Dynamic and Flexible Airline Schedule Design

Cynthia Barnhart
Hai Jiang

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De-banked (or De-peaked) Hubs

American de-peaked
ORD (2002), DFW

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 ($)

<table>
<thead>
<tr>
<th></th>
<th>Forecast A</th>
<th>Forecast B</th>
<th>P^B/P^A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Scheduling</td>
<td>99,541</td>
<td>49,991</td>
<td>50.22%</td>
</tr>
<tr>
<td>Re-fleeting Only</td>
<td>28,031</td>
<td>7,542</td>
<td>26.91%</td>
</tr>
<tr>
<td>Re-timing Only</td>
<td>44,297</td>
<td>37,800</td>
<td>85.33%</td>
</tr>
</tbody>
</table>

- 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

![Graph showing load factor over days](image)
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

<table>
<thead>
<tr>
<th>Average daily profit improvement</th>
<th>Daily</th>
<th>Weekly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast A</td>
<td>99,541 (5.26%)</td>
<td>92,384 (4.97%)</td>
</tr>
<tr>
<td>Forecast B</td>
<td>49,991 (2.64%)</td>
<td>42,463 (2.28%)</td>
</tr>
</tbody>
</table>
Other Statistics

- System load factors went up 0.5-1%

- Aircraft savings

<table>
<thead>
<tr>
<th>Date</th>
<th>Perfect + Retime + Swap</th>
<th>Average + Retime + Swap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Aug</td>
<td>1 A320</td>
<td>1 A320</td>
</tr>
<tr>
<td>2-Aug</td>
<td>1 A320, 1 CR9</td>
<td>1 A320, 1 CR9</td>
</tr>
<tr>
<td>3-Aug</td>
<td>1 A320, 2 CR9</td>
<td>1 A320</td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Revenue</th>
<th>Cost</th>
<th>Profit</th>
<th>No. of aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (banked)</td>
<td>8,170,245</td>
<td>6,001,400</td>
<td>2,168,845</td>
<td>171</td>
</tr>
<tr>
<td>B (de-banked)</td>
<td>8,146,066</td>
<td>5,929,789</td>
<td>2,216,277</td>
<td>170</td>
</tr>
<tr>
<td>C (robust de-banked)</td>
<td>8,165,746</td>
<td>5,929,789</td>
<td>2,235,957</td>
<td>170</td>
</tr>
</tbody>
</table>

- Revenue: -0.30% to -0.06%
- Cost: -1.19%
- Profit: 2.19% to 3.09%
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?