Dynamic Airline Slot Exchange during Ground Delay Programs

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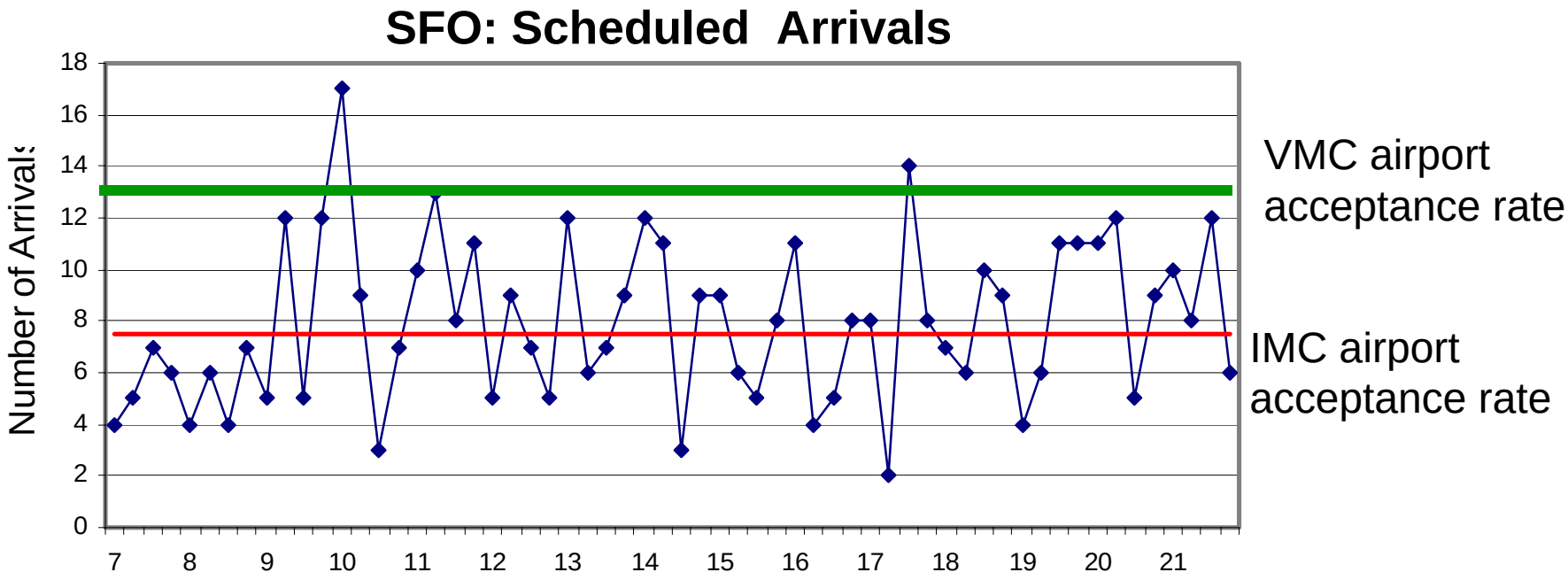
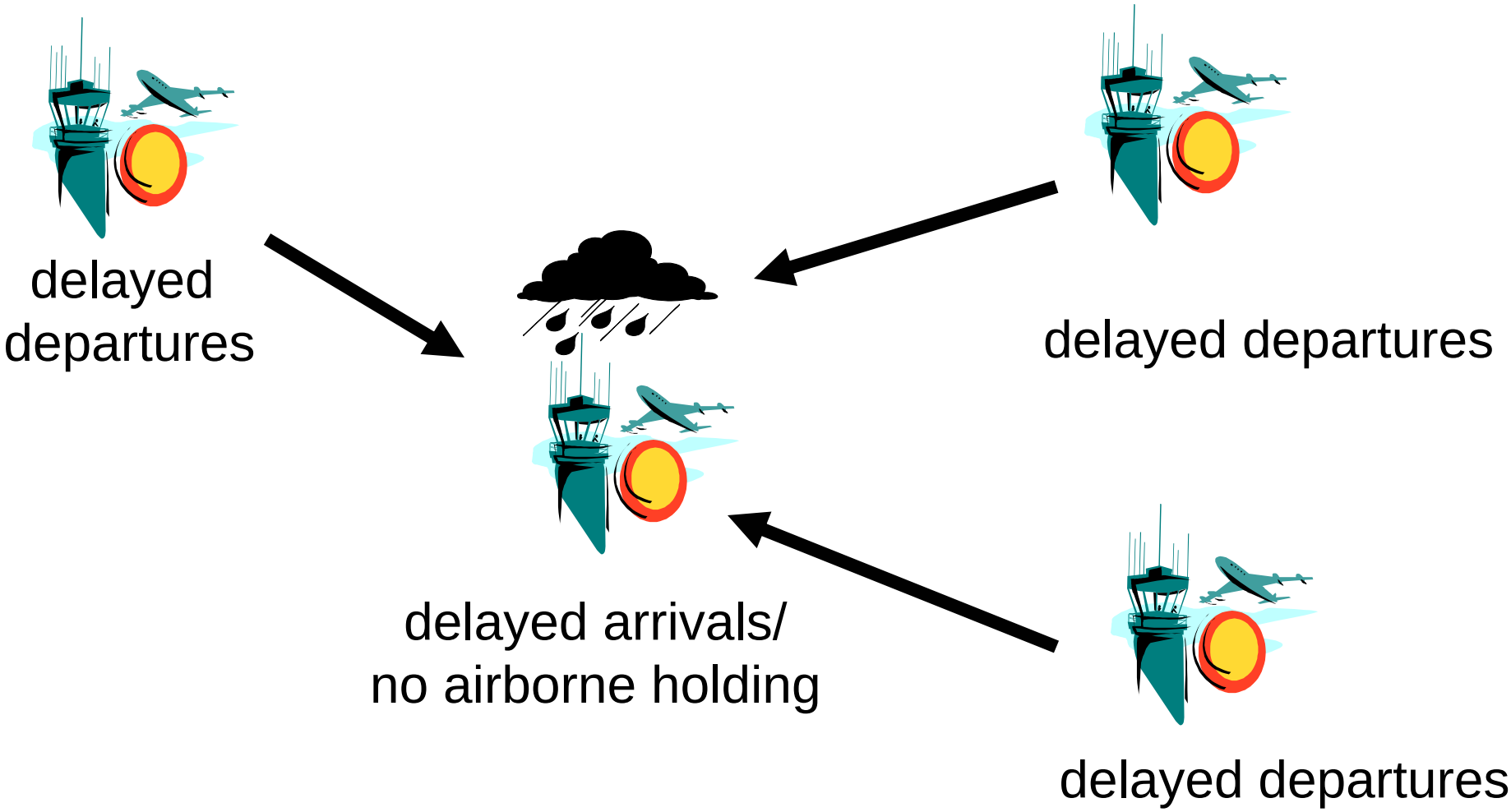
Ground Delay Programs:

Motivation:
airline schedules “assume” good weather



Ground Delay Programs



GDPs under CDM

Resource Allocation Process:

- FAA: *initial "fair" slot allocation*
  [Ration-by-schedule]

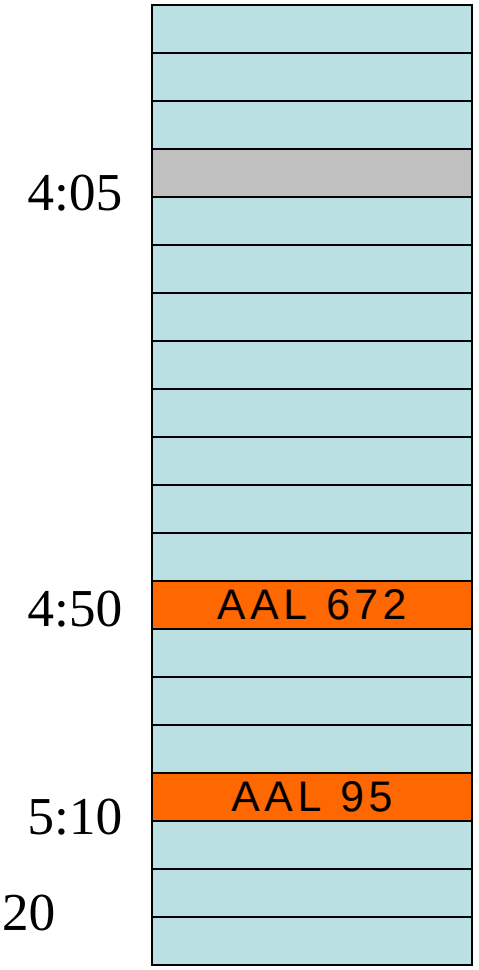
- Airlines: *flight-slot assignments/reassignments*
  [Cancellations and substitutions]

- FAA: *periodic reallocation to maximize slot utilization*

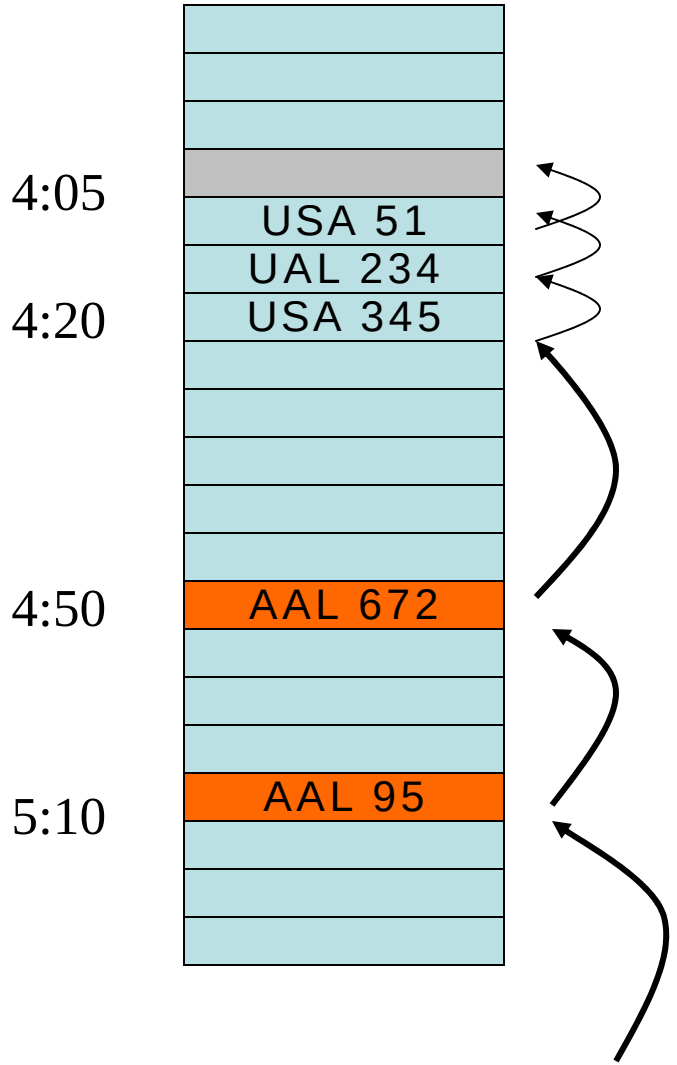
  [Compression]

Compression Example

Slot released by canceled/ delayed flight



Earliest time of arrival = 4:20



Slot Exchange Alternatives

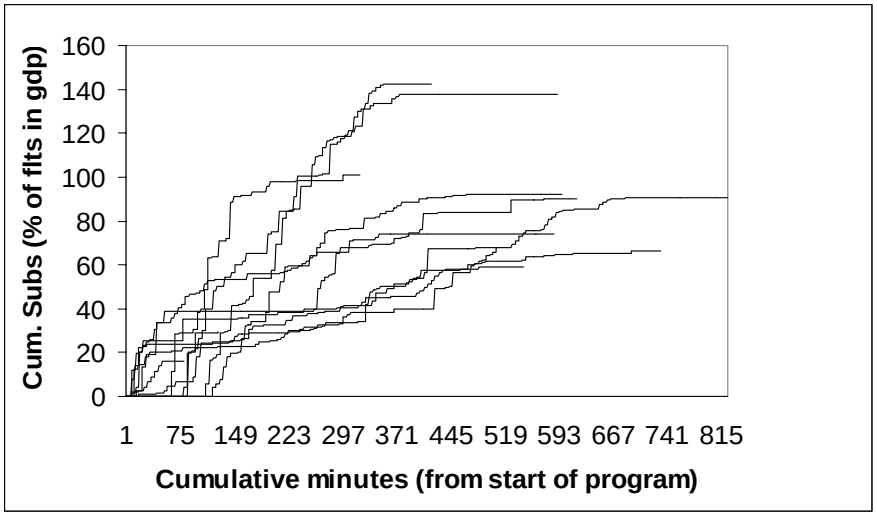
- Compression as Reallocation
  - Dynamic changes to airline "demand profiles" necessitate (re)rationing

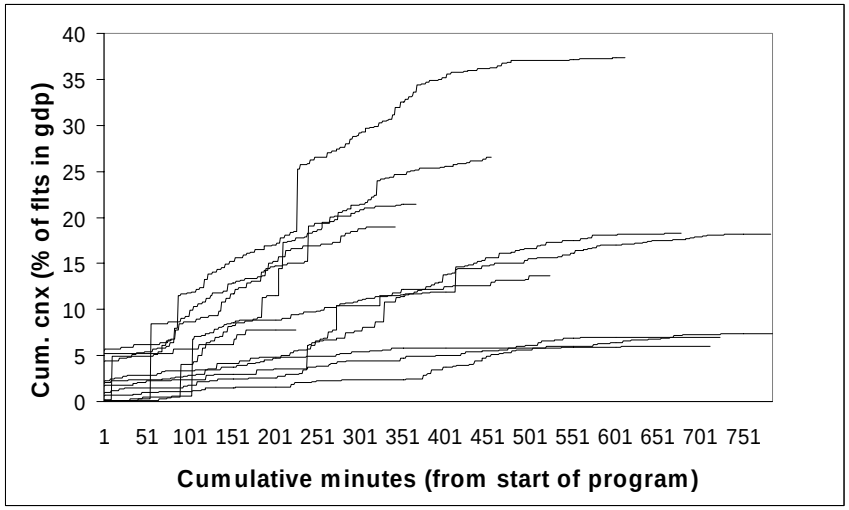
- Compression as Slot Trading
  - e.g., Slot Credit Substitutions:

    "I am willing to cancel flight f_1 if I can move up flight f_2".

Slot Trading Opportunities

Airline Substitution/Cancellation Patterns



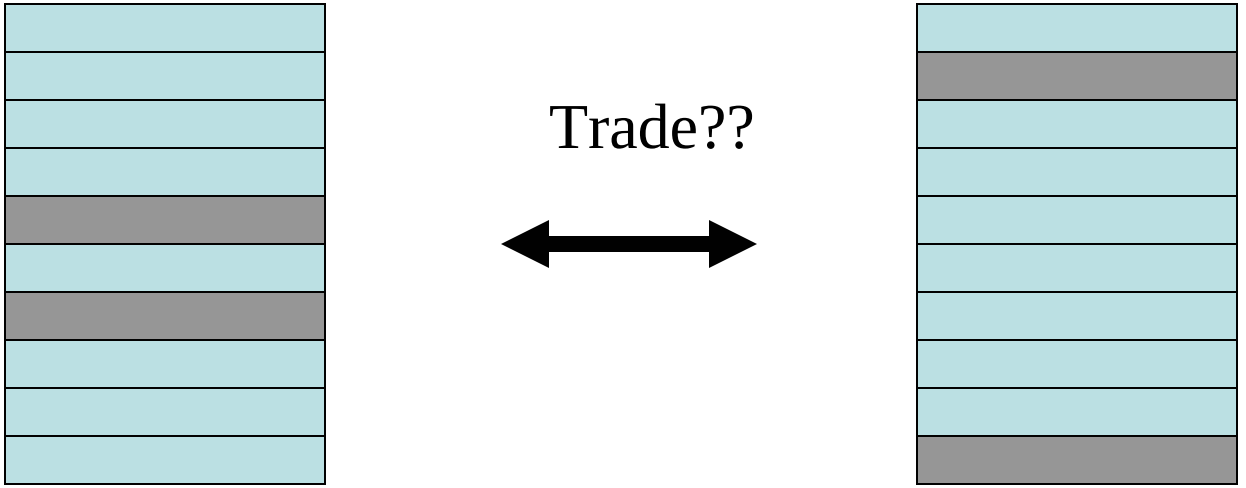


Consider potential benefits of extending slot trading framework

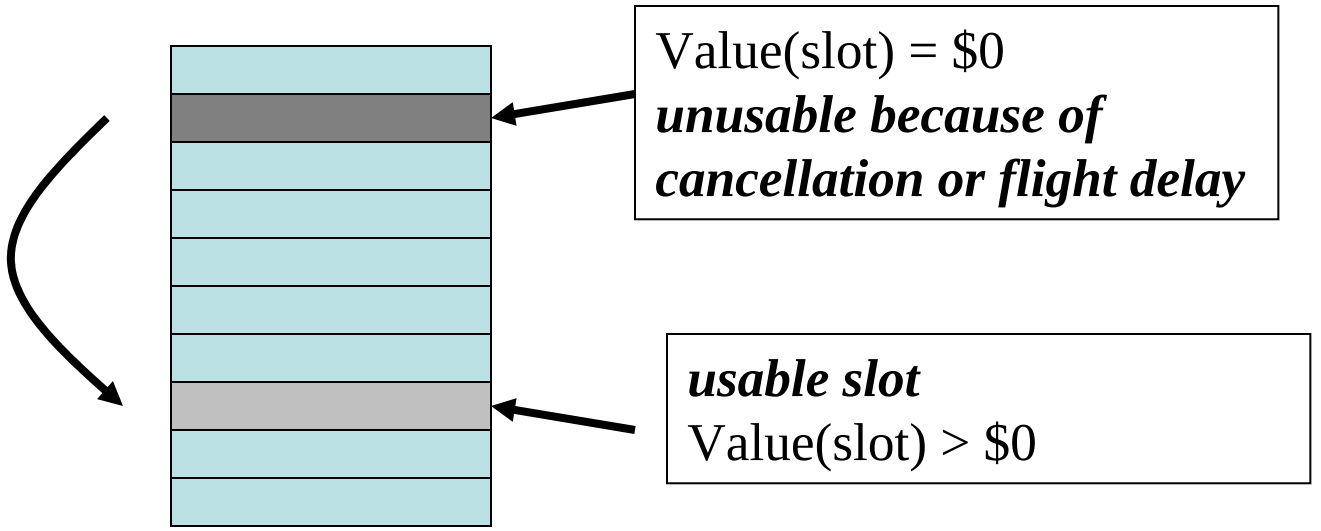
- e.g., Increase offers submitted by airlines

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:

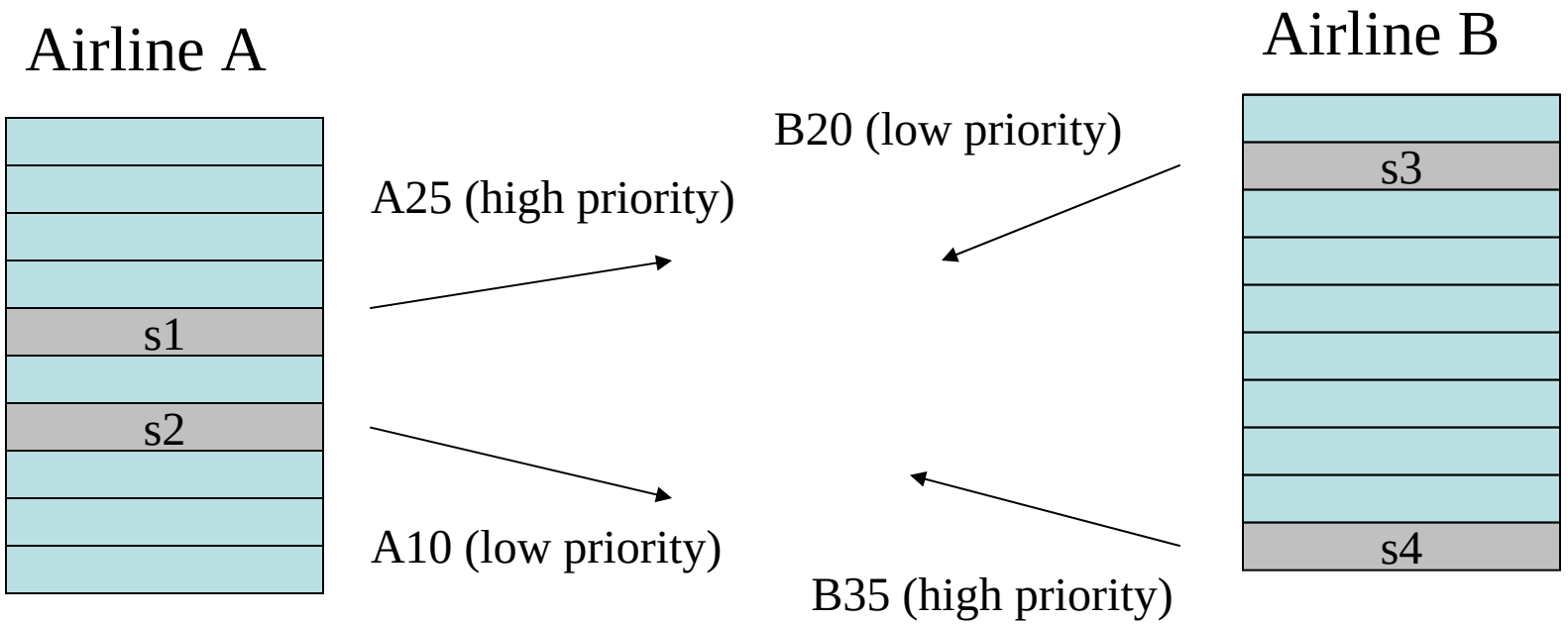


Value proposition for compression & SCS



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

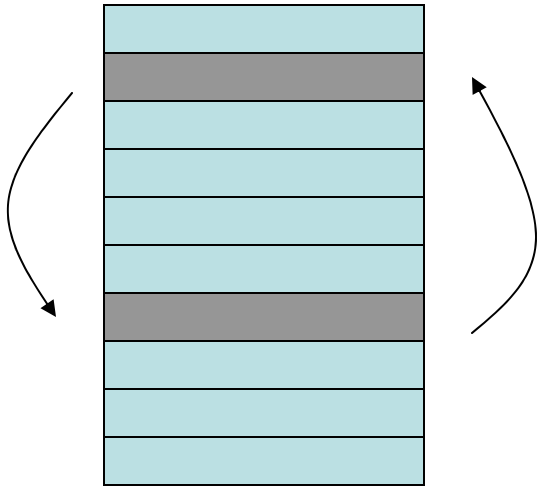
2-for-2 trades enable airlines to profit by exchanging pairs of usable slots that result in an increase in overall value to the carrier.



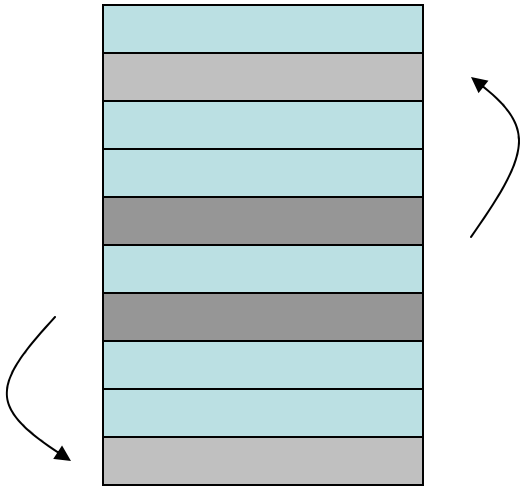
A's value proposition: $val_A(s3) - val_A(s1) + val_A(s4) - val_A(s2) =$
$2000 - 1500 + 300 - 500 = \$300$

B's value proposition: $val_B(s1) - val_B(s3) + val_B(s2) - val_B(s4) =$
$500 - 800 + 2500 - 1800 = \$400$

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



Normal Substitution



Generalized Substitution

Issues

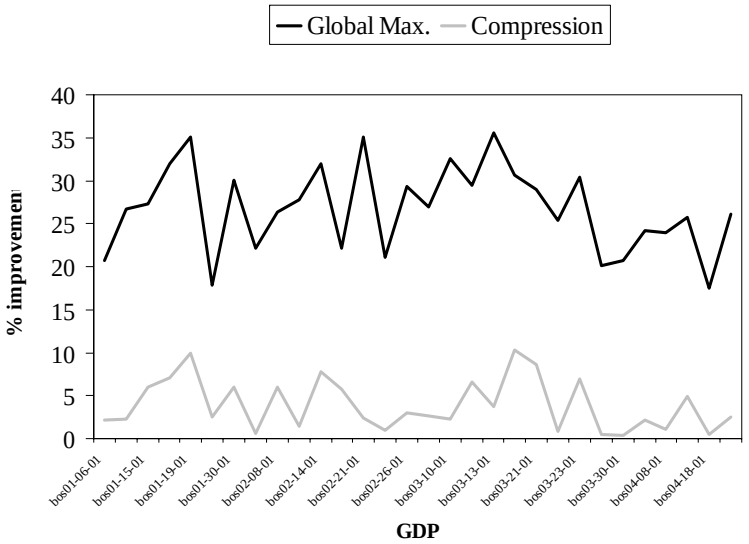
- System Design:
  - How do airlines represent and generate offers?
  - Formulation and solution of FAA mediation problem
- System Evaluation:
  - Airline objectives and strategies
  - Performance Measurement:
    - comparison with optimal centralized solution (system efficiency)

Initial Results

- Airline Objective: On-time Performance

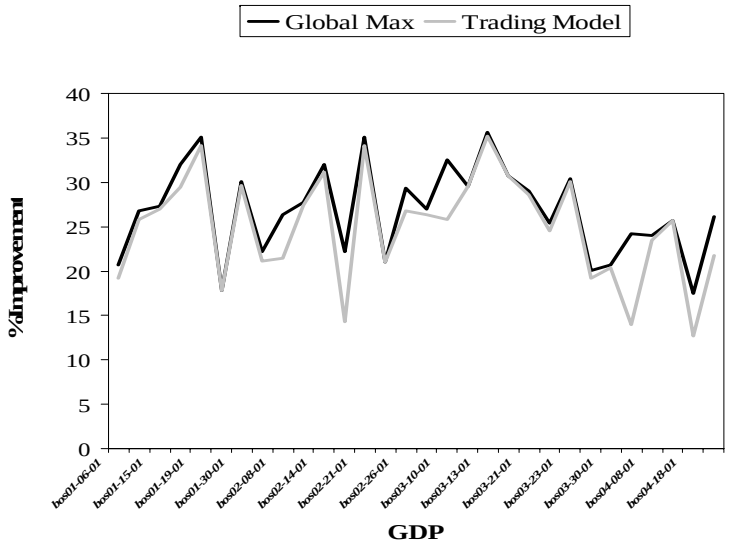
Compression Benefits

- 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

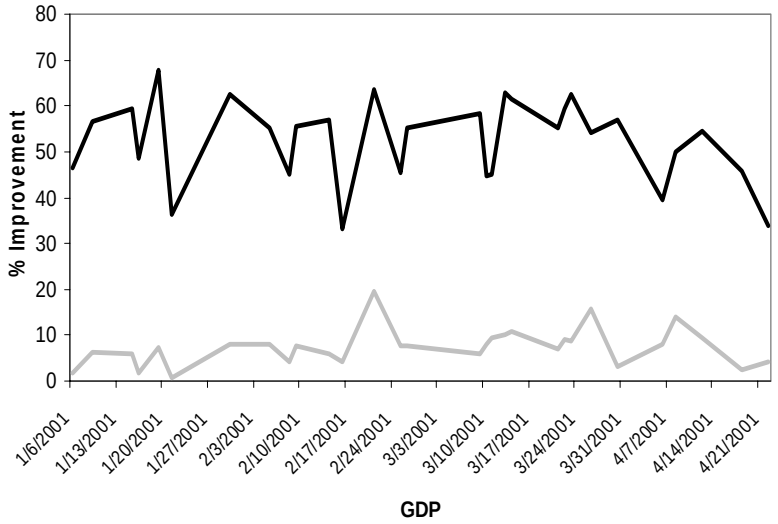


Initial Results

- Airline Objectives: Passenger Delay Costs

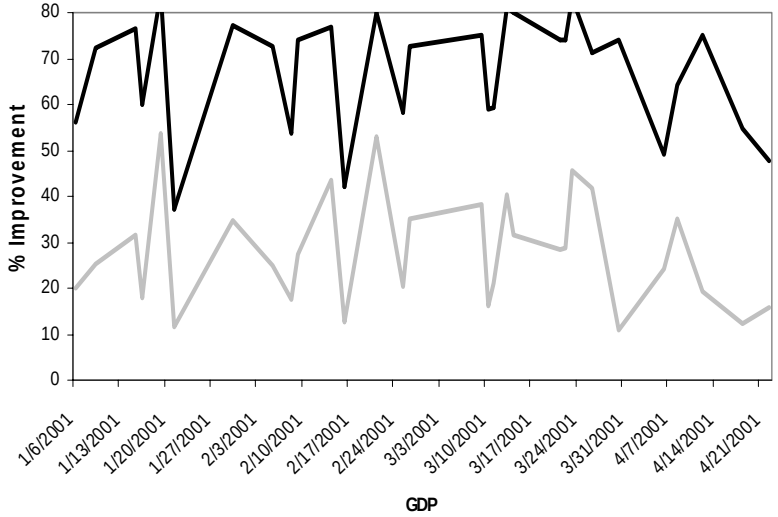
Objective Function 1

- "Standard" Passenger Delays

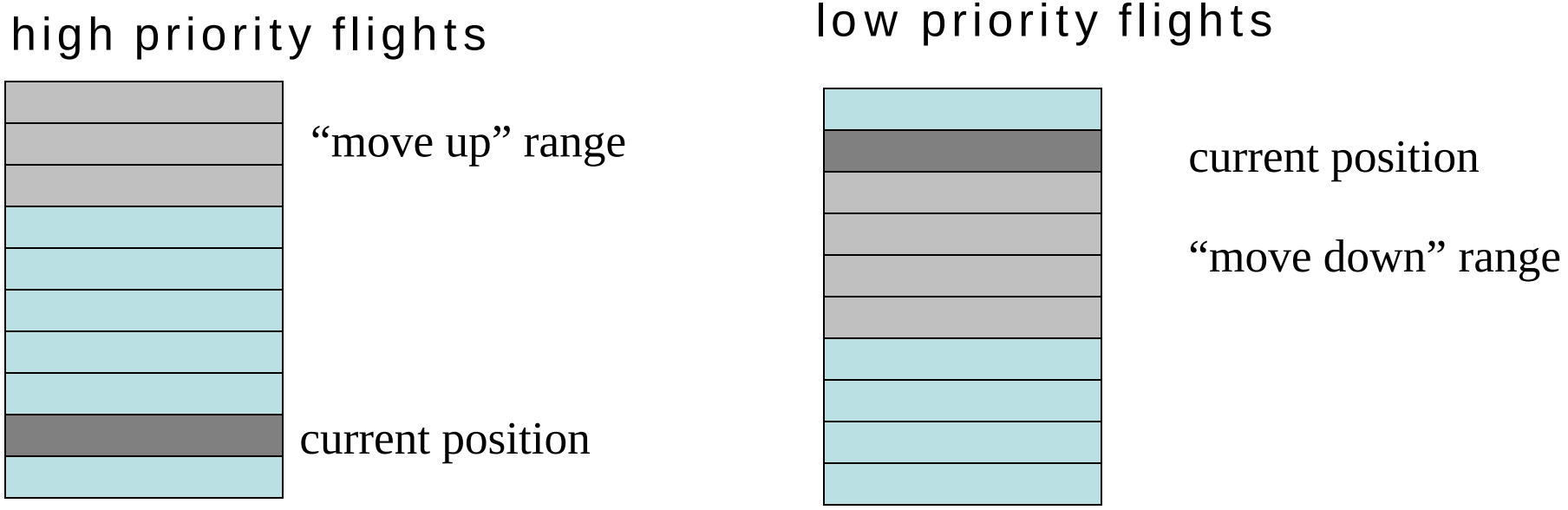


Objective Function 2

- Imposed "Staircase" structure



Towards a practical system: offer structure



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

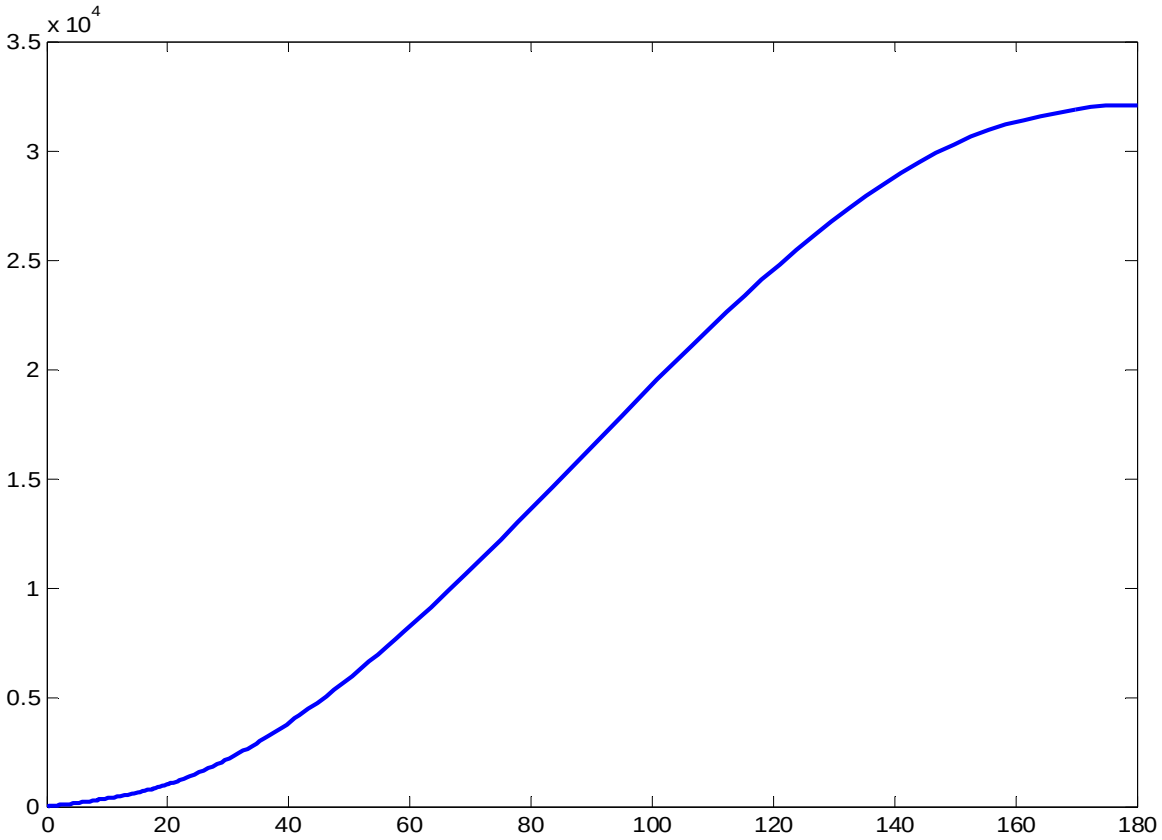
Towards a practical system: mediation problem

- 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



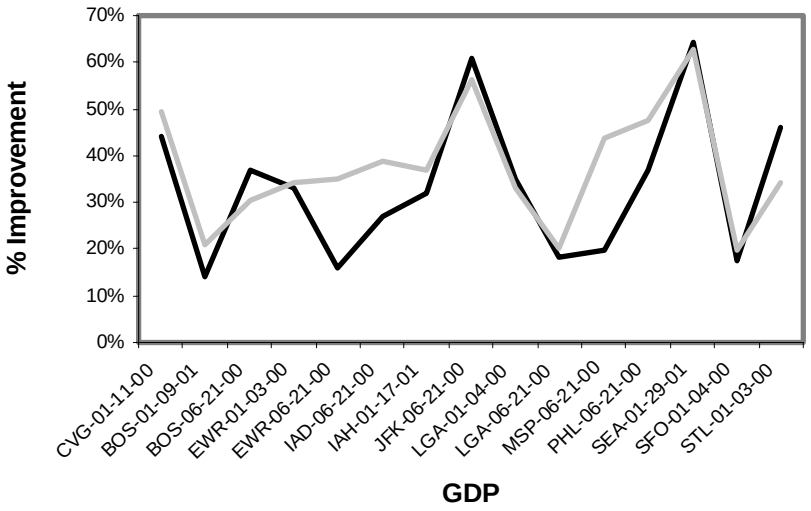
Time (delay)

2 to 3 hrs

Towards a Practical System: Initial Results

Objective:

- Maximize total distance of Up moves

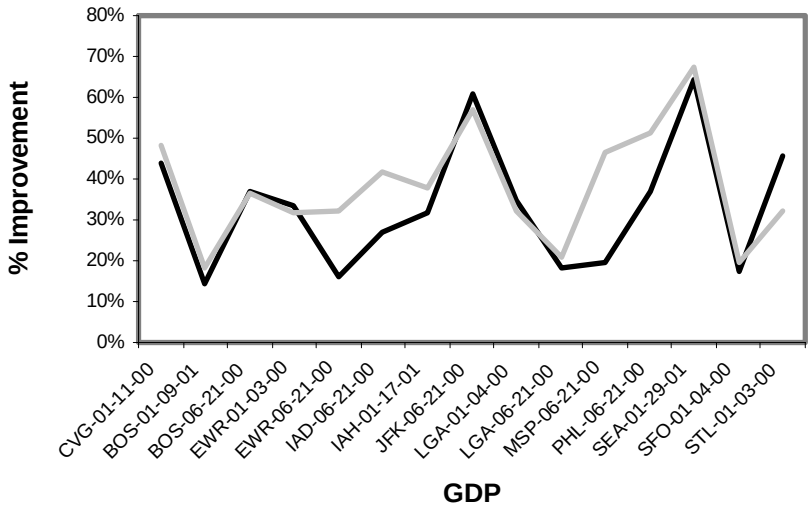


Compression

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.