

# Resource Rationing and Exchange Methods in Air Traffic Management Part II

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# GDPs under CDM

## Resource Allocation Process:

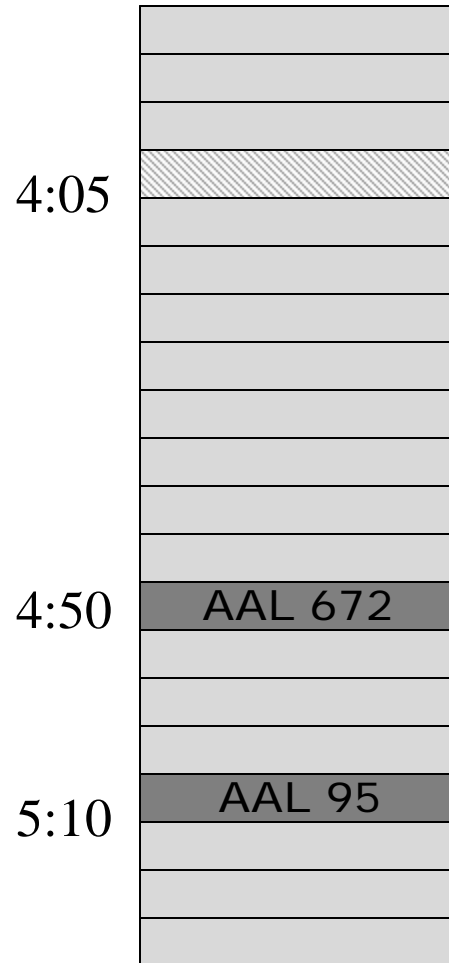
- FAA: *initial “fair” slot allocation*  
[Ration-by-schedule]
- Airlines: *flight-slot assignments/reassignments*  
[Cancellations and substitutions]
- FAA: *periodic reallocation to maximize slot utilization*

***[Compression]***



# Compression Example

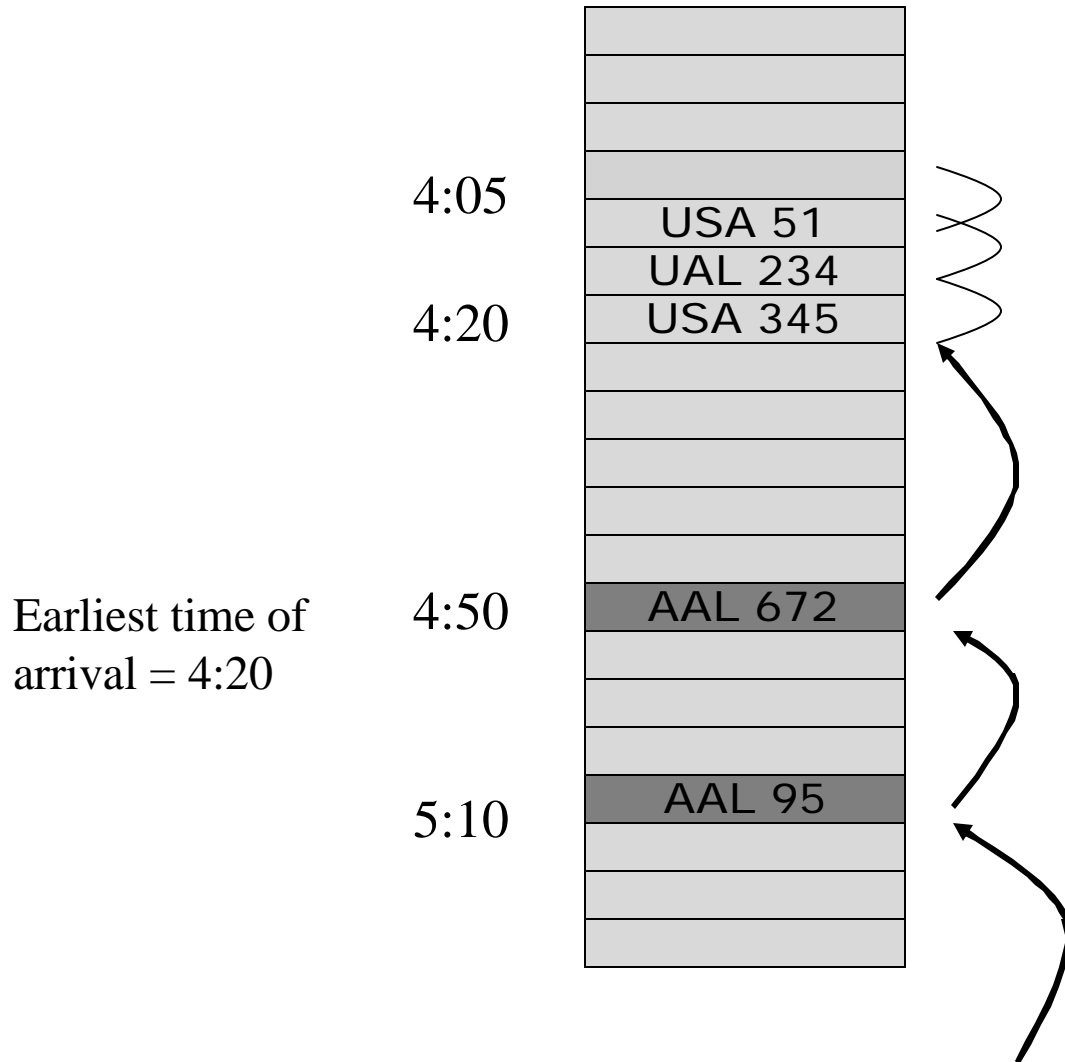
Earliest time  
of arrival = 4:20



Slot made available  
by canceled or delayed  
flight



# Compression Example





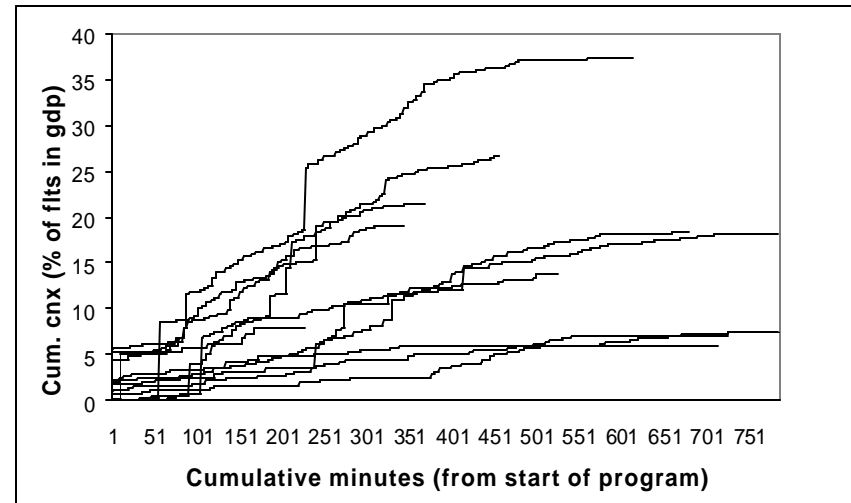
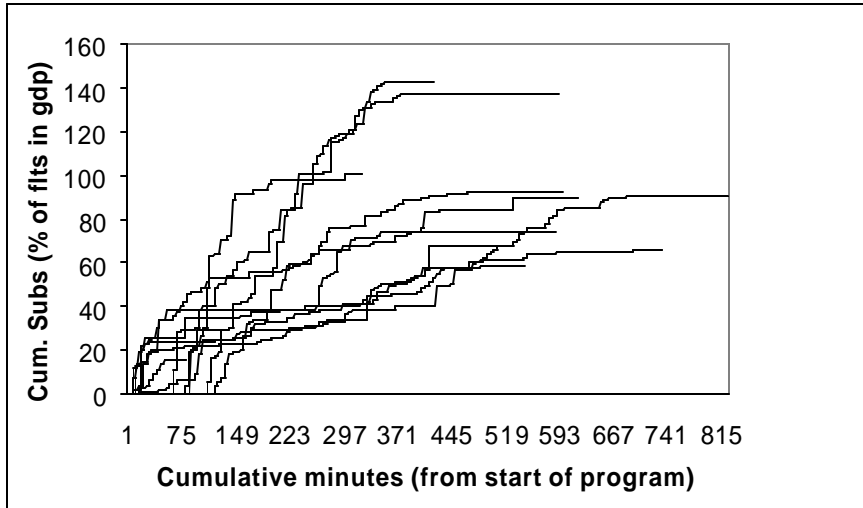
# Slot Exchange Alternatives

- Compression as Reallocation
  - Dynamic changes to airline “demand profiles” necessitate (re)rationing
- Compression as Slot Trading
  - e.g., Slot Credit Substitutions:  
*“I am willing to cancel flight  $f_1$  if I can move up flight  $f_2$ ”.*



# Slot Trading Opportunities

## Airline Substitution/Cancellation Patterns



Consider potential benefits of extending slot trading framework

- e.g., Increase offers submitted by airlines



# Mediated Slot Trading

## General Framework:

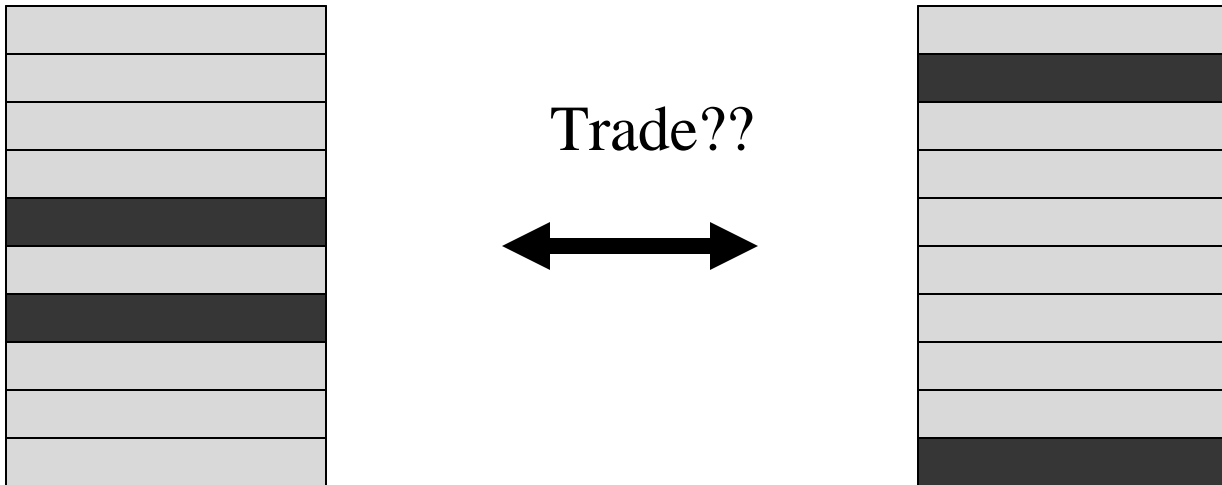
- Each airline submits a set of offers
- Offer:
  - $O_{a,t}$  : slots willing to give up
  - $R_{a,t}$  : slots required in return
- Mediator (FAA) determines which offers to select and execute
  - *Alternate interpretation of Compression Procedure*



# Approach:

## From 1-for-1 trades to 2-for-2 trades

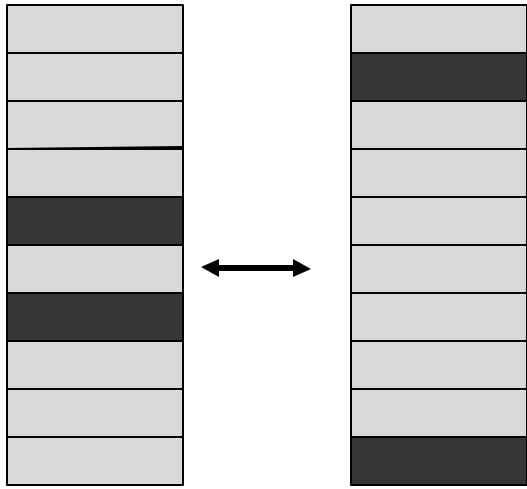
- Compression
  - 1-for-1 trading system, i.e. offers involve giving up one slot and getting one in return (many offers processed simultaneously)
- What about k-for-k or k-for-n offers, e.g. 2-for-2:



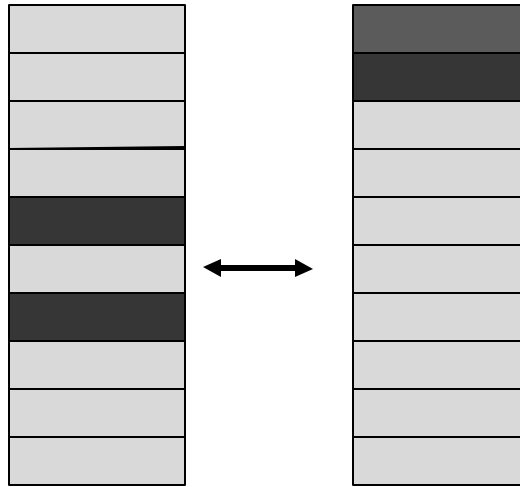




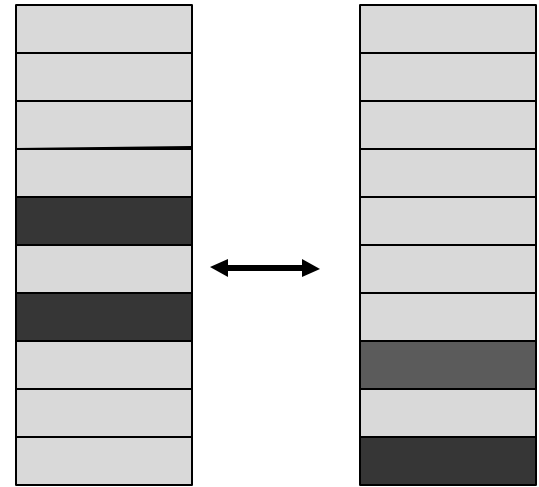
# Possible 2-for-2 trades:



1 up for 1 down: reduce delay on 1 flight/increase delay on another;  
Model as reduce delay *at least*  $d^-$  on f1 in exchange for increasing delay *at most*  $d^+$  on f2.



2 down: reduce delay on two flights; handled by 2 “reduce delay” single flight trades.

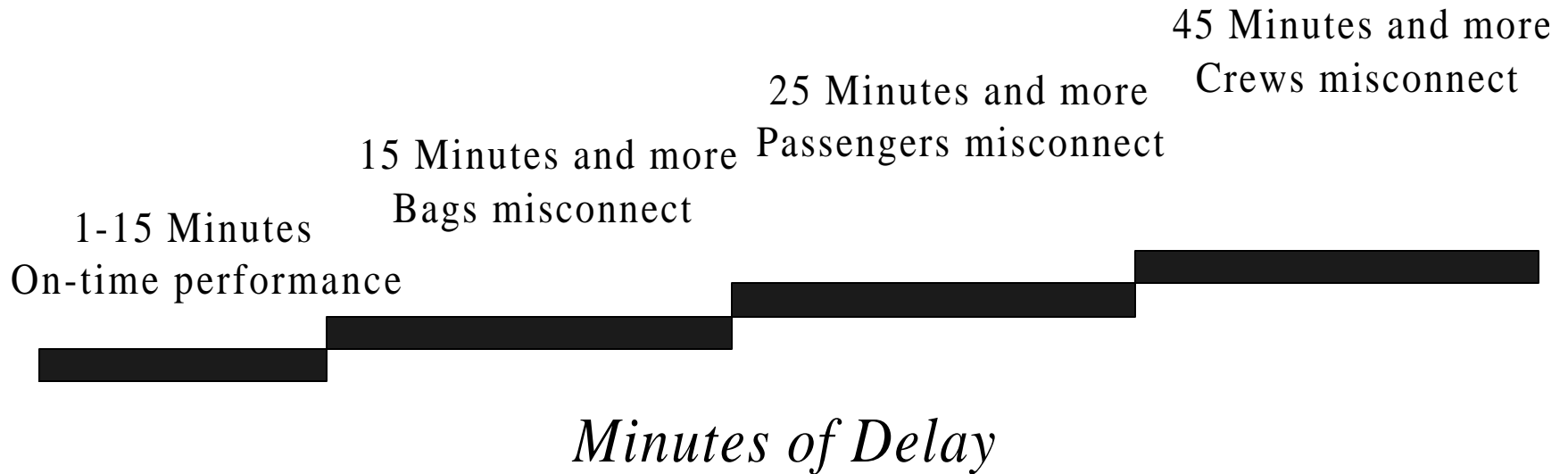


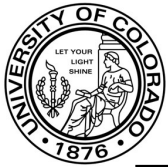
2 down: increase delay on two flights; not reasonable.



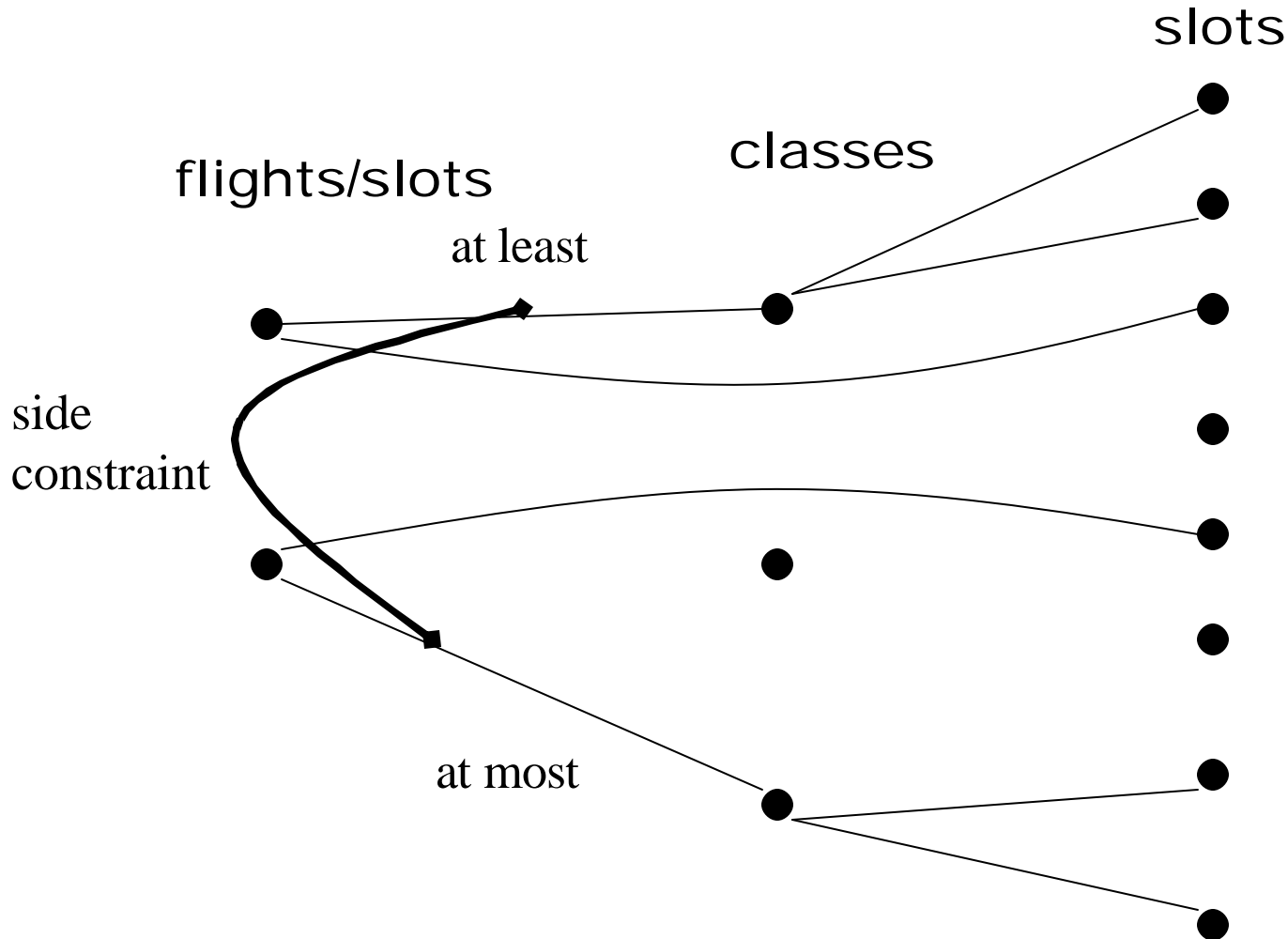
# Motivation

- Operationally significant delay levels often follow a “staircase” pattern





# Formulation of 2-for-2 trading problem as network flow problem w side constraints:





# Case Studies

Different Airline Objectives:

1. Maximize On-Time Performance
2. Minimize Passenger Delay Costs



# Airline Objective: On-time Performance

- Offers proposed:  
*“I am willing to delay flight  $f_1$ , in return for a delay reduction that will let flight  $f_2$  arrive on time” (< 15 minutes delay)*
  - Additional use of “aspiration levels” to limit additional delay
- Mediation Problem:
  - Maximize number of offers executed



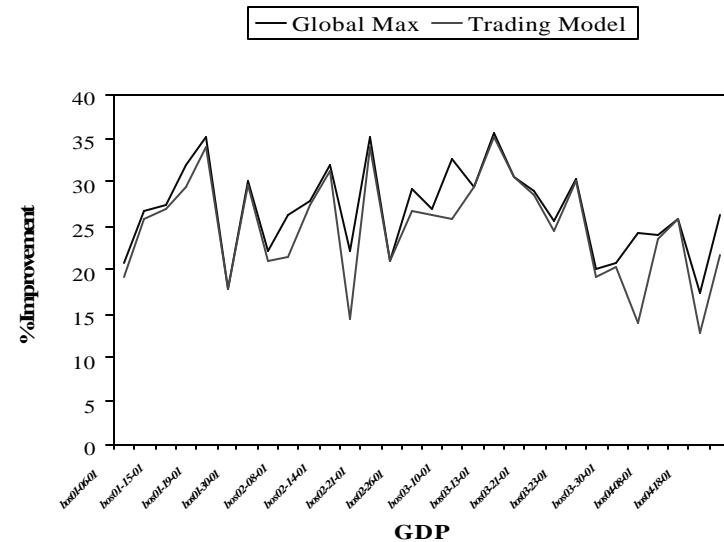
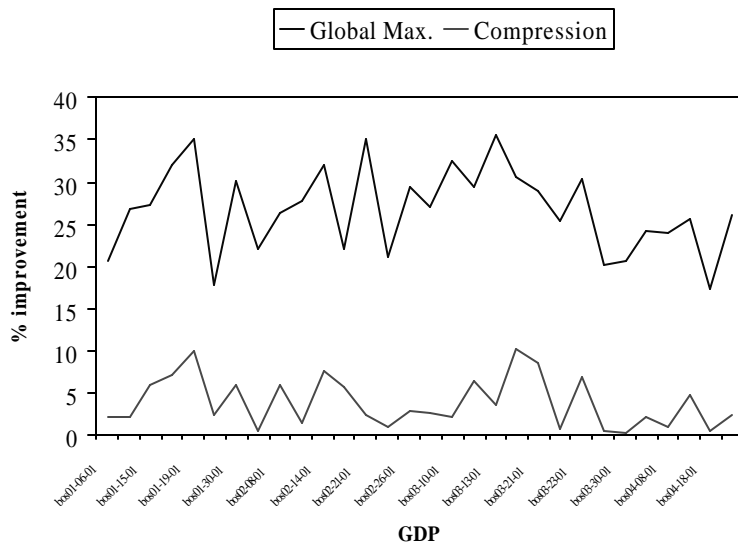
# Airline Objective: On-time Performance

## Compression Benefits

- compression executed after flights with excessive delay (>2hrs) are canceled

## 2-for-2 Trading Model

- proposed offers: all at-least, at-most pairs that improve on-time perf.

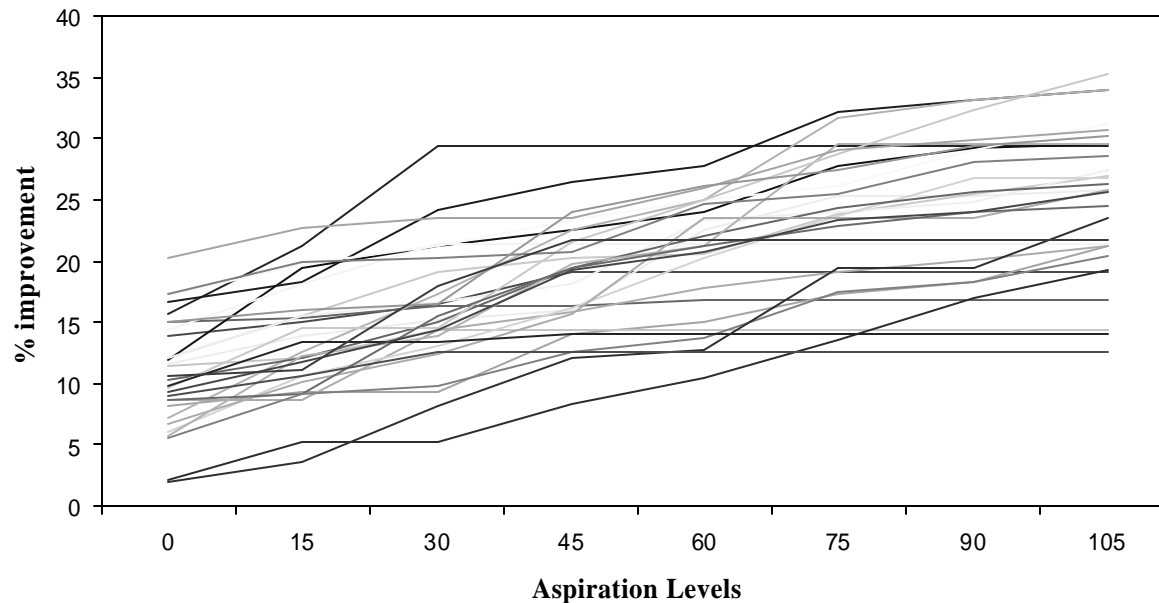




# Airline Objective: On-time Performance

- Impact of limiting offers proposed:
  - Use of “aspiration levels” to restrict willingness to delay flights

Trading Improvement





# Airline Objective: On-time Performance

## Summary

- 2-for-2 trading offers significant improvement over Compression
  - Approximates “global” optimum
- 2-for-2 trading improvements are “robust”
  - Gradual performance degradation as offers are restricted





# Airline Objective: Passenger Delay

- Offers proposed:

*“I am willing to delay flight  $f_1$ , in return for a delay reduction on flight  $f_2$  that will reduce net passenger delay by at least  $D$  minutes”*

– Additionally, use of “staircase” pattern to represent passenger delays

- Mediation Problem

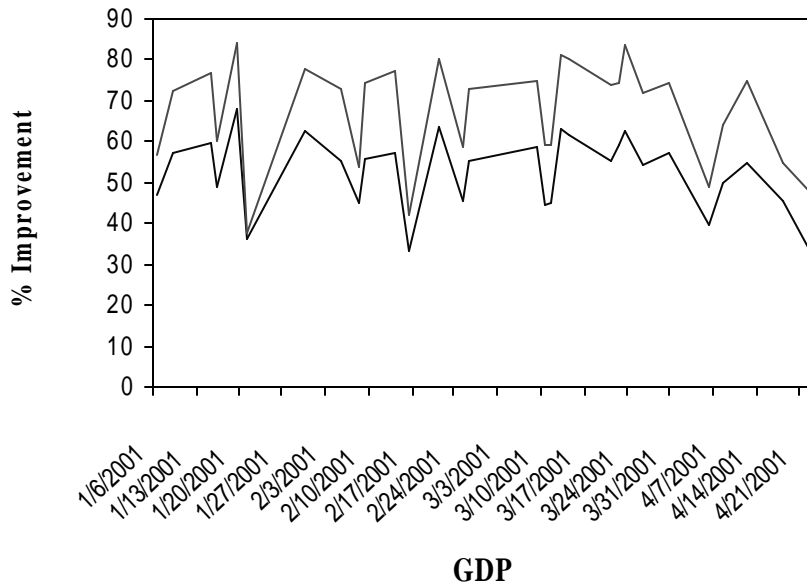
– Maximize number of offers executed



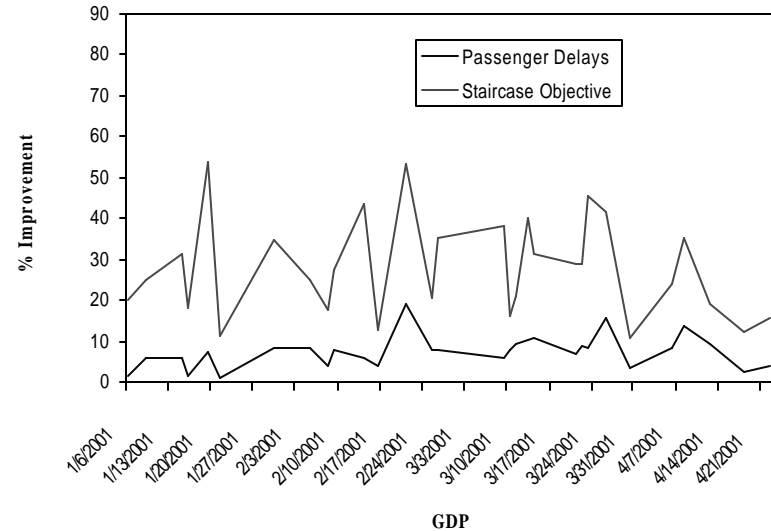
# Airline Objective: Passenger Delay

- Two passenger delay minimization objectives

Maximum achievable improvement:



Improvement from slot trading model:





# Airline Objective: Passenger Delay

## Summary:

- Trading benefits rely on “staircase” structure of airline preferences
- Trading benefits limited by carriers which operate smaller aircraft
  - Potential benefits of allowing side payments to compensate carriers for delay