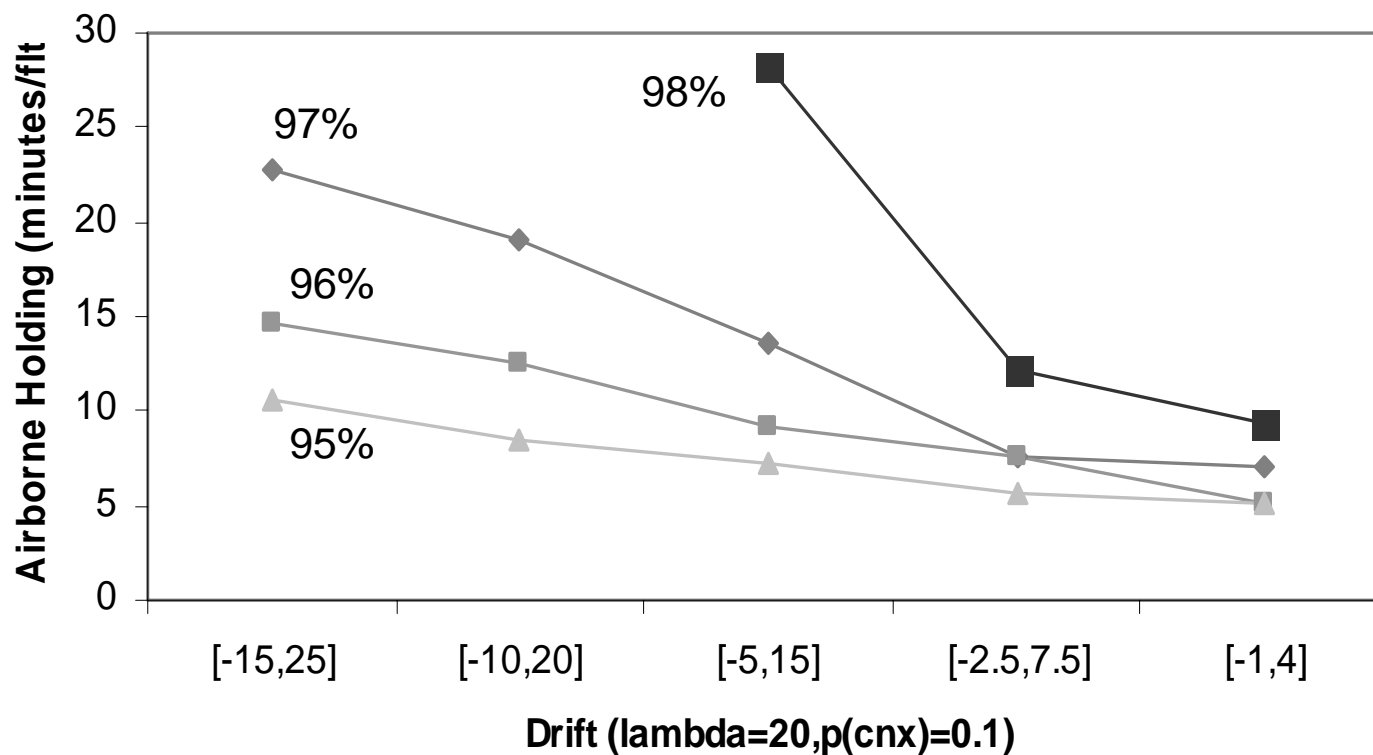


*Simulation Model used to obtain results*



# “Marginal” Effects of Demand Uncertainty

- Impact of Drift



*Simulation Model used to obtain results*



# Summary & Conclusions

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- 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