Fair Allocation Concepts in Air Traffic Management

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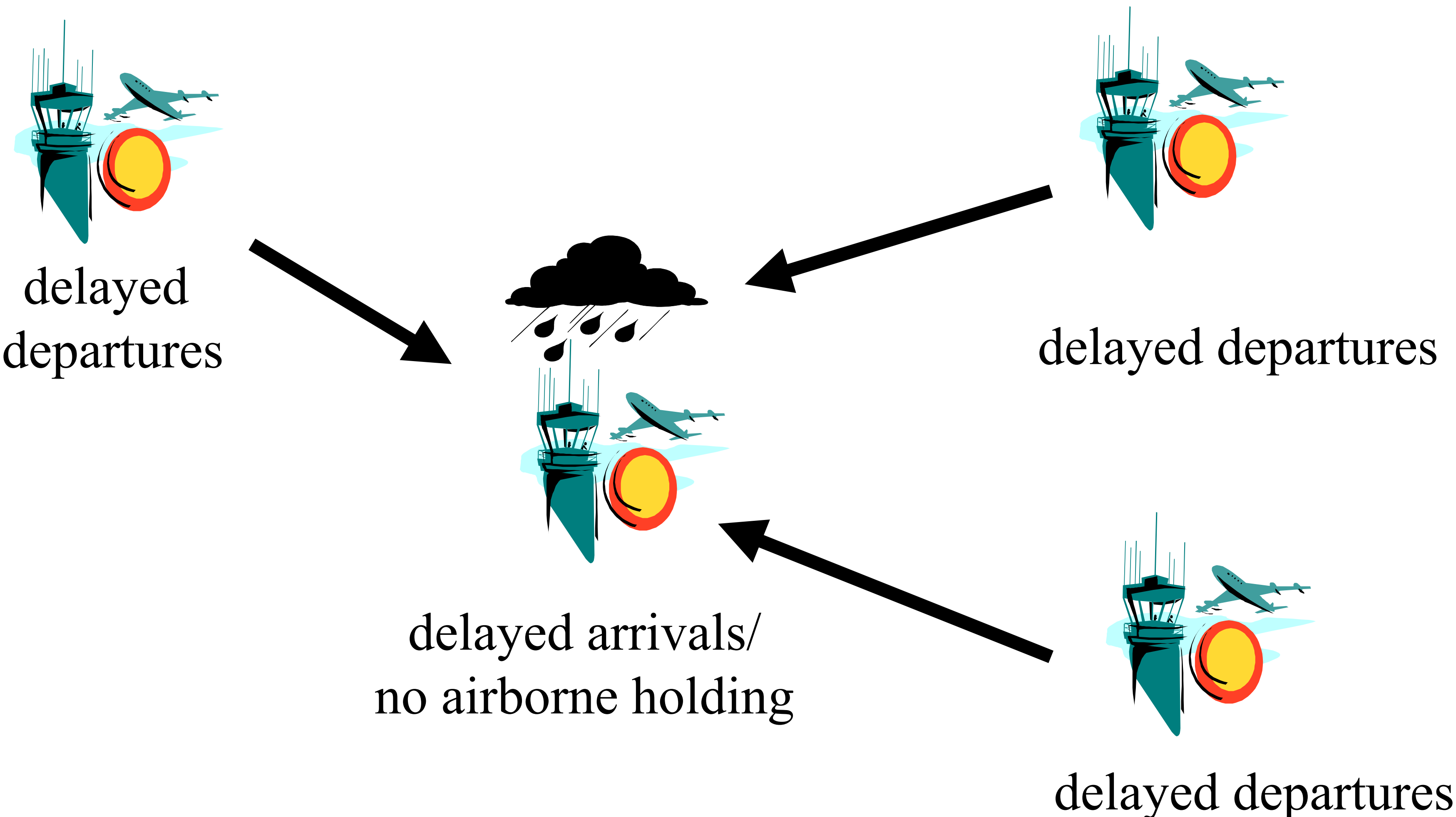
Ground Delay Programs



Collaborative Decision-Making

Traditional TFM:

- Flow managers alter routes/schedules of individual flights to achieve system wide performance objectives

Collaborative Decision-Making (CDM)

- airlines and aircraft operators share information and collaborate in determining resource allocation

CDM in GDP context:

- CDM-net, communications network that allows real-time information exchange
- Allocation procedures that increase airline control and encourage airline provision of up-to-date information

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]

Note:

- *reduced capacity is partitioned into sequence of arrival slots*
- *ground delays are derived from delays in arrival time*

Allocating Slots under CDM

Ration-By-Schedule:

Step 1: Order flights by their
original scheduled time of arrival

Step 2: Select the first flight that has not been assigned an arrival slot.

- assign the selected flight to the earliest unassigned slot
- repeat step 2.

The resulting allocation is independent of current status of flights and is not affected by status information given by airlines!!

Slot Reallocation under CDM

Need for Inter-airline slot exchange:

slots made available through flight cancellations and delays

Compression Algorithm

Initial

AAL1:1200	→	S1200
AAL2:1201		S1202 *CNX*
UAL1:1202	→	S1204
USA1:1203	→	S1206
UAL2:1204	→	S1208
COA1:1210	→	S1210
USA2:1212	→	S1212
AAL3:1214	→	S1214

Final

AAL1:1200	→	S1200
AAL2:1201		S1202
UAL1:1202		S1204
USA1:1203		S1206
UAL2:1204	→	S1208
COA1:1210	→	S1210
USA2:1212	→	S1212
AAL3:1214		S1214

Motivation

Fairness Issues:

- Flight-based vs. airline-based,
  - e.g. RBS:flight-based, Compression: airline-based
- Possible “standards of comparison”
- Impact of program dynamics
  - flight cancellations/delays (compression)
  - flight exemptions

Related Allocation Problems

Apportionment problems:

- *How to assign house seats to states according to proportion of their populations*

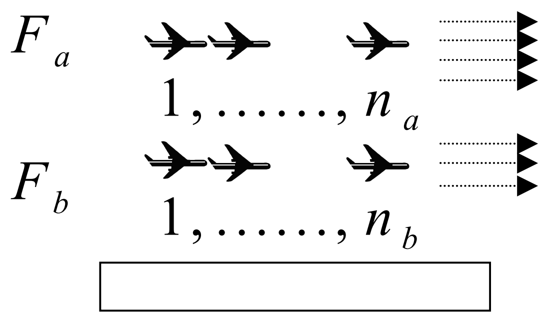
Balanced just-in-time scheduling problems:

- *How to determine production schedules that minimize variation in the production rate of successive units of different product types.*

GDPs as apportionment

"Coarse-grained" one-period GDP:

Flights:



Delay: $D = n - C$

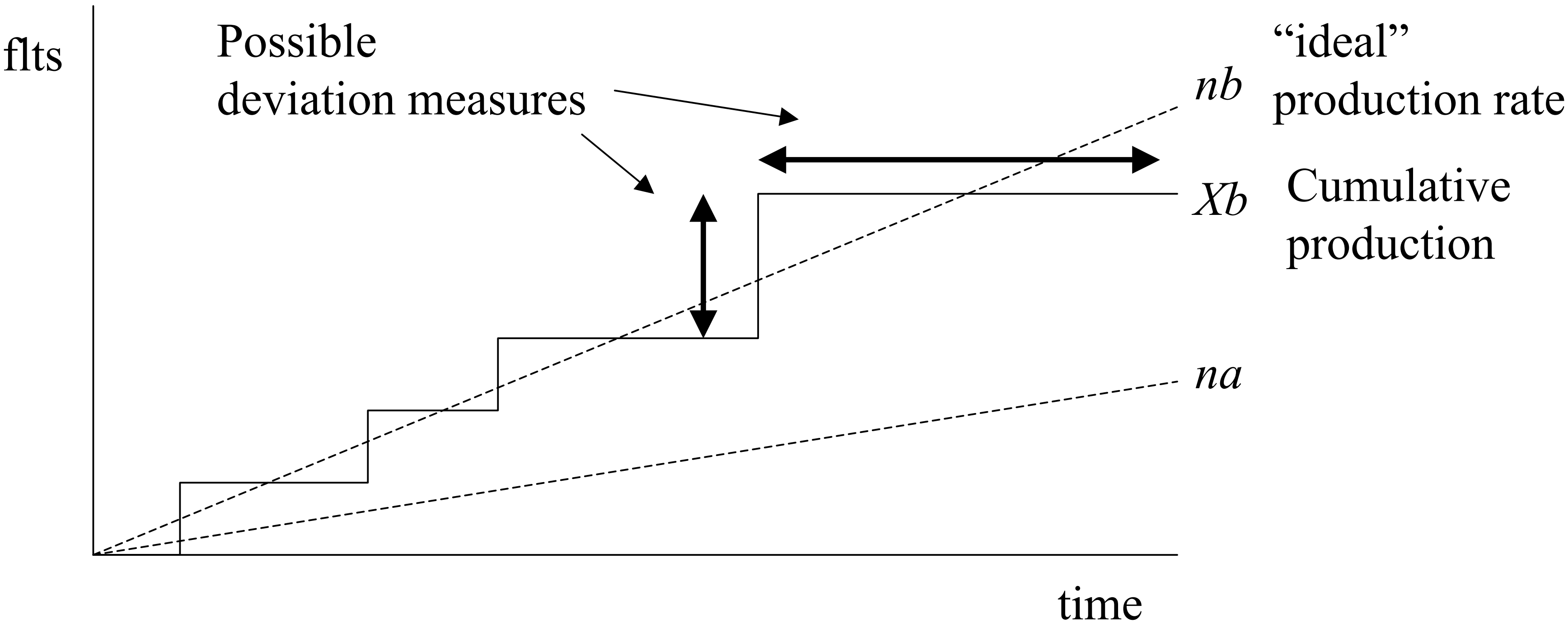
Slot: capacity C

Interpretation as apportionment:

- capacity C = house seats
- airlines = states
- flights = populations

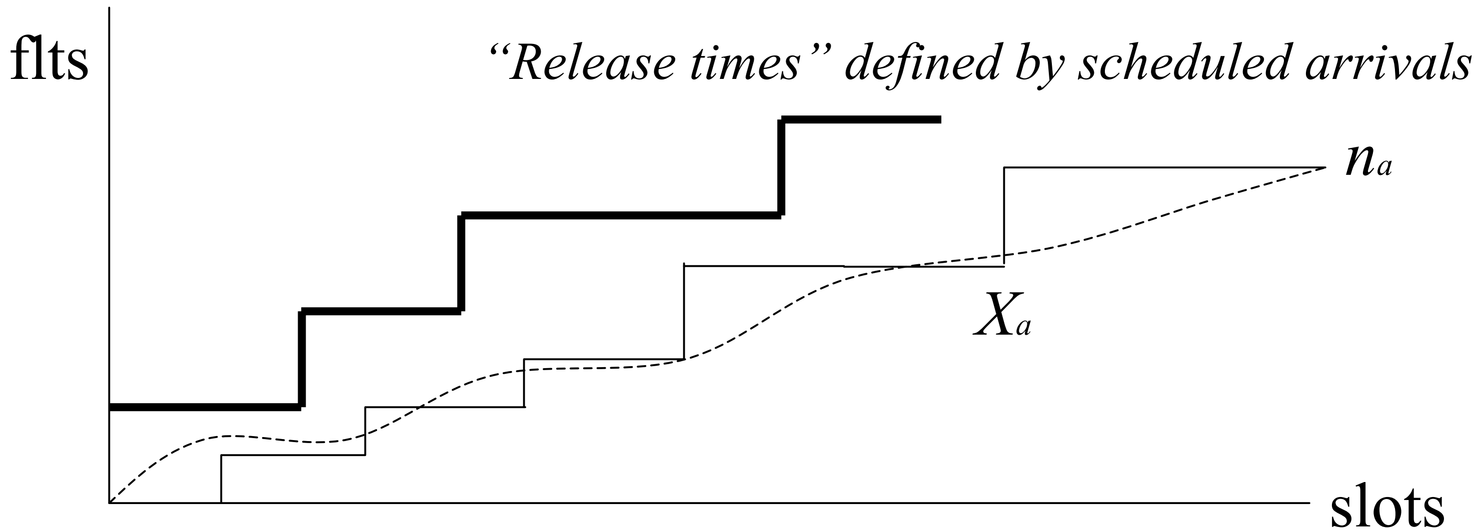
GDPs as balanced JIT problem

"Finer-grained" GDP:



- Airlines = products, flights = product quantities
- Minimize deviation between "ideal" rate and actual production

GDP Situation



Questions:

- What are appropriate "production rates" ?
- How to minimize deviations ?
- Managing program dynamics

Determining fair shares

Sketch:

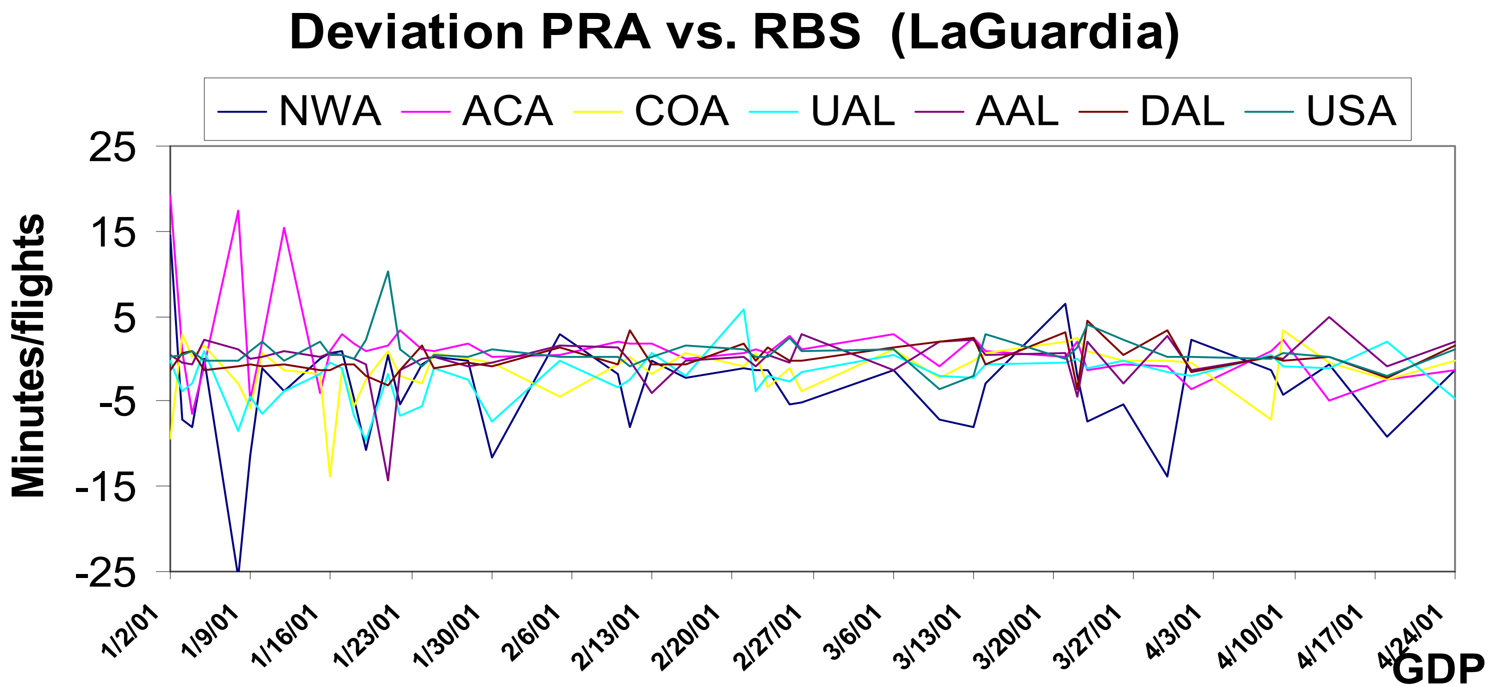
- Assume slots are *divisible*
  - leads to probabilistic allocation schemes
- Approach: impose properties that schemes need to satisfy
  - fairness properties
  - structural properties (consistency, sequence-independence)

Determining fair shares

Two possibilities:

- earlier flights have priority over later flights
  - *e.g. Ration-by-schedule*
- all flights have equal priority
  - leads to *"proportional random assignment":*
  - At each step, assign next slot to airline *a* with probability proportional to airlines' current flights.

Empirical Comparison



- On the aggregate, both methods give similar shares
- no systematic biases

Program Dynamics

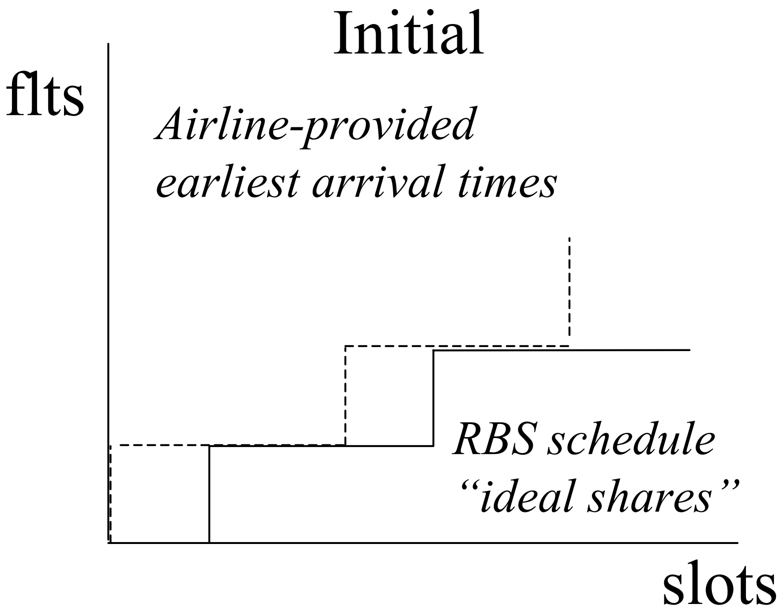
Question:

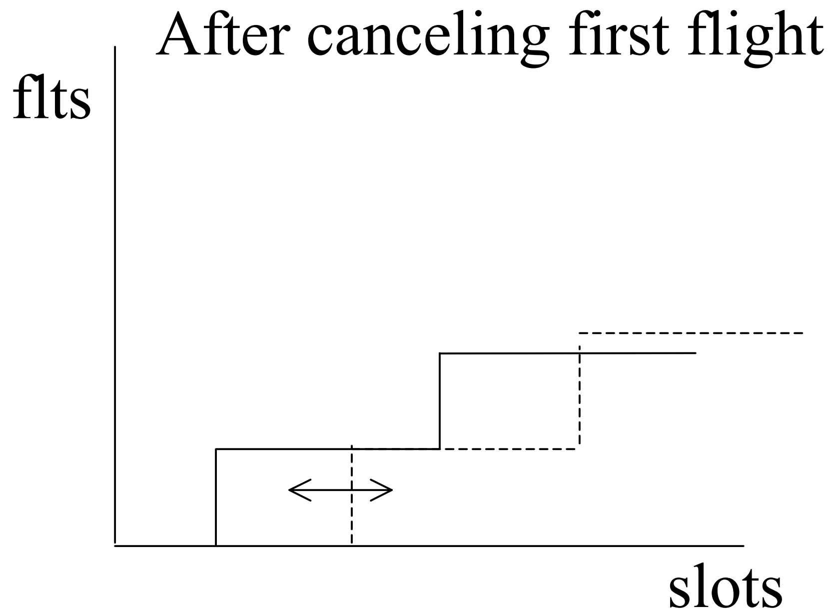
- If RBS is fine, why bother with minimizing deviation, balancing the schedule ?

Answer: *GDP dynamics*

- Flight cancellations, delays (e.g. compression)
- Exemption-handling

1.Flight Cancellations/Delays





- Infeasibility/suboptimality require rescheduling
- Use balanced jit paradigm to minimize airline deviations from RBS schedule

1.Flight Cancellations/Delays

Approach:

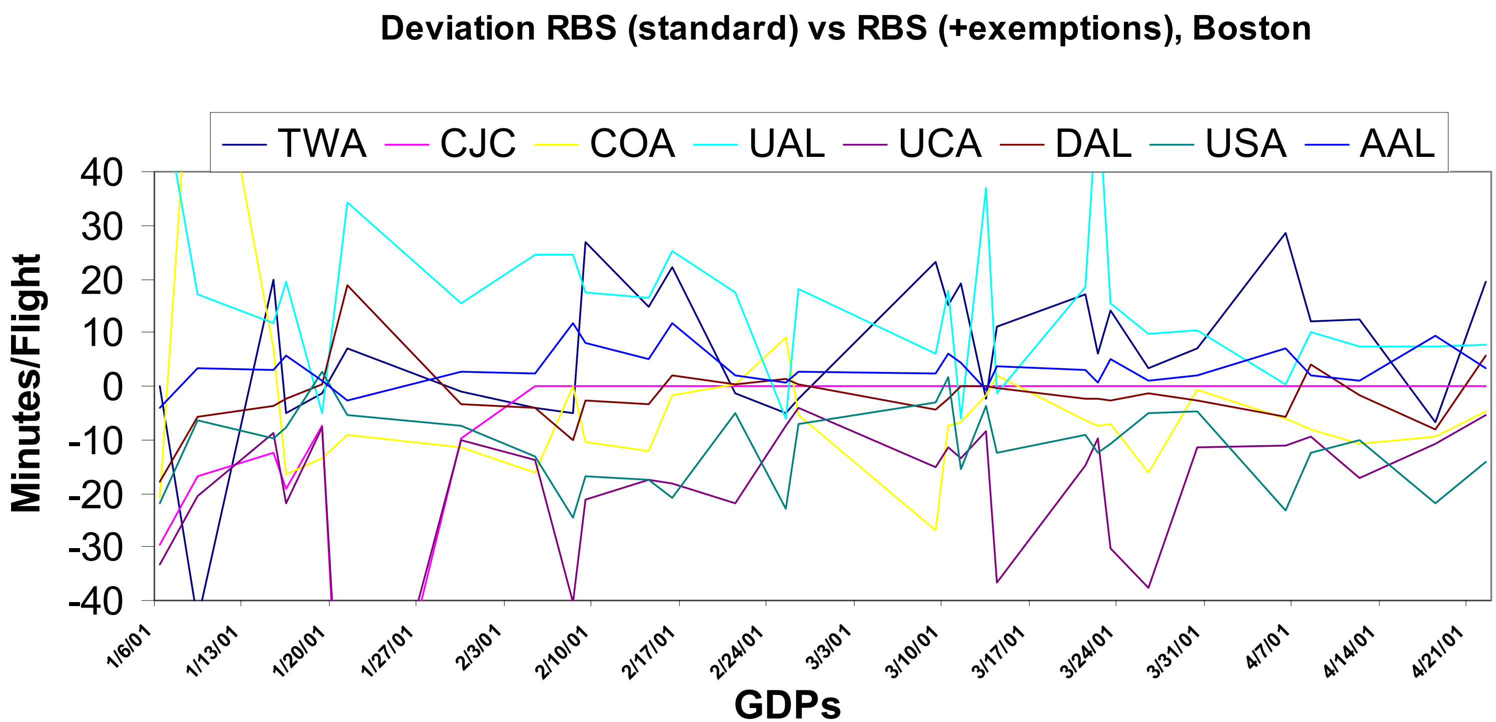
- Minimize deviation between ideal and actual position for *k*-th flight of airline *a,* for all *a,k*

Priority Method:

- Input: ordered list of priorities for each airline
- Sequentially assign slots:
  - Assign current slot to airline with highest remaining priority that can use slot (given its earliest arrival times)

- Results similar to compression algorithm

2. Flight exemptions



Flight exemptions introduce systematic biases:

- USA (11m/flt), UCA (18m/flt) “lose” under exemptions

2. Flight Exemptions

Objective :

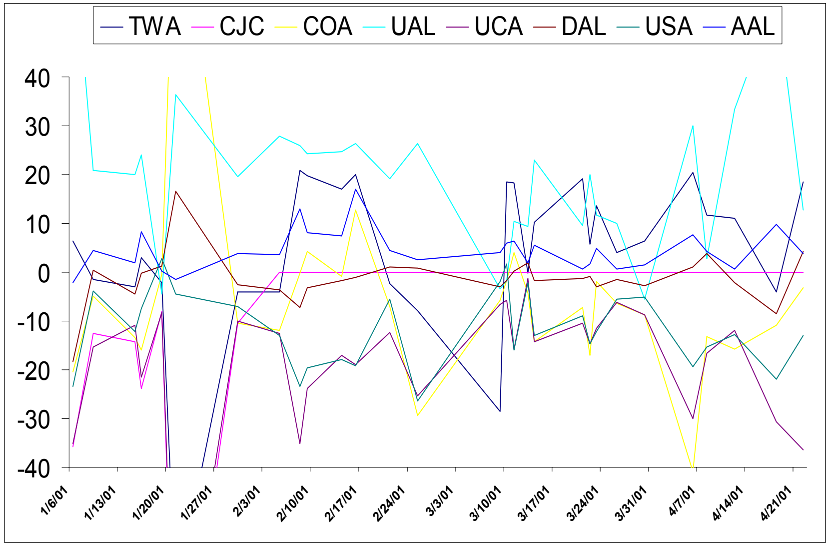
- Use deviation model to mitigate exemption bias
  - e.g. “inverse” compression

Possible approaches:

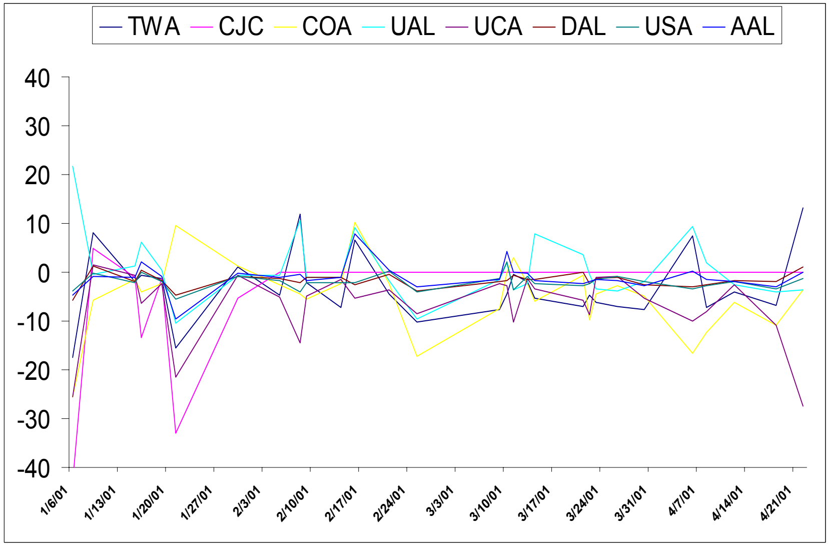
- Optimization model adjusted for constraints posed by exempted flights
- Adjustment of priority method
  - may not minimize overall deviation measure

2. Flight Exemptions

Deviation RBS ideal-RBS actual



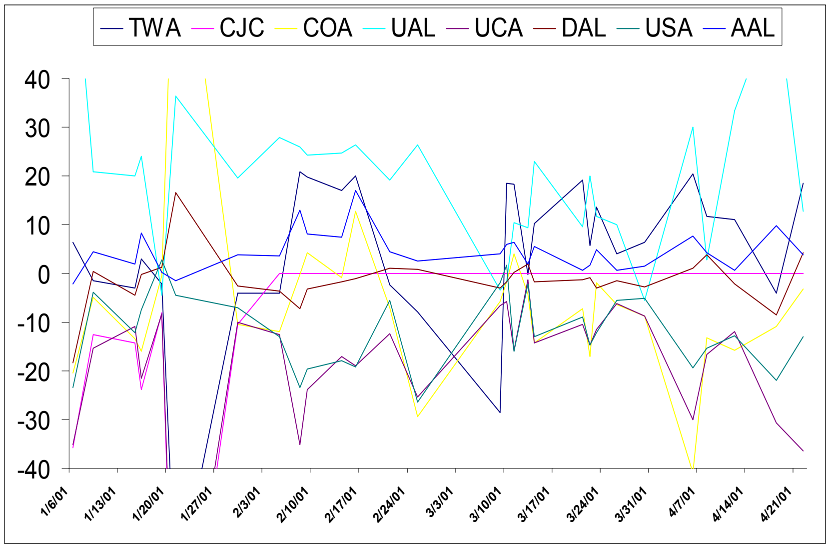
Deviation RBS ideal-Opt. model



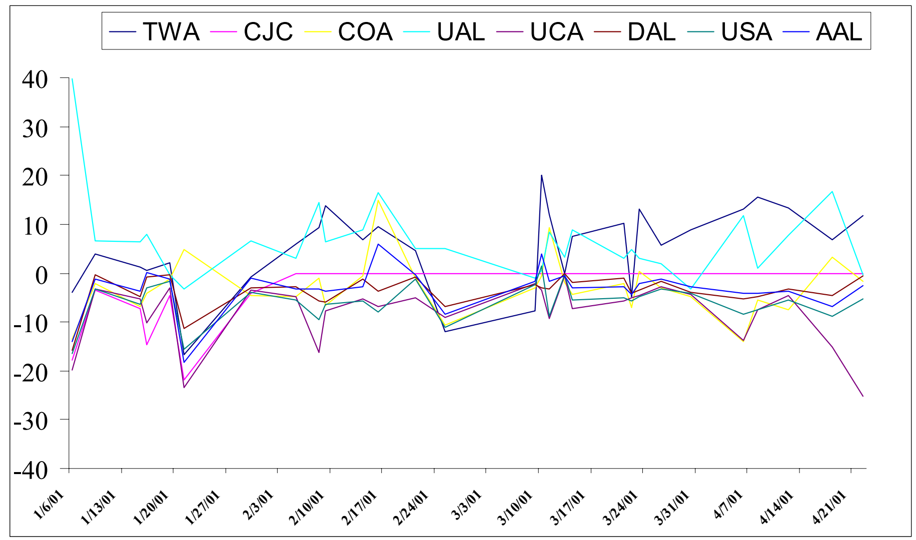
- Minimize deviations using optimization model that incorporates exemptions
- reduces systematic biases, e.g. USA from 11m/flt to 2m/flt, UCA from 18m/flt to 5m/flt

2. Flight Exemptions

Deviation RBS ideal-RBS actual



Deviation RBS ideal-priority alg.



- Minimize deviations using adjustment of priority scheme
- lesser, but still significant bias reduction, e.g. USA from 11m/flt to 5m/flt, UCA from 18m/flt to 7m/flt

Discussion

Approach yields system where:

- airlines are assigned priority *lists*
  - based on sched. arr. times, constant during GDP
- dynamic changes (capacity, airline data) initiate (re)rationing
  - ration according to *airline* priorities
- priority scheme cannot (completely) be maintained with flight exemptions
  - deviation model shows potential to reduce exemption bias