Dynamic and Flexible Airline Schedule Design

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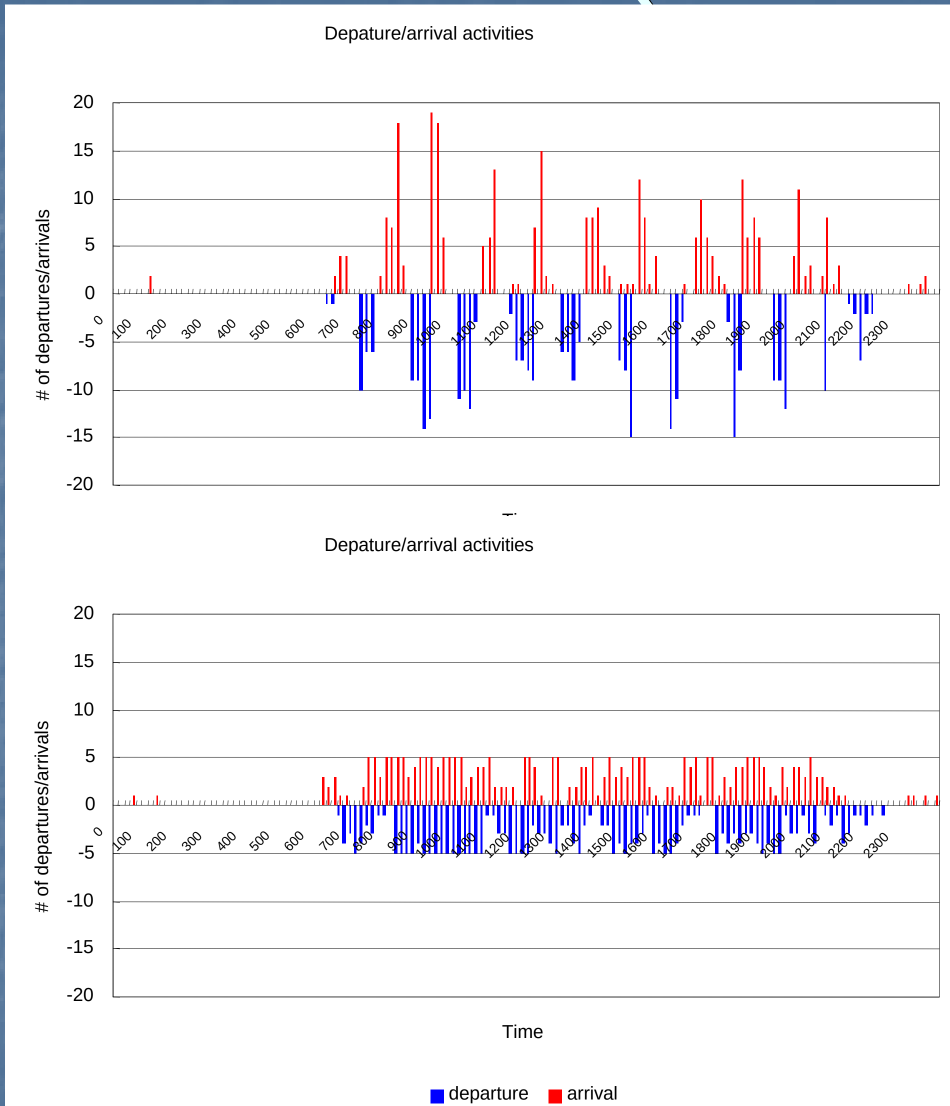
De-banked (or De-peaked) Hubs



American de-peaked ORD (2002), DFW (2002), MIA(2004)

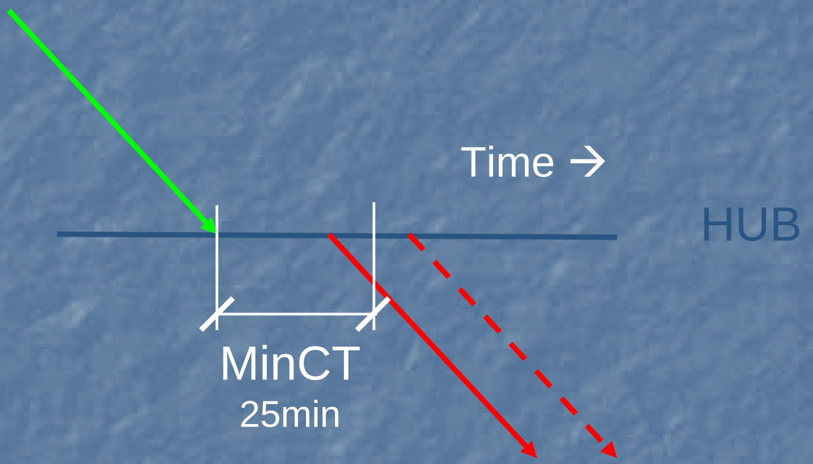
Continental de-peaked EWR

United de-peaked ORD (2004), LAX (2005), SFO (2006)

Delta de-peaked ATL (2005)

Lufthansa de-peaked FRA (2004)

Opportunity in a De-Peaked Schedule



Flight re-timing creates new itineraries, adjusts market supply

Dynamic Airline Scheduling

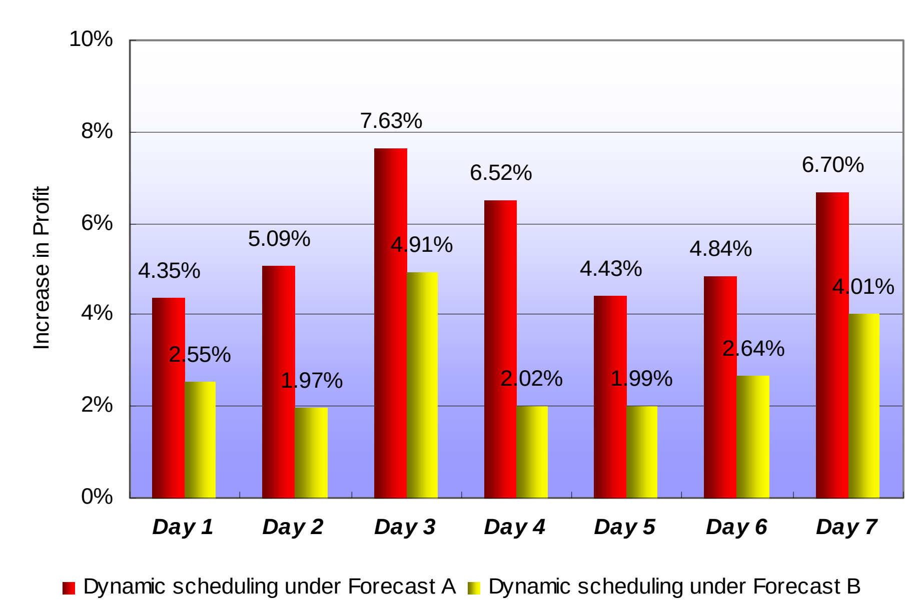
- Dynamic scheduling idea
  - Move the capacity (supply) in various markets so as to optimize profitability in response to demand variability:
    - Retiming flights
      - Creating new itineraries and eliminating itineraries only if no bookings to date
    - "Swapping" aircraft
      - Re-assigning aircraft within the same fleet family
        - Maintaining crew feasibility
        - Maintaining conservation of flow (or balance) by fleet type
        - Maintaining satisfaction of maintenance constraints

Case Study

- Major US Airline
  - 832 flights daily
  - 7 aircraft types
  - 50,000 passengers
  - 302 inbound and 302 outbound flights at hub daily
    - Banked hub operations- must de-bank
- Re-time
  - +/- 15 minutes
- Re-fleet
  - A320 & A319
  - CRJ & CR9
- One week in August, with daily total demand:
  - higher than average (Aug 1)
  - average (Aug 2)
  - lower than average (Aug 3)
- Protect all connecting itineraries sold in Period up to *d*-*t*
  - *t* =21 or 28 days
- Two scenarios concerning forecast demand
  - Perfect information
  - Historical average demand

Improvement In Profitability

- Consistent improvement in profitability
  - Forecast A
    - 4-8% improvement in profit
    - 60-140k daily
  - Forecast B
    - 2-4% improvement in profit
    - 30-80k daily
    - Benefits remain significant when using Forecast B- a lower bound
  - not including benefit from aircraft savings, reduced gates and personnel …



Comparison: Re-Time & Re-Fleet

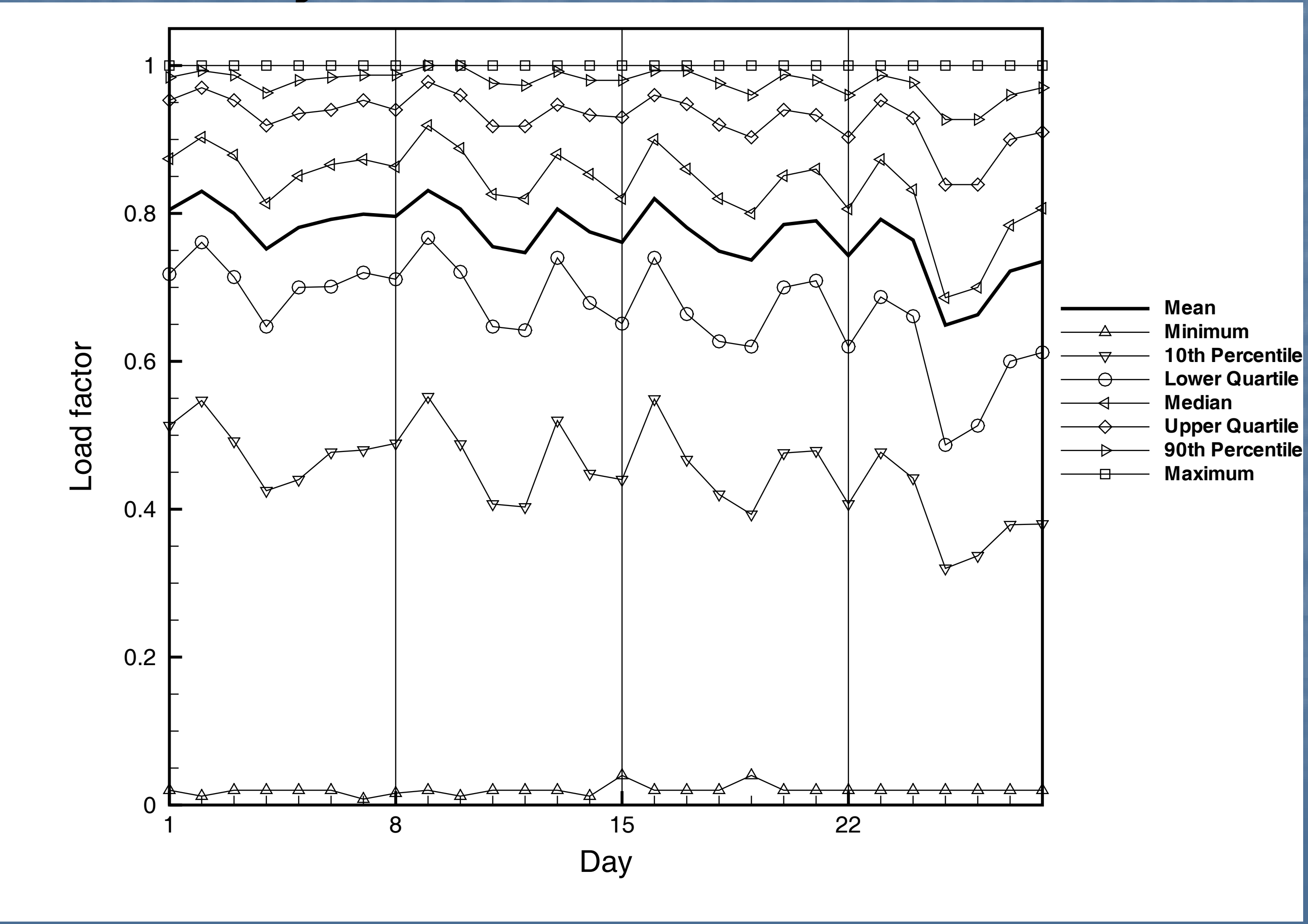
Average daily profitability results ($)

	Forecast A	Forecast B	P^B/P^A
Dynamic Scheduling	99,541	49,991	50.22%
Re-fleeting Only	28,031	7,542	26.91%
Re-timing Only	44,297	37,800	85.33%

- The two mechanisms are synergistic
  - P^A(Dynamic scheduling) > P^A(re-fleeting)+P^A(re-timing)
  - P^B(Dynamic scheduling) > P^B(re-fleeting)+P^B(re-timing)
- Re-timing is less affected by deterioration of forecast quality
  - Larger P^B/P^A ratios
- Re-timing contributes more than flight re-fleeting
  - P^A(re-fleeting) < P^A(re-timing)
  - P^B(re-fleeting) < P^B(re-timing)

Case Study 2: Weekly Schedules

- Assess the performance of dynamic scheduling under a weekly schedule



Weekly Schedule Results

- Schedule Generation
  - Approach A: Extend the daily schedule design model to a weekly model (computationally intractable)
  - Approach B:
    - Generate Monday schedule using average Monday forecast; generate Tuesday schedule using average Tuesday forecast; and so on
    - These schedules do not form a weekly schedule, but are able to take weekly demand variation into consideration
- Dynamic scheduling continues to improve profitability

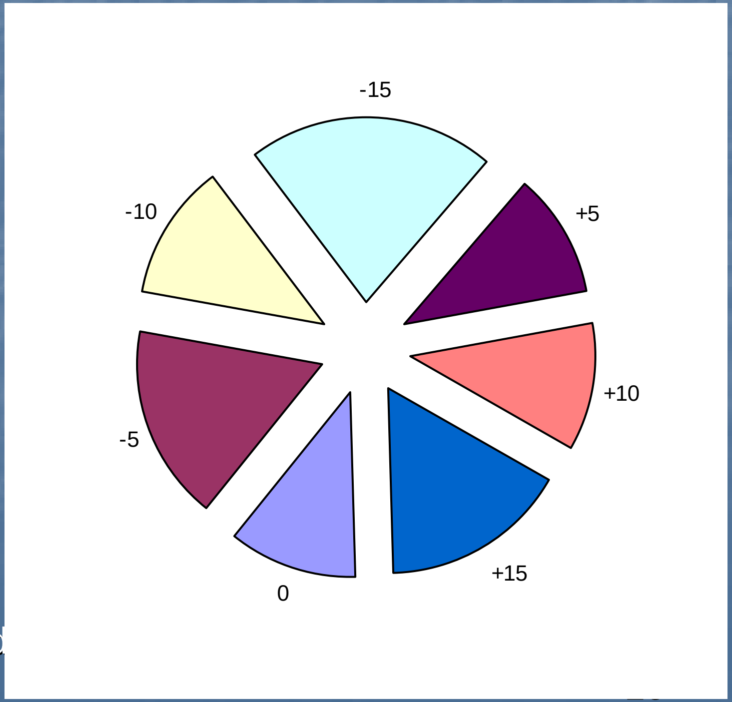
Average daily profit improvement		
	Daily	Weekly
Forecast A	99,541 (5.26%)	92,384 (4.97%)
Forecast B	49,991 (2.64%)	42,463 (2.28%)

Other Statistics

- System load factors went up 0.5-1%
- Aircraft savings

	perfect + retime + swap	average + retime + swap
1-Aug	1 A320	1 A320
2-Aug	1 A320 1 CR9	1 A320 1 CR9
3-Aug	1 A320 2 CR9	1 A320

- Schedule changes
  - About 100 fleet changes
  - 85-90% flights are retimed
    - Average retiming of 8 minutes

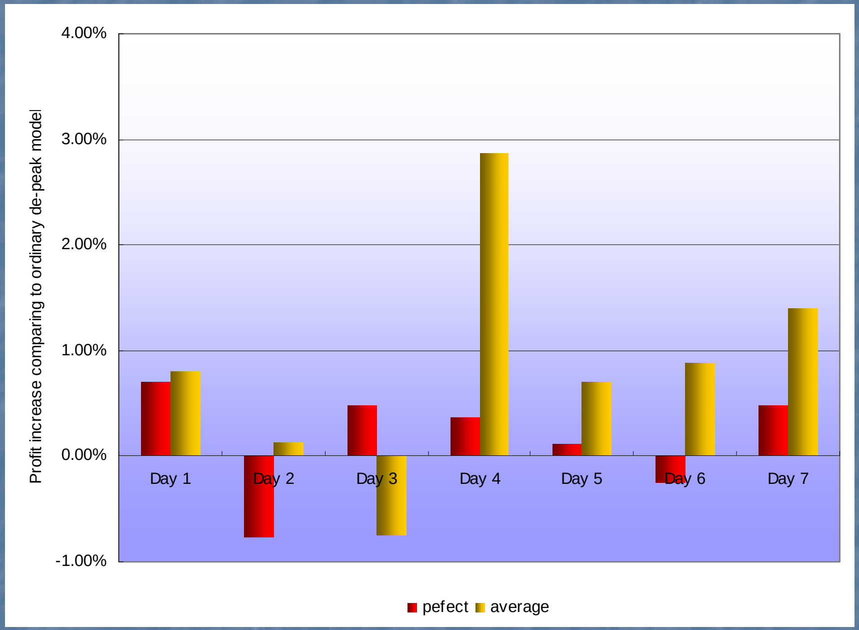


Flexible Planning

- Re-optimization decisions constrained by original schedule
  - Can we design our original schedule to facilitate dynamic scheduling?
- Goal
  - Maximize the number of *connections* that can be created to accommodate unexpected demands
    - Objective function value within .0% of original schedule

Preliminary Results

- Under Forecast A, improvement is not significant
  - When forecast is perfect, don't need to create a schedule that can be altered to accommodate variations in demand
- Under Forecast B, improvements obtainable
  - When forecast is imperfect, an improved schedule can be constructed with dynamic scheduling



De-Banking and Robust Optimization-No Dynamic Scheduling

	Schedule A (banked)	Schedule B (de-banked)	Schedule c (robust de-banked)
Revenue	8,170,245	8,146,066	8,165,746
	-	-0.30%	-0.06%
Cost	6,001,400	5,929,789	5,929,789
	-	-1.19%	-1.19%
Profit	2,168,845	2,216,277	2,235,957
	-	2.19%	3.09%
No. of aircraft	171	170	170

Summary of Findings

- Flexible planning and dynamic scheduling result in consistent improvement in
  - Profitability
    - Allows additional revenue capture without additional resources
      - Flight retiming effectively increases the number of connecting passengers served
  - Load factor
  - Number of passengers (connecting/nonstop) served
  - Savings in number of aircraft used
  - Benefit remains significant when the forecast is relatively simple
    - Re-timing decisions more robust to demand uncertainties

Questions?