



NATIONAL CENTER OF EXCELLENCE FOR  
**NEXTOR**

Quantifying and Reducing Demand  
Uncertainty in Ground Delay  
Programs

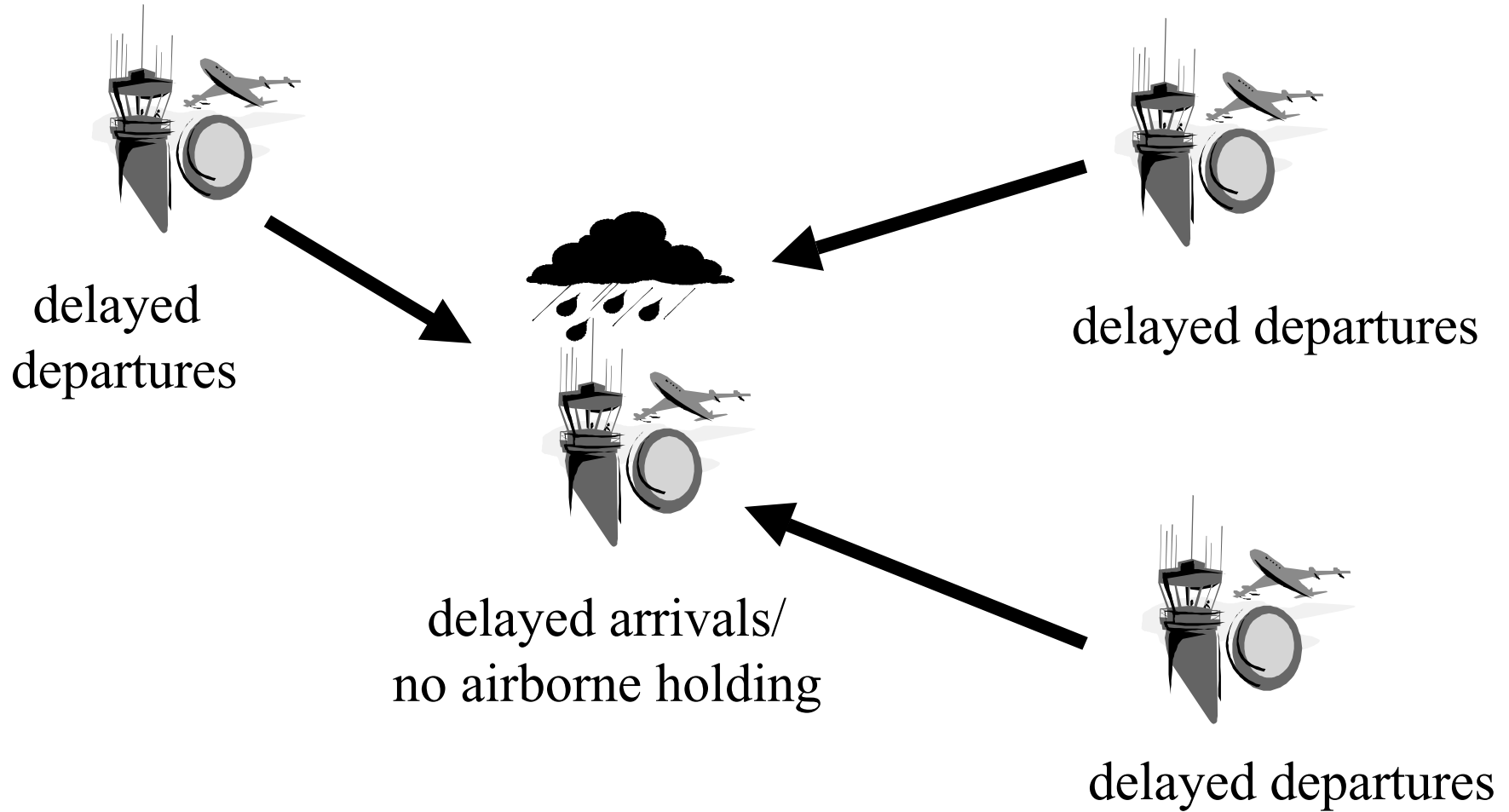
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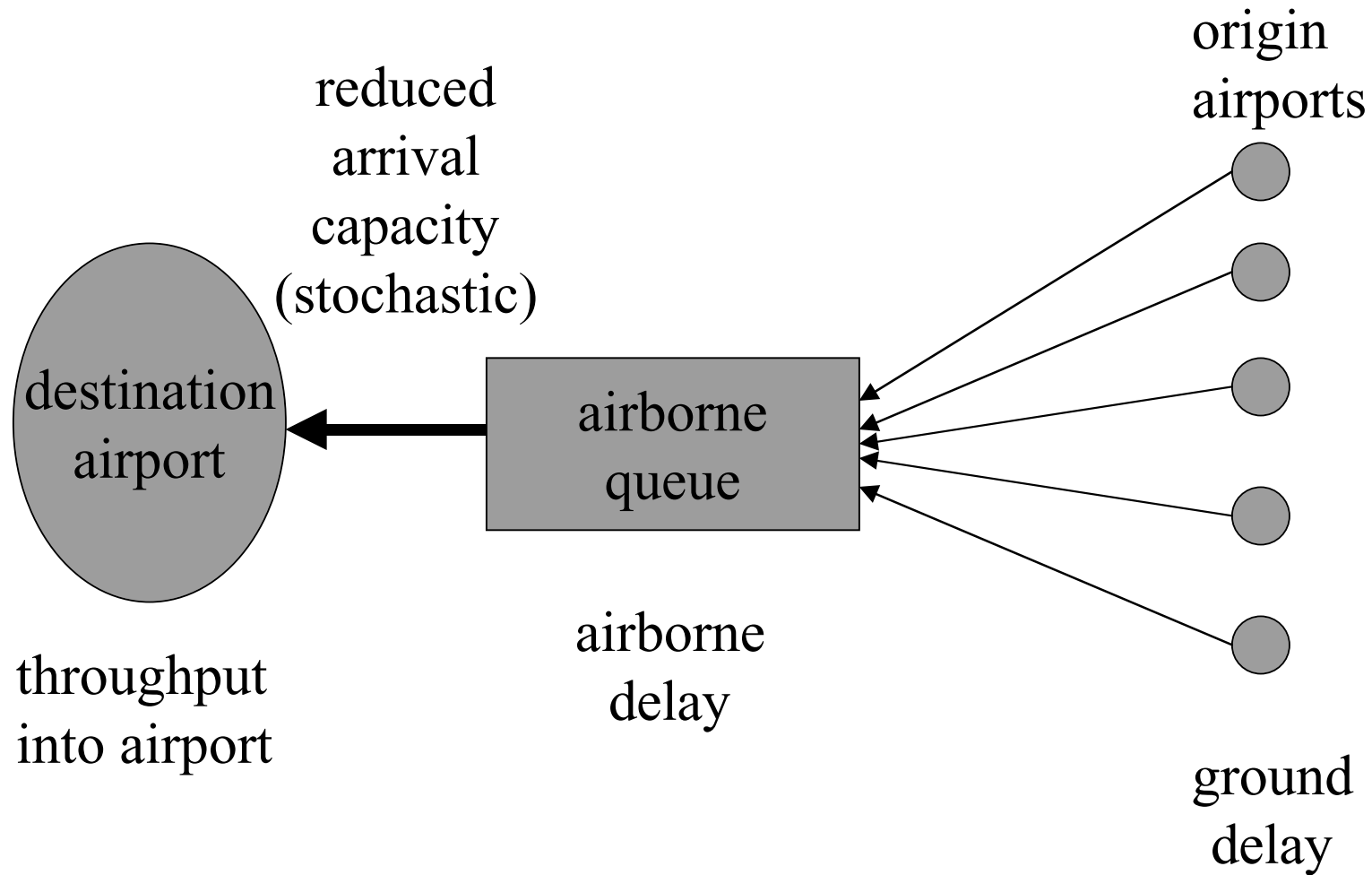


# Ground Delay Program (GDP)





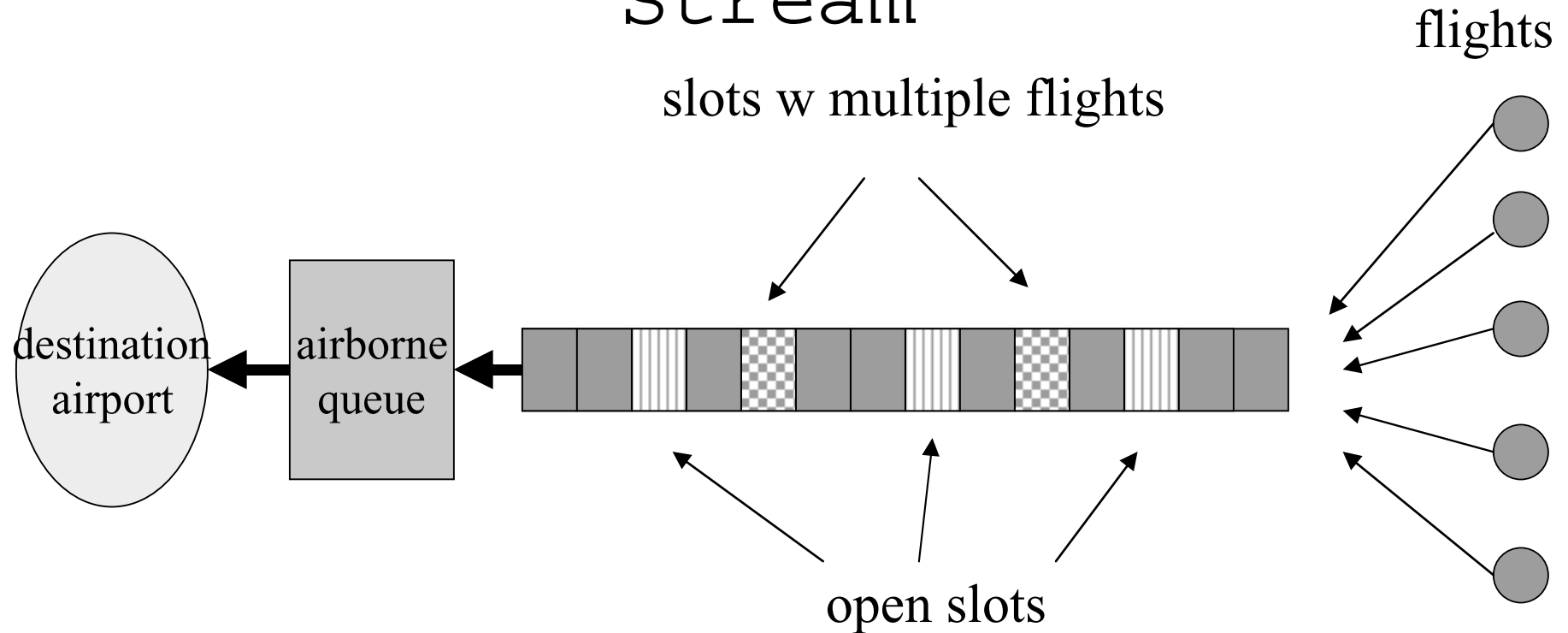
# Measuring Quality of GDP Planning and Execution





# Uncertainty in Arrival

## Stream



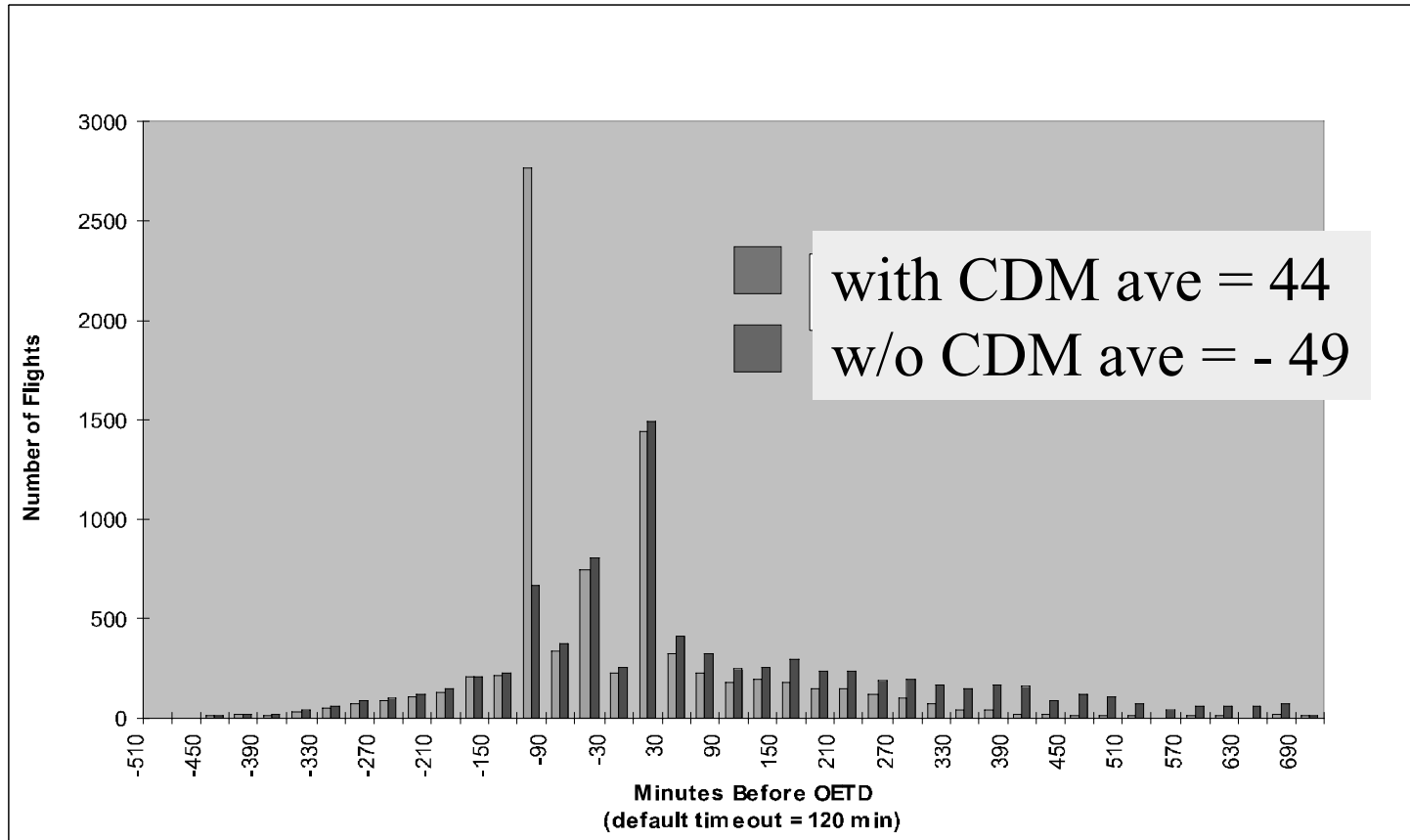
Sources of uncertainty:

cancellations, pop-ups, drift



# Shift in Distribution of Cancellation Notification Time

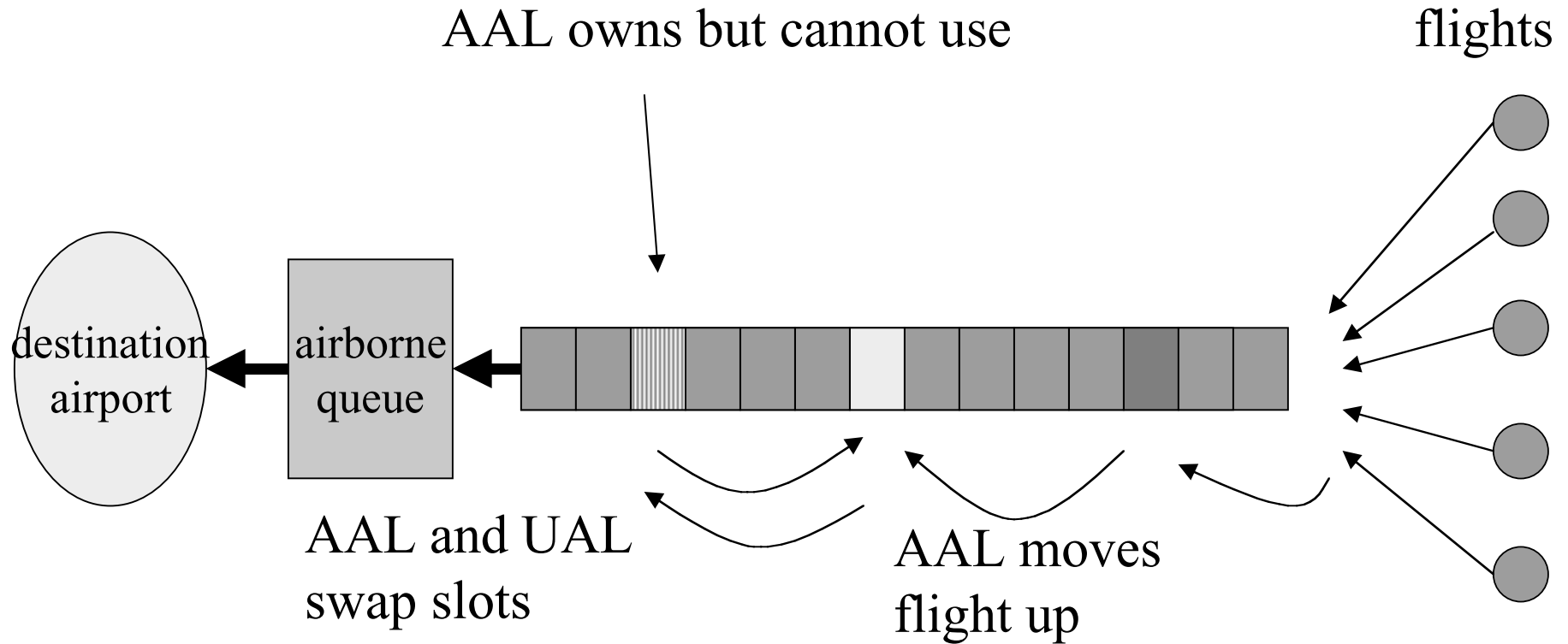
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Notification time given in ***minutes before OETD***  
(Original Estimated Time of Departure)  
Airport = SFO



# Effects of Compression Algorithm



Net effect:

¥ win-win for airlines

¥ *slots that may have gone unfilled are used*



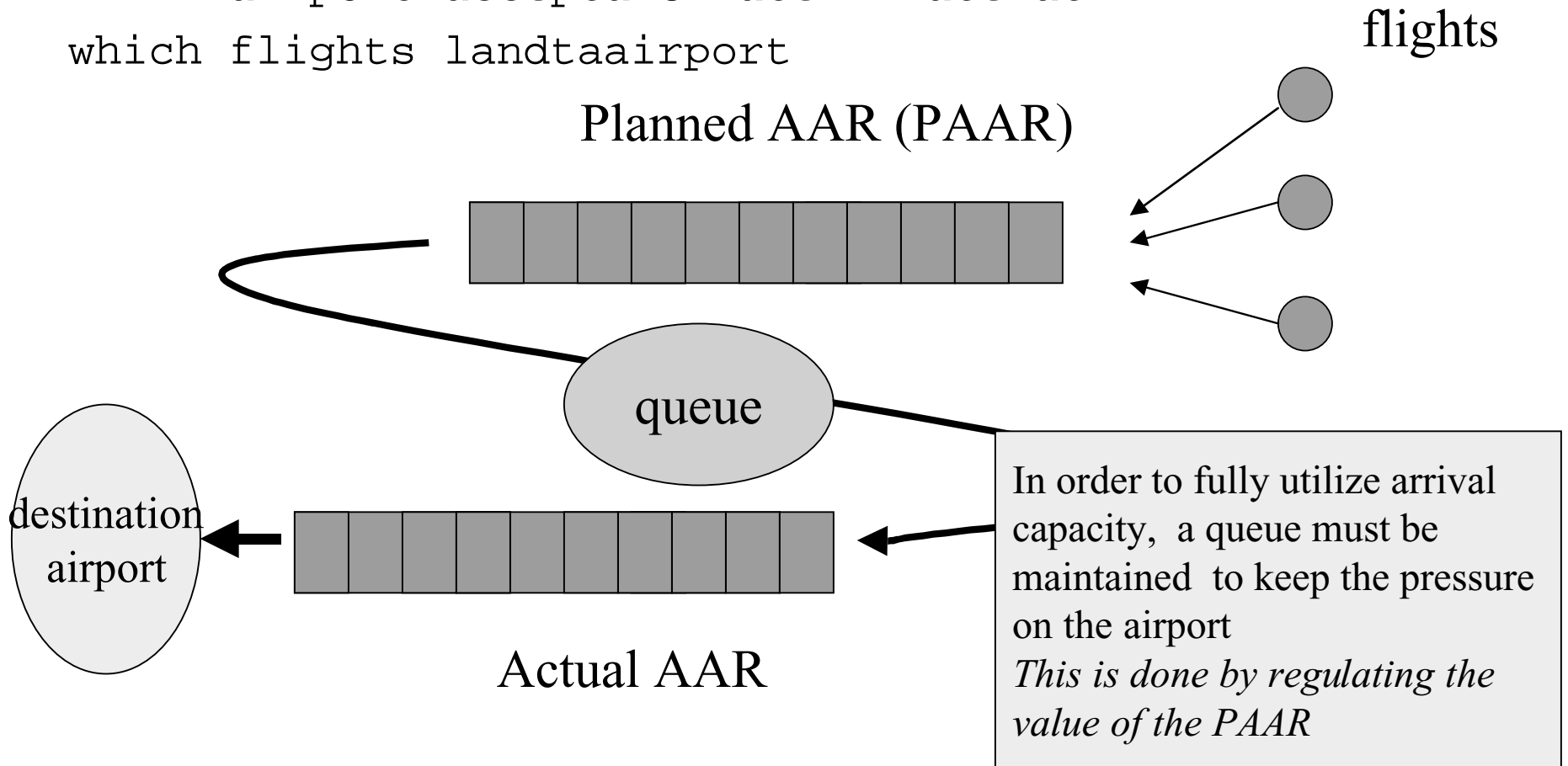
## Questions

- ⌘ What is cost of various forms of uncertainty and what is value of reducing that uncertainty?
- ⌘ What is extent and nature of benefits of compression?
- ⌘ Can any changes in approach to planning and controlling GDPs better deal with uncertainty?



# Planned vs Actual Airport Acceptance Rate

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







## Models

### ∕ Integer Program

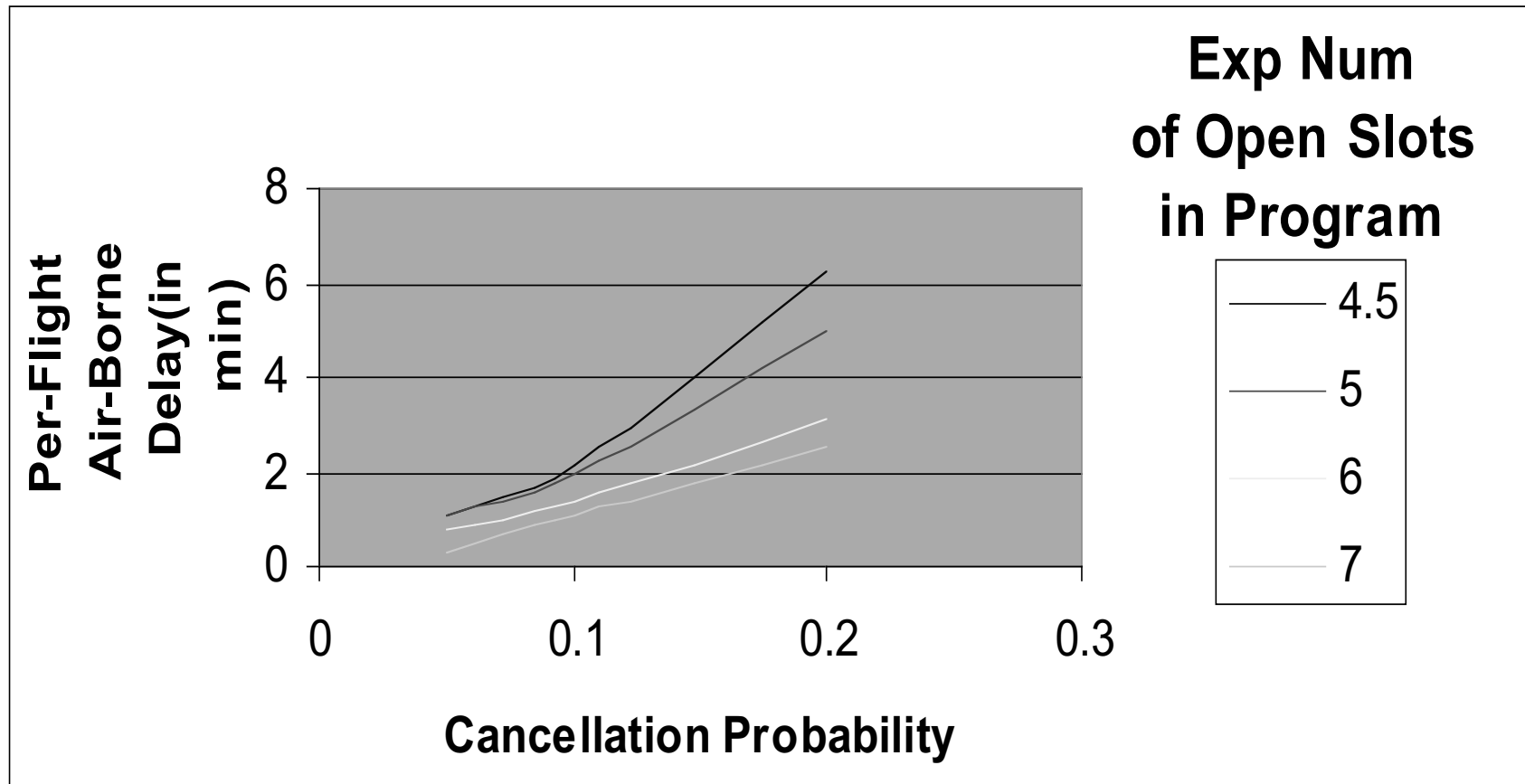
- considers only flight cancellations
- variables: PAAR in each time period,  $\Pr\{k \text{ flights in airborne queue at end of period } i\}$
- obj fcn: min total exp airborne delay
- inputs: flight cancellation prob, overall slot utilization, AAR

### ∕ Simulation

- Considers cancellations, pop-ups, drift

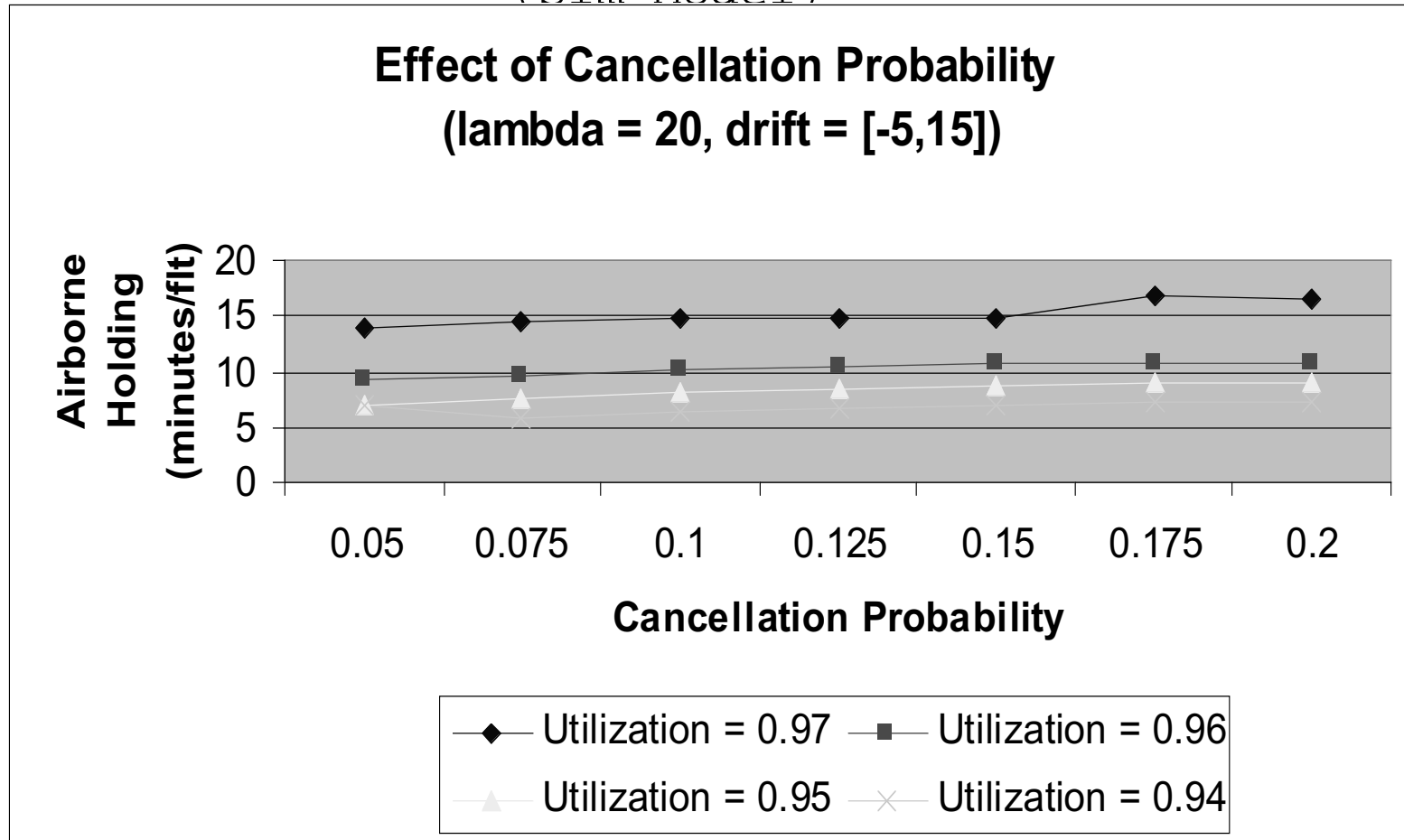


# Airborne Delays Cancellation Prob (IP Model)





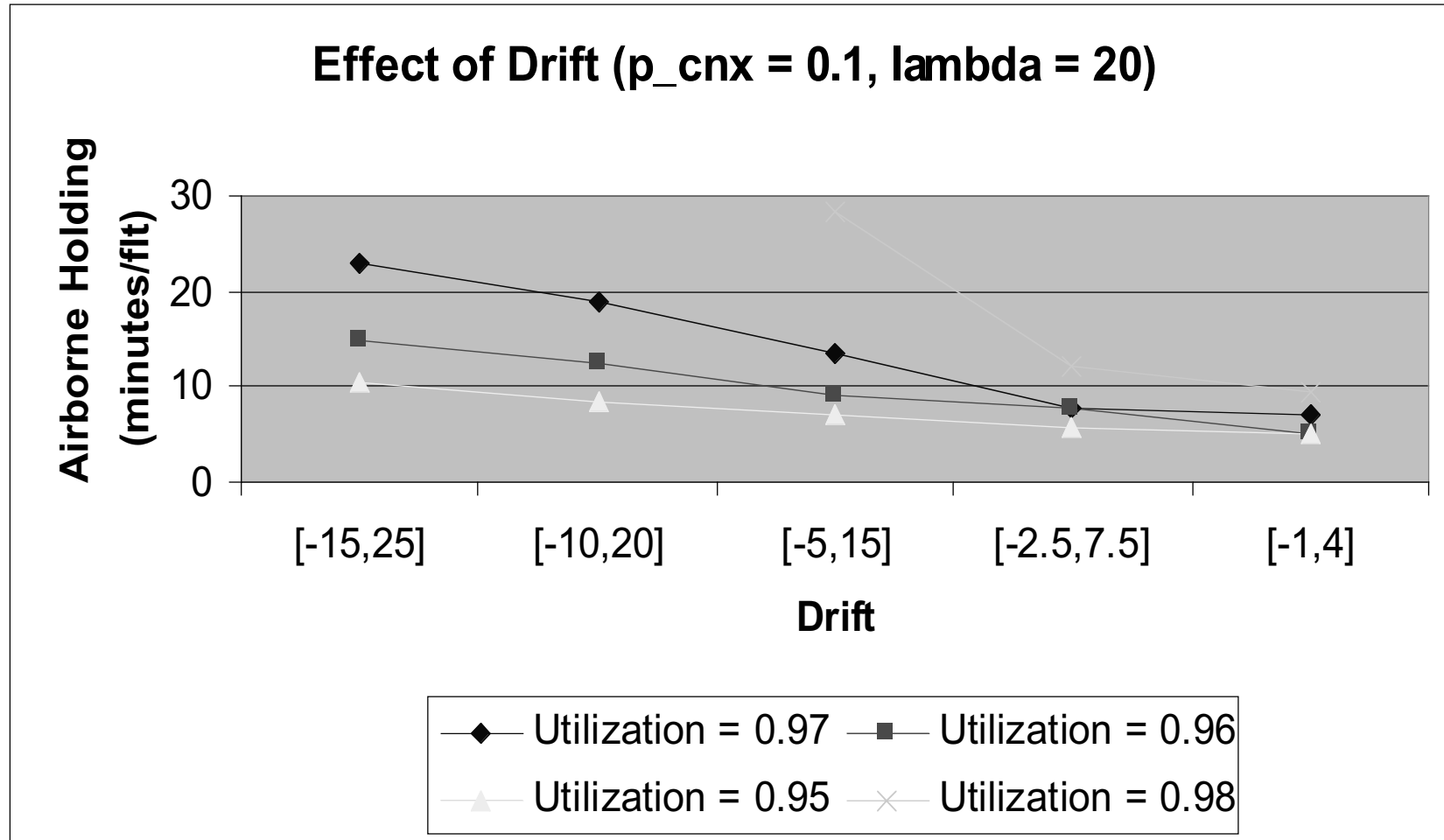
# Marginal Effects of Uncertainty in Presence of Cancellations, Pop-ups, Drift (Sim Model)





# Marginal Effects of Uncertainty in Presence of Cancellations, **NEXTOR**

## Pop-ups Drift (Sim Model)

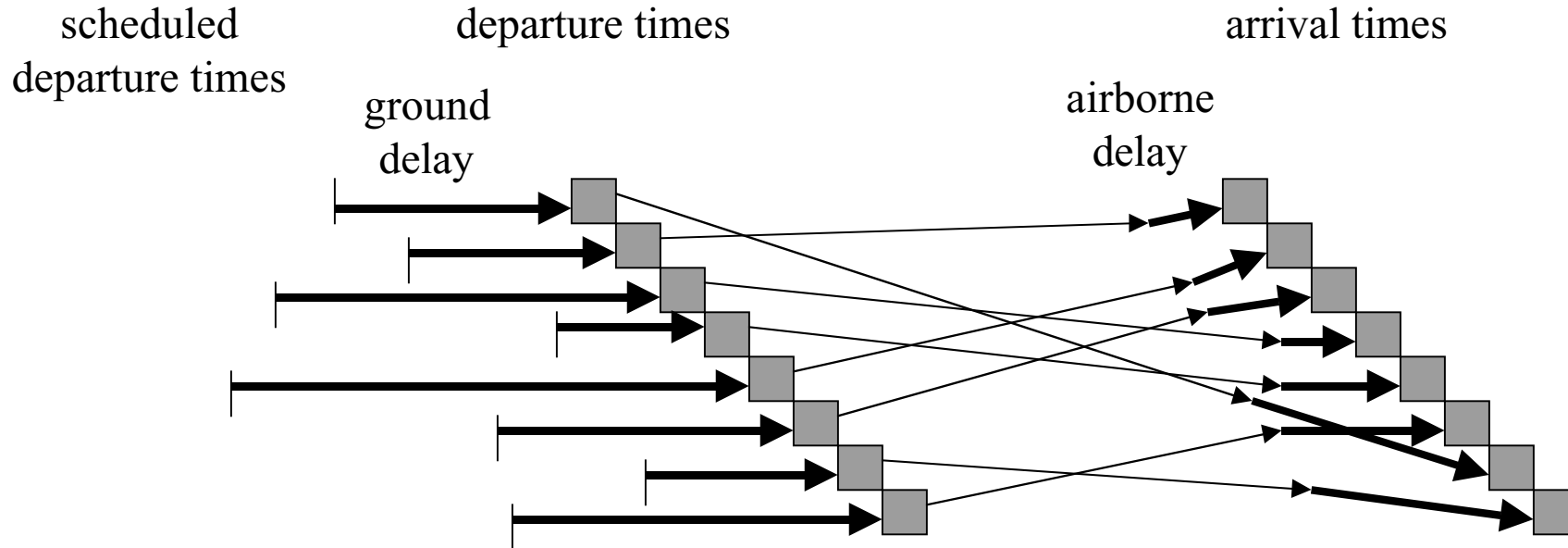




# Prelude to Understanding

## Compression Impact:

### Delay vs Arrival Times



$$\text{Delay}(f) = \text{arr\_time}(f) - \text{sched\_arr\_time}(f)$$

$$\text{Delay}(f) = \text{arr\_time}(f) - \text{sched\_dep\_time}(f) - \text{dir\_en\_route\_time}(f)$$

$$\text{Tot\_delay} = \sum \text{arr\_time}(f) - \sum \text{sched\_dep\_time}(f) - \sum \text{dir\_en\_route\_time}(f)$$

∃ As long as the overall set of arrival times (arrival slots used) remains the same total delay remains the same



## Compression Benefits

Compression has filled in holes in the PAAR which has reduced the amount of assigned ground delay

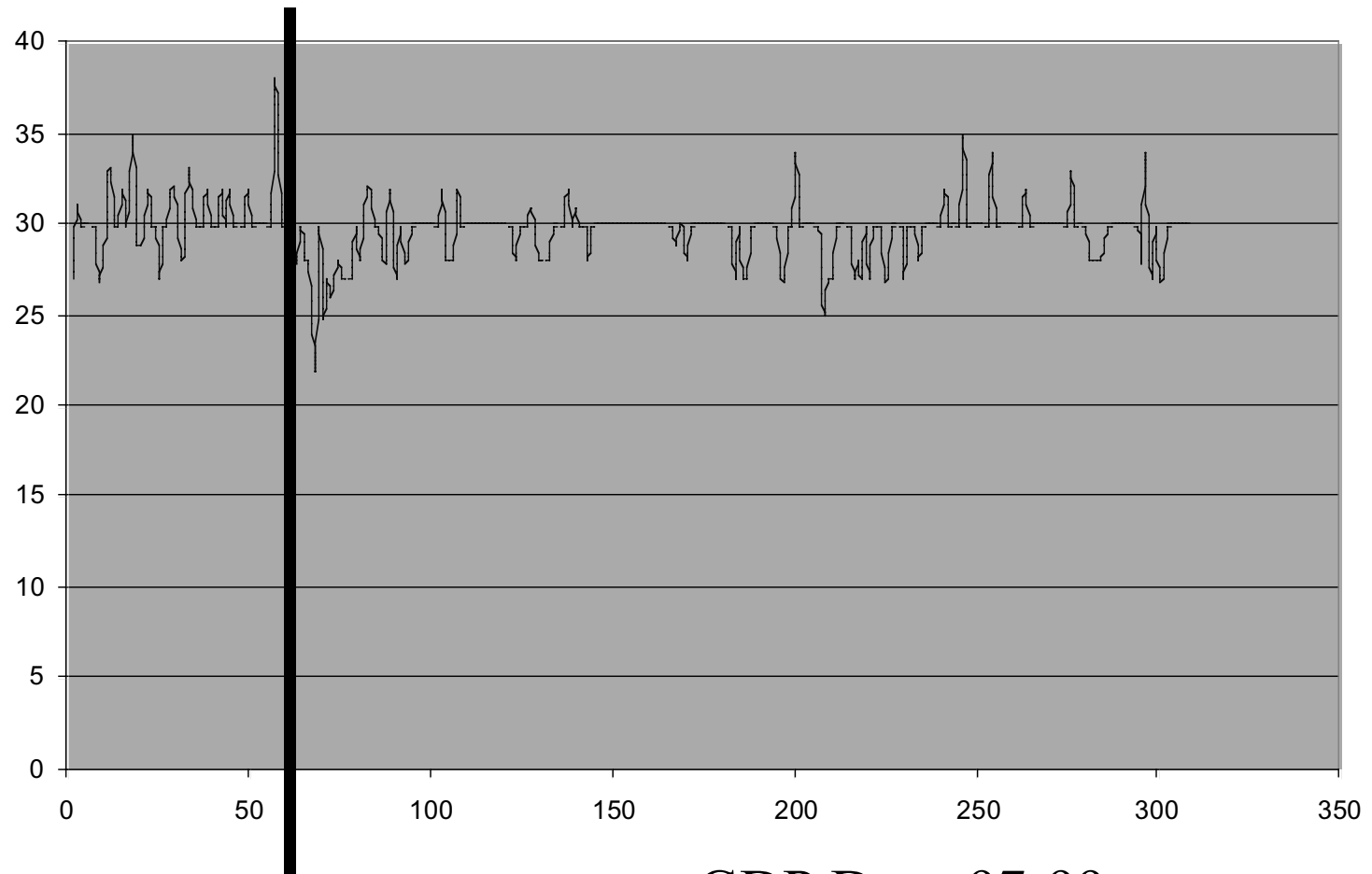
Possible system effects:

- ⌘ *Holes in AAR have been filled in and total delay has been reduced*
- ⌘ *There were no holes in AAR so reduced ground delay has been replaced by airborne delay*
- ⌘ *Uncertainty in the arrival stream has been reduced enabling a reduction in the PAAR required to achieve a given AAR and a reduction in overall airborne delay*



## Change in PAAR Policy??

PAAR  
during  
1800 Z



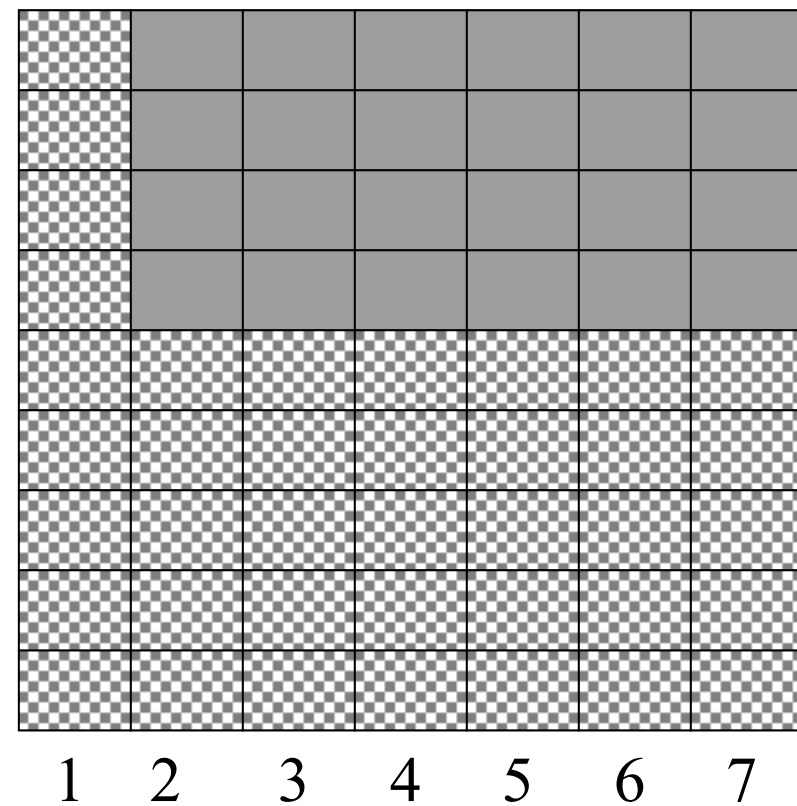
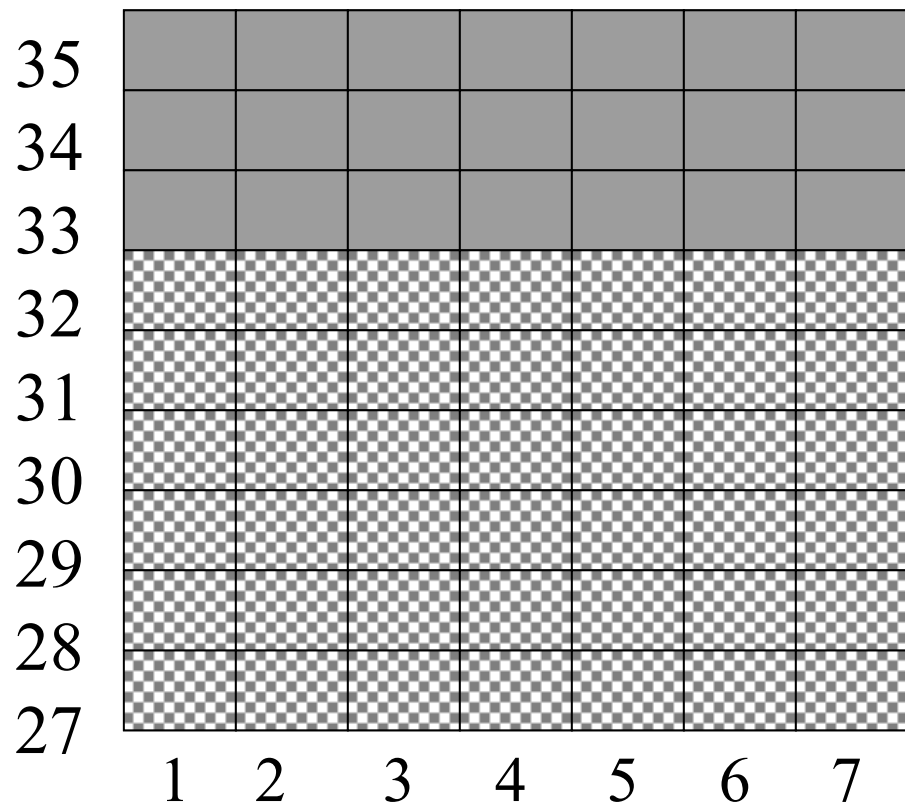
begin CDM

GDP Days 97-99  
at SFO



# Typical PAARs Used Today

PAAR



Time Period  
(hour)

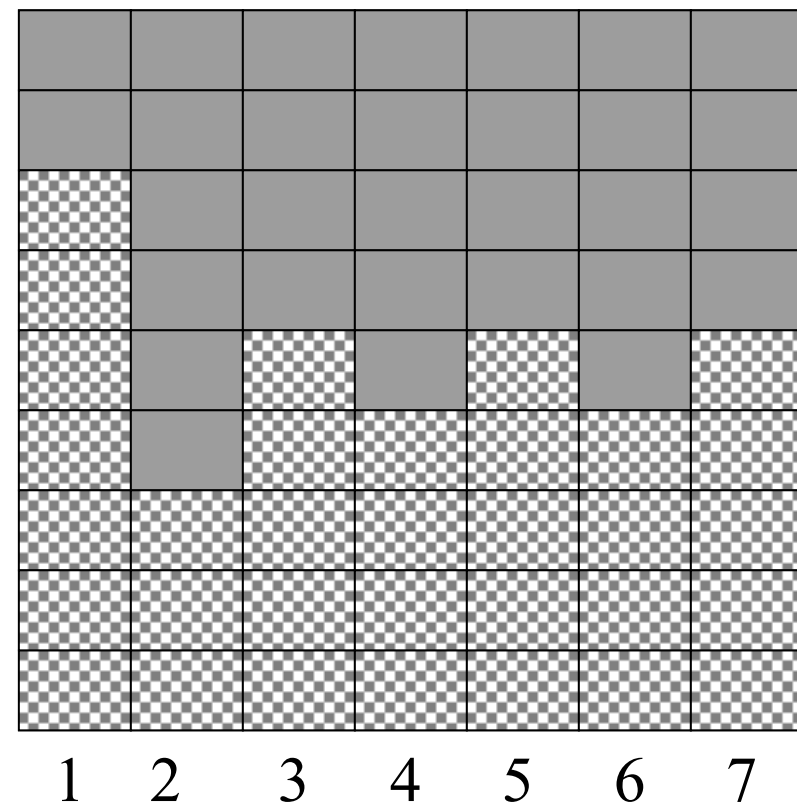
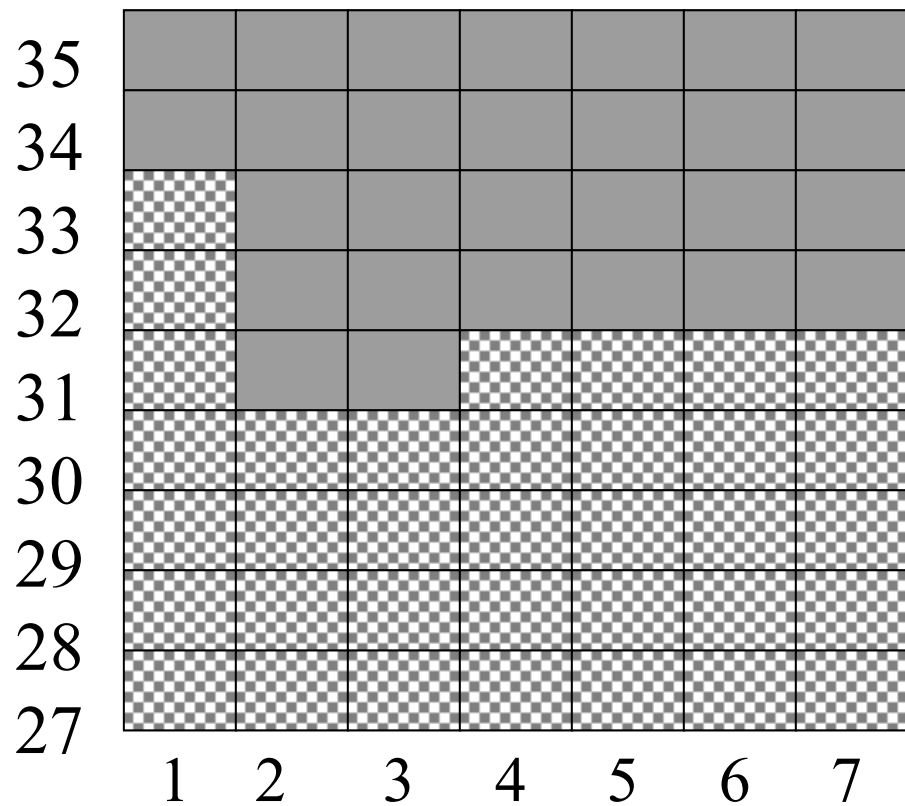




# Sample PAARs

Recommended by IP Mode 1

## PAAR



Time Period  
(hour)