Dynamic Airline Scheduling
- Models and Experiments

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Outline

- Introduction
- The Idea
- Models
- Experiments
- Contribution
Introduction

• Airline planning
  – Starts 6 months to 1 year before departure date
  – Flight times and fleet assignment are developed
    based on passenger demand forecast and available
    resources

• Air travel demand is highly variable
  – Even with an “optimized” flight schedule and fleet
    assignment, flight departures would have empty seats
    while others will experience more demand than
    capacity

• Motivation
  – Develop models to dynamically adjust airline
    networks in the booking process so as to better
    manage demand stochasticity
Background

• Airlines typically operate on a hub-and-spoke network with banked schedules
  – Advantages: “Multiplier” effect, consolidation of traffic
  – Disadvantages: low utilization of aircraft, peaking in aircraft movement and passenger activity

• New Trend: De-Peaking
  – AA (DFW, MIA), LH (FRA), DL (ATL), …
  – Advantages:
    • Increase aircraft utilization
    • Alleviate airport runway/gate congestion
    • Improve schedule reliability
    • Smooth operation in ground operations, ticketing, etc
  – Downside
    • Connecting passengers will have slightly longer waits on the ground
    • This is no longer a big problem
      – In the old times, elapsed time is a key factor
      – Nowadays, fare plays a more important role

• Opportunity in a De-peaked Schedule
Dynamic Airline Scheduling

• The idea
  – Employ both flight retiming and aircraft swapping in the booking process to match capacity to demand

• The impact
  – Provide us a tool to respond to demand variation
  – Enable making wise schedule decision by utilizing information from revealed bookings and improved accuracy in forecast
    • Forecast accuracy improves when we are closer to departure

• Related literature
  – Peterson (1986) was the first to introduce dynamism in airline scheduling
    • Have “rubber” planes that can expand or contract to precisely match the final demand
  – Berge and Hopperstad (1993) followed the idea and developed Demand Driven Dispatch
Experiment Setup

• An original schedule
• A demand forecast engine
• A passenger mix model
• Retime and refleet flights $n$ times during the booking process.
• For simplicity, let $n = 1$.
  – Divide the booking period into Period 1 and Period 2
• Assume: the new schedule obtained are crew and maintenance feasible
Flow Chart

Period 1
- Period 1 pax demand
  - Booking Limit
    - Passenger Mix Model
      - Period 1 Leg pax assigned
        - Assumptions on connecting itineraries’ flexibility
          - Period 2 Pax Demand Forecast
            - Period 1 Flexible pax
              - Itineraries to be Preserved in Period 2
                - Remaining Leg capacity
                  - # of Aircraft Overnigh ted At Each Station
                    - Re-optimize fleet & flight timing
                      - New schedule

Period 2
- Period 2 pax demand
  - Remaining Leg capacity
    - Passenger Mix Model
      - Period 1 Inflexible pax
        - Re-optimize fleet & flight timing
          - # of Aircraft Overnigh ted At Each Station
            - New schedule

Period 2 Static
- Period 1 pax demand
  - Passenger Mix Model
    - Period 1 Leg pax assigned
      - Assumptions on connecting itineraries’ flexibility
        - Period 2 Pax Demand Forecast
          - Period 1 Flexible pax
            - Itineraries to be Preserved in Period 2
              - Remaining Leg capacity
                - # of Aircraft Overnigh ted At Each Station
                  - New schedule

Period 2 Dynamic
- Period 2 pax demand
  - Remaining Leg capacity
    - Passenger Mix Model
      - Period 1 Inflexible pax
        - Re-optimize fleet & flight timing
          - # of Aircraft Overnigh ted At Each Station
            - New schedule

Comparison
Experiment Setup

• Airline statistics
  – 832 flights daily
  – 50k path passengers/70k leg passengers daily
  – 302 inbound and 302 outbound flights at hub daily

• Retime window
  – +/- 15 minutes

• Refleet
  – A320 & A319
  – CRJ & CR9

• We experimented with three dates, when daily total demand is:
  – higher than average (Aug 1)
  – at average (Aug 2)
  – lower than average (Aug 3)

• Protect all connecting itineraries sold in Period 1
• Two scenarios about forecast quality
  – Perfect information
  – Historical average demand
Summary of Findings

• Consistent improvement in
  – Profitability
  – Load factor
  – Number of passengers (connecting/nonstop) served
  – Savings in number of aircraft used

• Benefit remains significant when the forecast is reasonably good

• Flight retime effectively increases the number of connecting pax served
Improvement In Profitability

- Consistent improvement in profitability
  - Perfect information
    - 4-8% improvement in profit
    - 70-150k daily (25-55 million annually)
  - Average information
    - 2-5% improvement in profit
    - 40-80k daily (15-30 million annually)
    - not including benefit from aircraft savings, reduced gates and personnel ...
- When demand is higher, benefit is larger
- Accurate forecast is valuable
- Benefit remains significant when forecast quality is reasonably good
Comparison between Retime and Swap

- Retiming has a larger contribution toward profit improvement
- Retiming always improves profitability
- The profit improvement under retiming using historical average as forecast is even greater than that under swap using perfect forecast information
- Swap is more sensitive to forecast quality and can lead to negative return
Increases in Passengers

- Retiming effectively captures connecting passengers
Properties of New Itineraries

- Define two types of new itineraries
- Average connection time for new itineraries
  - 35 minutes for Type I
  - 150 minutes for Type II
- The majority of passengers are on Type I itineraries
Other Statistics

• System load factors went up 0.5-1%

• Aircraft savings

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• Schedule changes
  – About 100 fleet changes
  – 85-90% flights are retimed
    • Average retime of 8 minutes
    • These changes are released well before departure
Another Dimension to Dynamism

- Differentiate passengers according to their flexibility
  - Time-sensitive passenger: a passenger who specifically request an itinerary when booking
  - Flexible passenger: a passenger who is indifferent to a set of itineraries

- Re-route flexible passengers off congested itineraries when high fare inflexible passengers arrive in future

- Related Literature
  - Cook proposed the idea of re-plane
  - Talluri 2001 proposed a flexible booking approach for the case in which passengers are indifferent among a number of routing alternatives (route set) between the OD pair
  - Gallego 2004 introduced flexible product
Preliminary Results

- We assume that passengers are indifferent to alternative itineraries if
  - The alternative itinerary is in the same departure window as the originally assigned itinerary
  - The alternative itinerary has the same level of service: nonstop/connecting
- For all passengers booked in the first period, we randomly select 30% of itineraries that has alternative paths
- Designate half of the passengers on them as flexible ones.
- Results
  - Additional 1-2% increase in profitability
  - 40-50% of total flexible passengers get re-routed
Contribution

• Proposed a framework of dynamic airline scheduling, developed models that integrated a series of dynamic mechanisms.
• Demonstrated its significant improvements in profitability using data from a major airline
• Studied the effectiveness of retiming and swapping
• Quantified the potential benefit to exploit passenger flexibility in a network context