

Dynamic Airline Slot Exchange during Ground Delay Programs

Thomas Vossen,

University of Colorado, Boulder

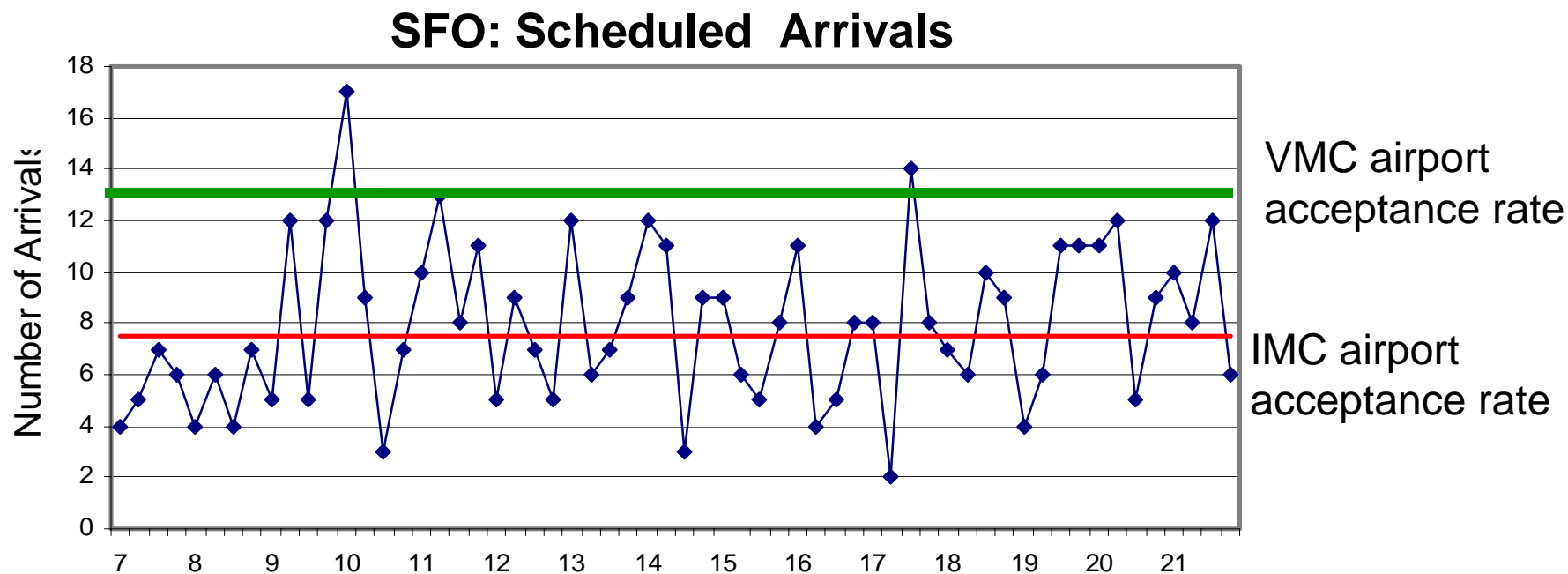
Michael Ball, Philippe Montebello

University of Maryland, College Park



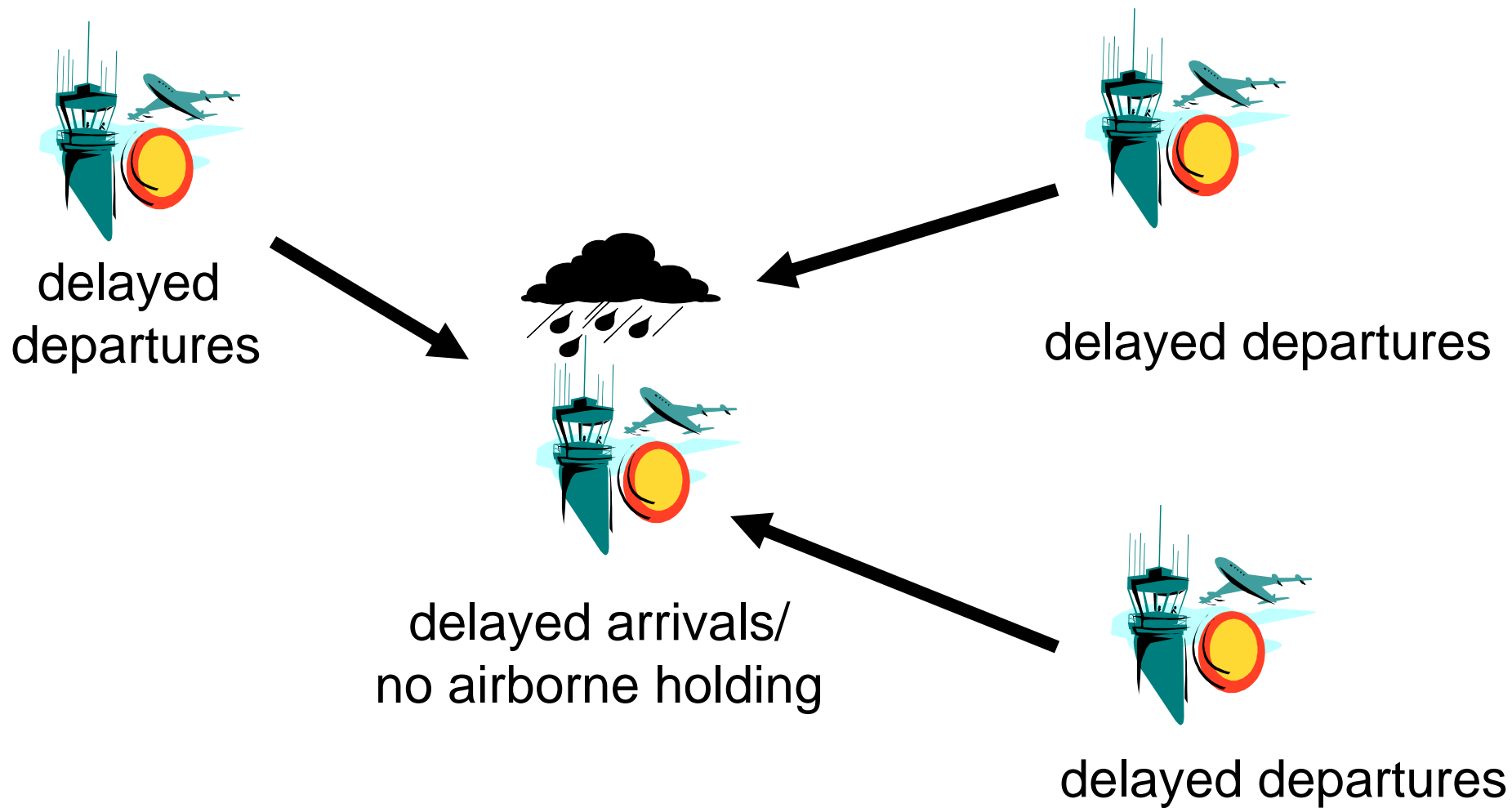
Ground Delay Programs:

Motivation:
airline schedules “assume” good weather





Ground Delay Programs





GDPs under CDM

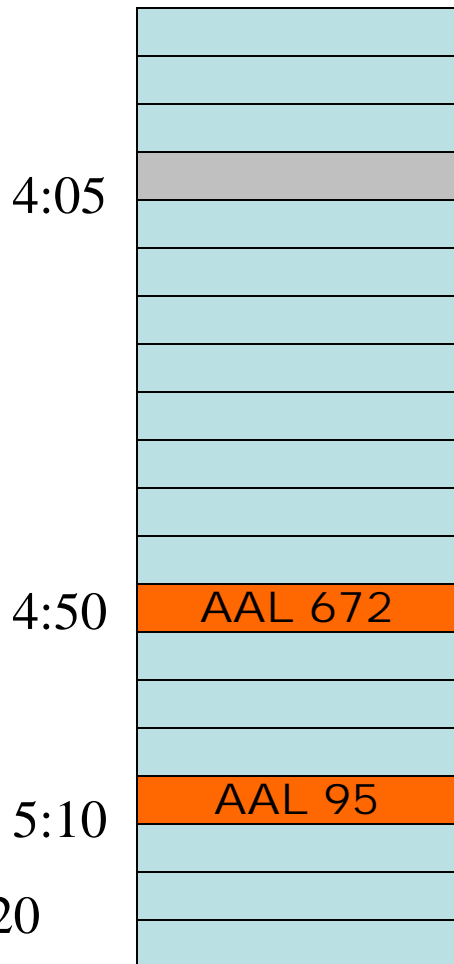
Resource Allocation Process:

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

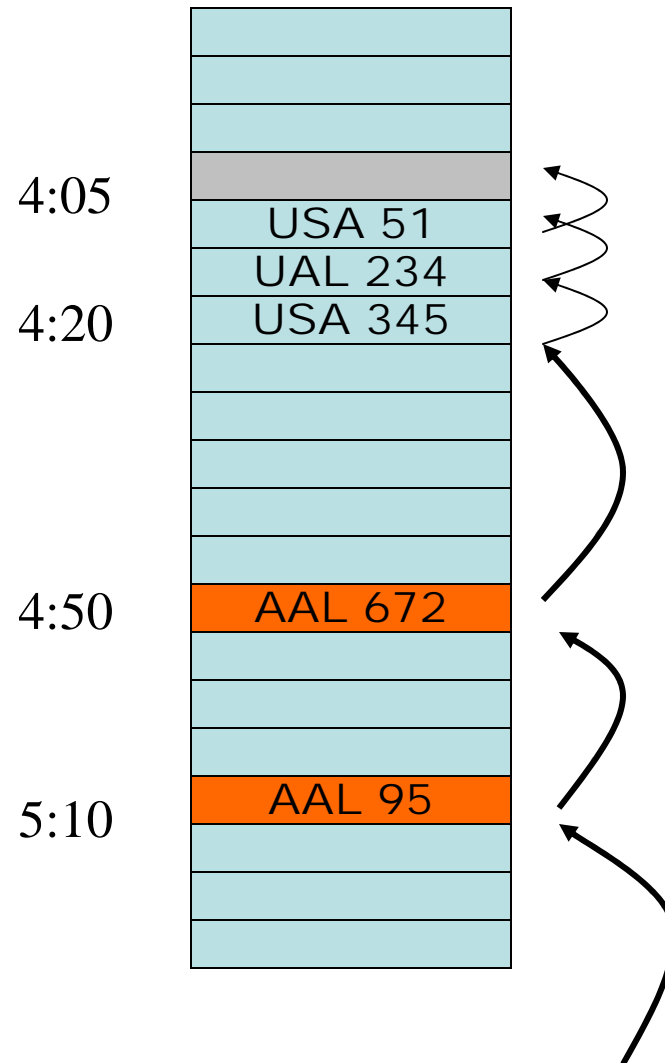


Compression Example

Slot released
by canceled/
delayed
flight



Earliest time
of arrival = 4:20





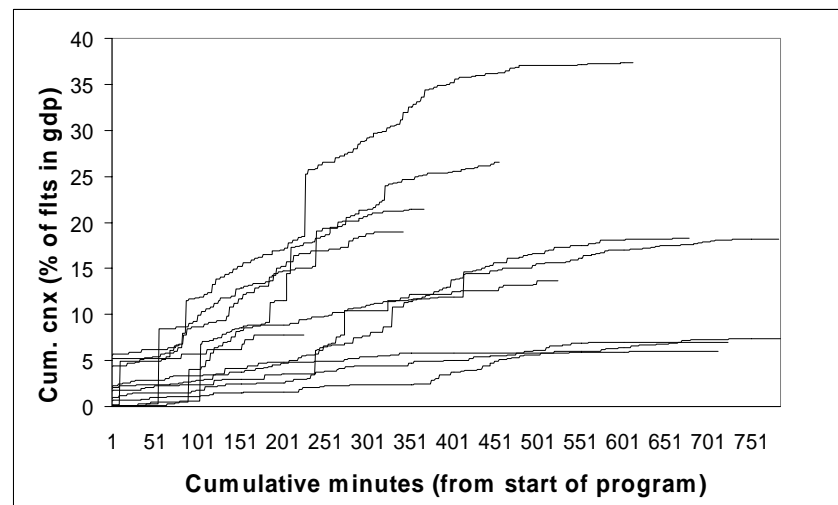
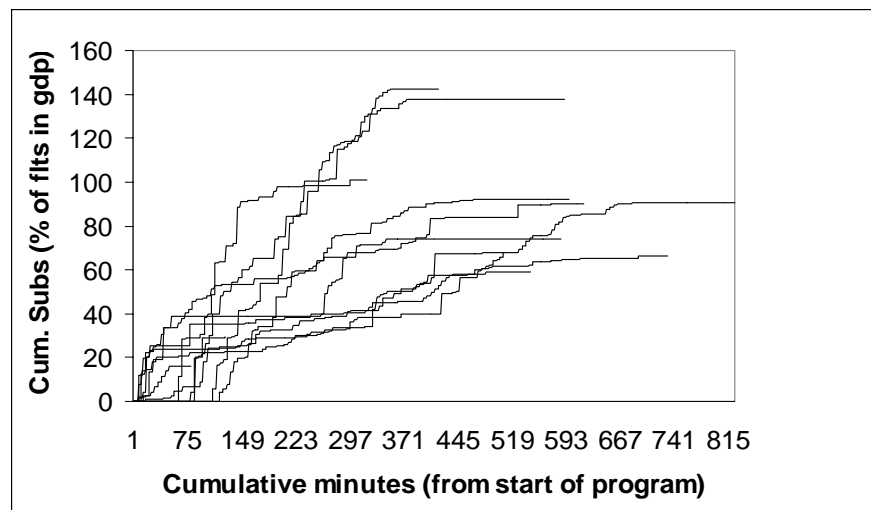
Slot Exchange Alternatives

- 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



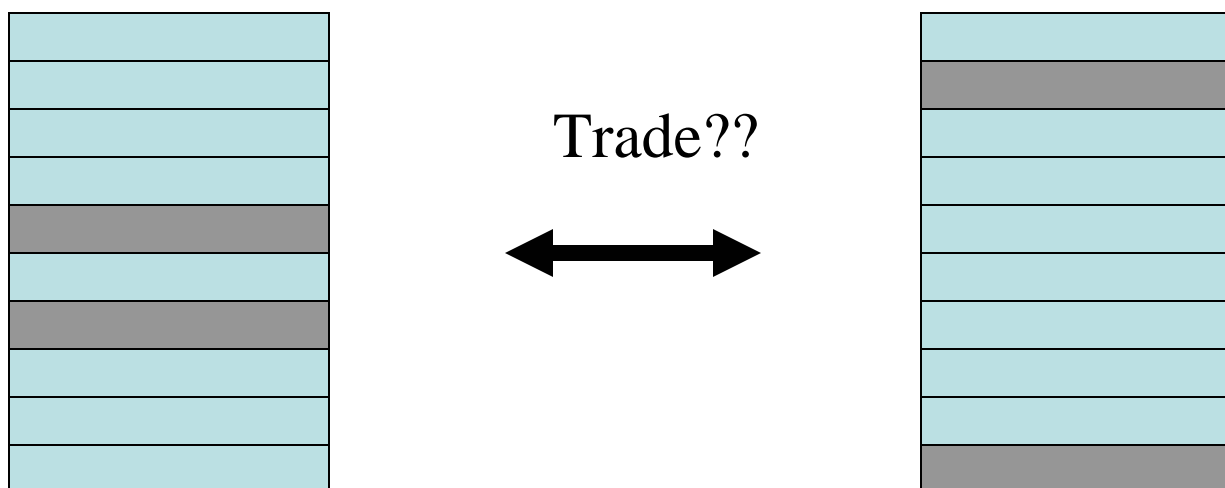
Consider potential benefits of extending slot trading framework

- e.g., Increase offers submitted by airlines



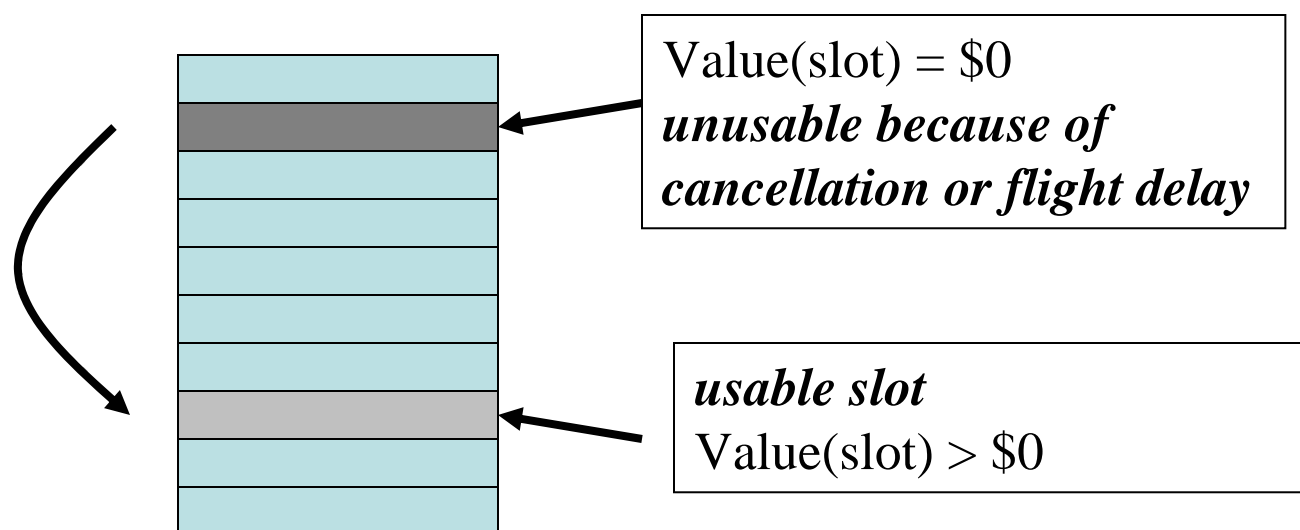
From 1-for-1 to 2-for-2 trades

- Compression and/or slot credit substitution can be interpreted as a 1-for-1 trading system, i.e. offers involve giving up one slot and getting one in return (many offers are processed simultaneously)
- What about k-for-k or k-for-n offers, e.g. 2-for-2:





Value proposition for compression & SCS

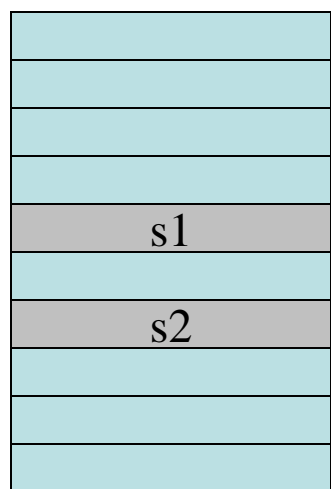


SCS/Compression “trades” are always driven by the exchange of a slot with value 0 and a slot with value > 0!!



2-for-2 trades enable airlines to profit by exchanging pairs of usable slots that result in an increase in overall value to the carrier.

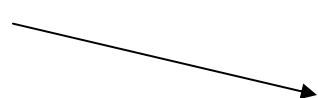
Airline A



A25 (high priority)



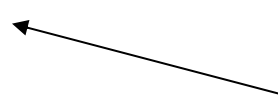
A10 (low priority)



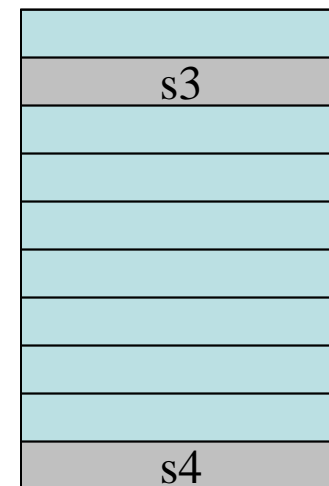
B20 (low priority)



B35 (high priority)



Airline B

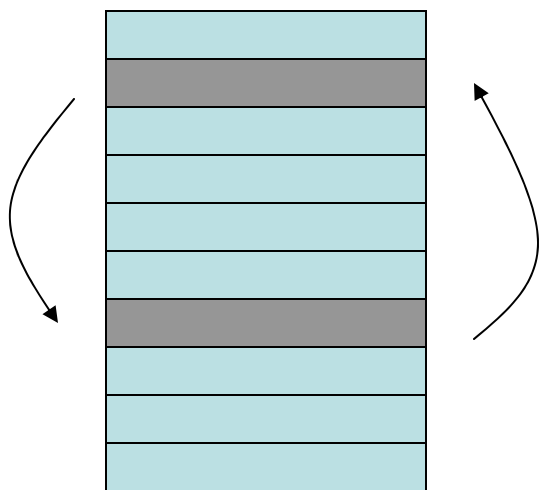


$$\begin{aligned} \text{A's value proposition: } & \text{val}_A(s3) - \text{val}_A(s1) + \text{val}_A(s4) - \text{val}_A(s2) = \\ & 2000 - 1500 + 300 - 500 = \$300 \end{aligned}$$

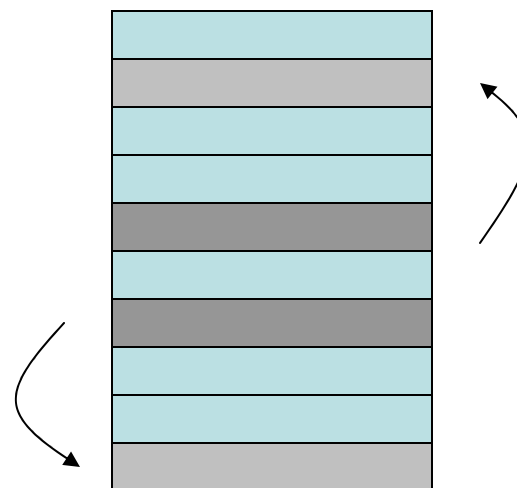
$$\begin{aligned} \text{B's value proposition: } & \text{val}_B(s1) - \text{val}_B(s3) + \text{val}_B(s2) - \text{val}_B(s4) = \\ & 500 - 800 + 2500 - 1800 = \$400 \end{aligned}$$



Another view of 2-for-2 trading: generalized substitutions



Normal Substitution



Generalized Substitution



Issues

- **System Design:**
 - How do airlines represent and generate offers?
 - Formulation and solution of FAA mediation problem
- **System Evaluation:**
 - Airline objectives and strategies
 - Performance Measurement:
 - comparison with optimal centralized solution (system efficiency)

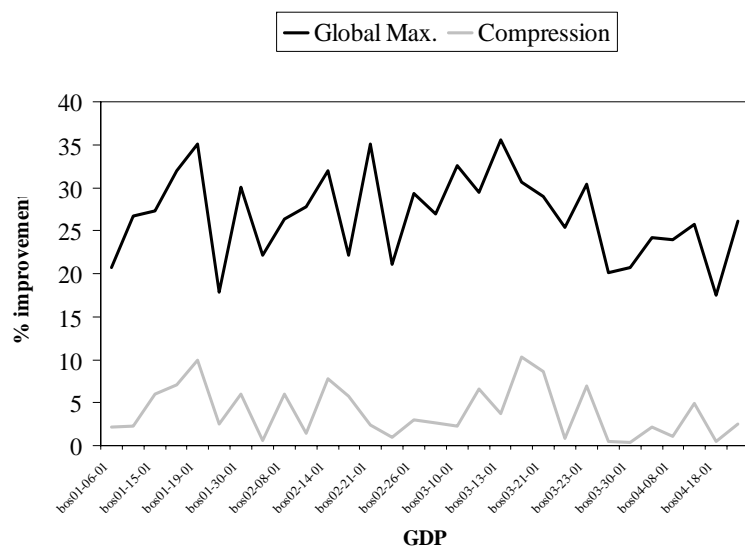


Initial Results

- Airline Objective: On-time Performance

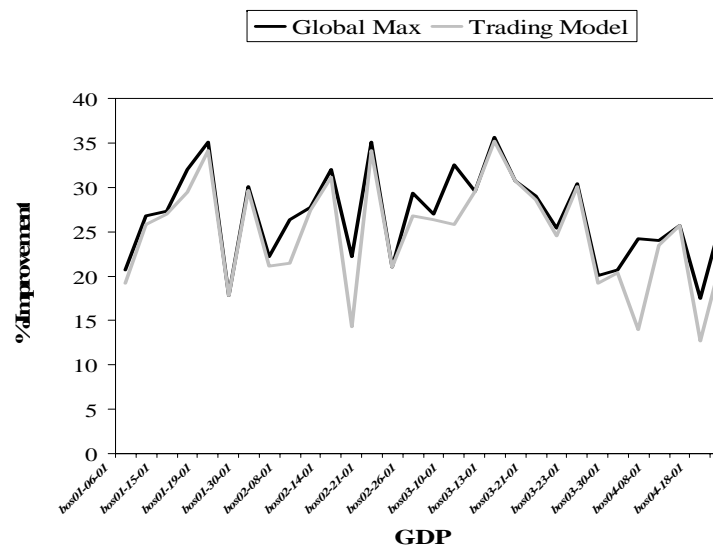
Compression Benefits

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



2-for-2 Trading Model

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



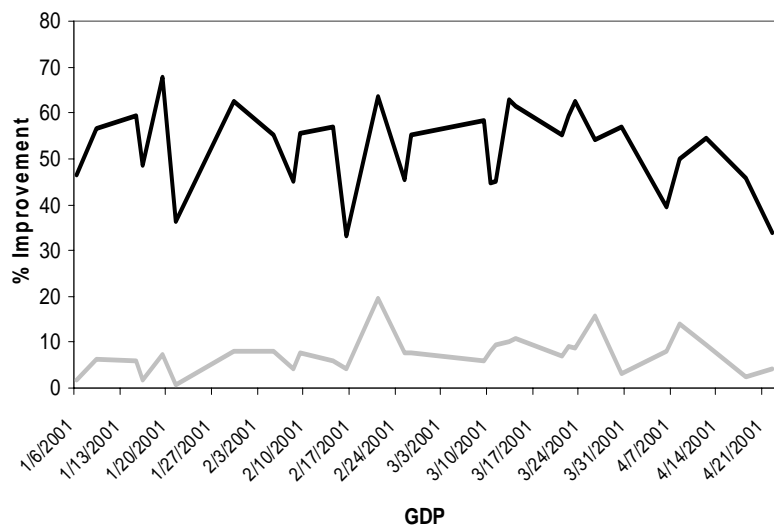


Initial Results

- Airline Objectives: Passenger Delay Costs

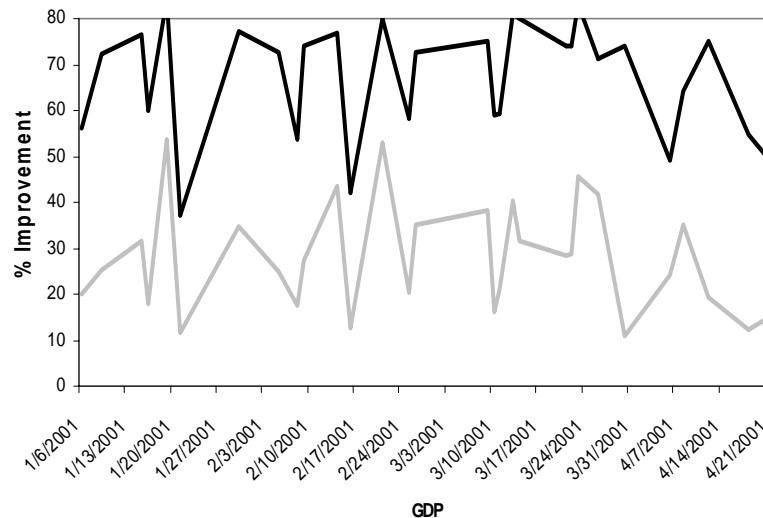
Objective Function 1

- “Standard” Passenger Delays



Objective Function 2

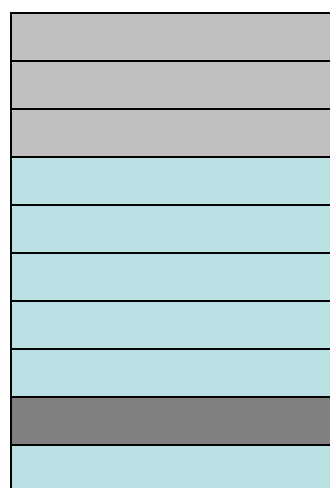
- Imposed “Staircase” structure





Towards a practical system: offer structure

high priority flights



“move up” range

current position

low priority flights



current position

“move down” range

Offers:

- Airlines willing to accept high priority moves up in exchange for low priority moves down

Data Requirements:

- 1 new data item per flight -- LET: latest exchange time



Towards a practical system: mediation problem

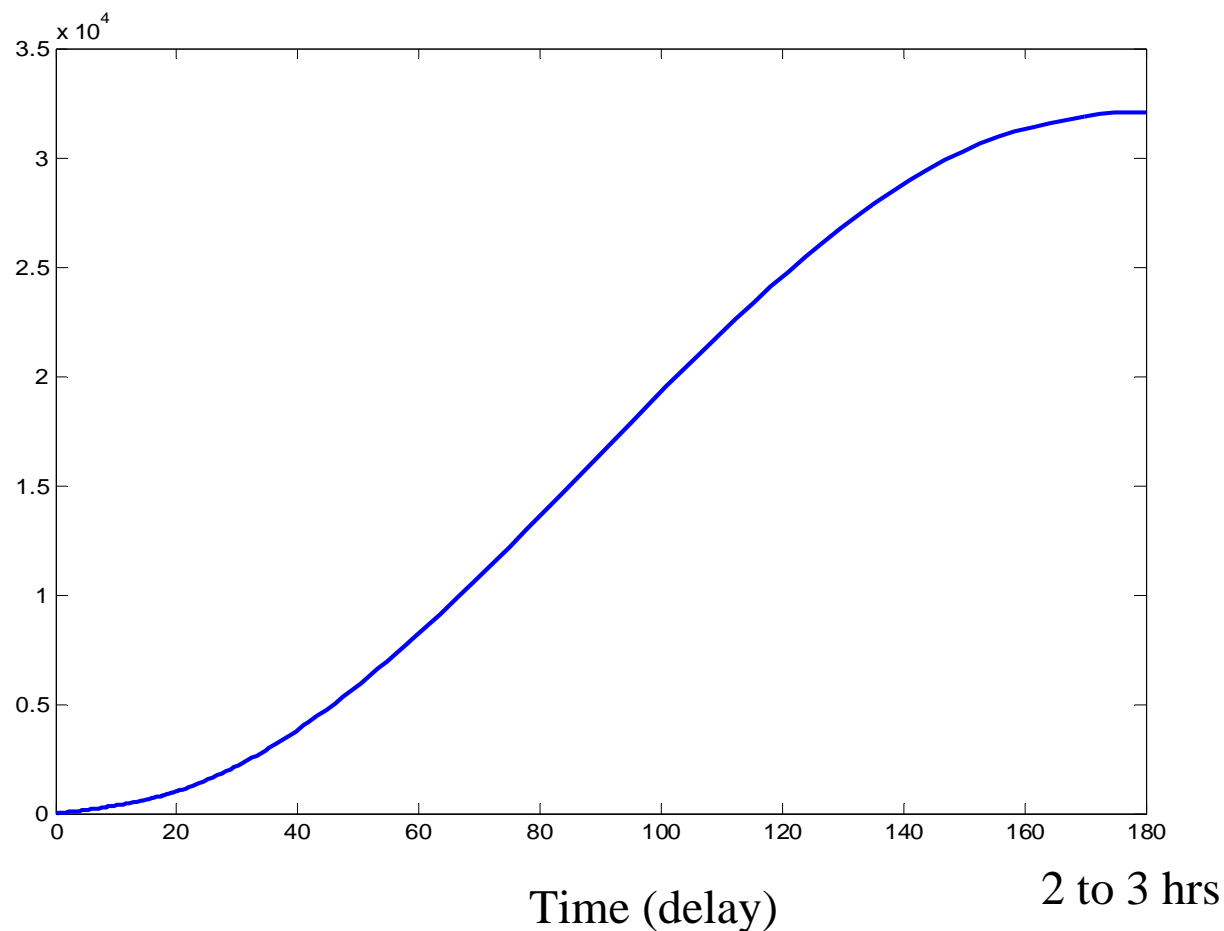


- IP formulation that assigns flights to slots in a manner consistent with offers
 - Allows airlines to express relative per unit value of up-moves vs down-moves
- Objective Function
 - Efficiency: maximize total distance or number of up moves
 - Equity: aims to distribute benefits in proportion to offers submitted



Towards a Practical System: Airline Cost Function for Simulation

cancellation
cost



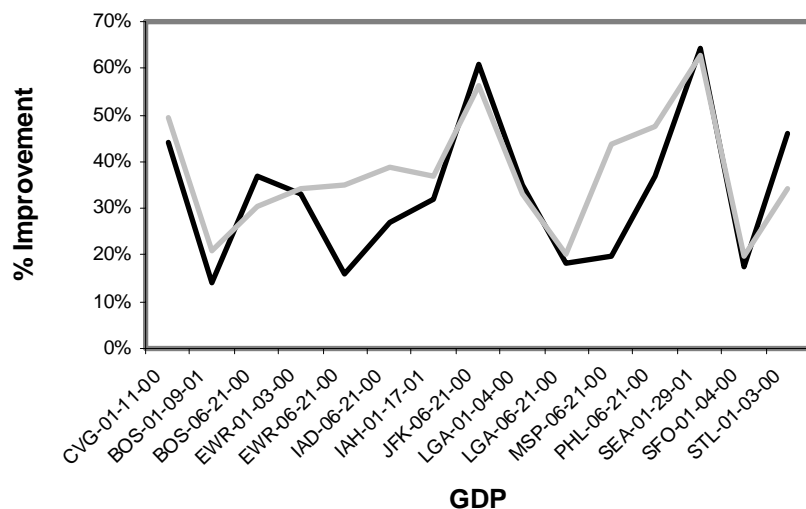


Towards a Practical System: Initial Results



Objective:

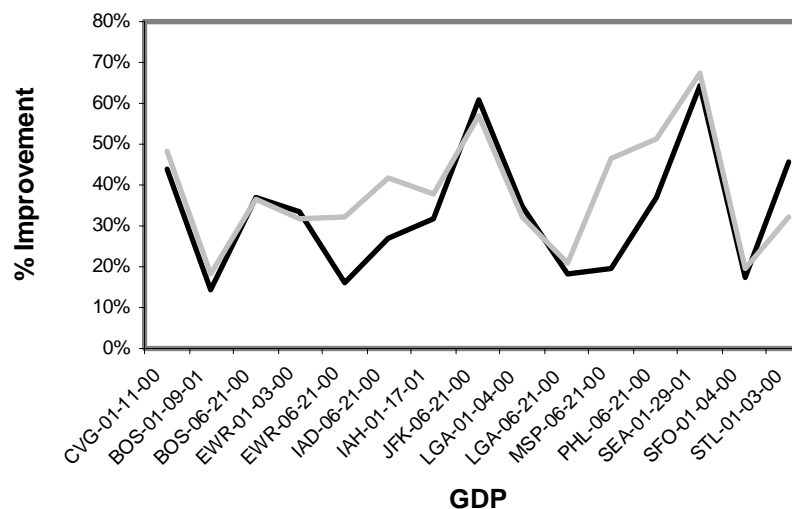
- Maximize total distance of Up moves



— Compression

Objective:

- Maximize total distance of Up moves
+ *sum of equity components*



— Trading Model



Summary and Conclusions

- Results illustrate potential benefits of slot trading framework
- Trading benefits may be limited by carriers which operate smaller aircraft
 - Introducing side payments may “induce” small carriers to accept delays
- Results depend significantly on airline bid generation strategies.
 - Best airline approach depends on internal schedule and cost structure, attitude toward risk and strategy of competitors.
 - Competitive simulations currently being constructed.