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

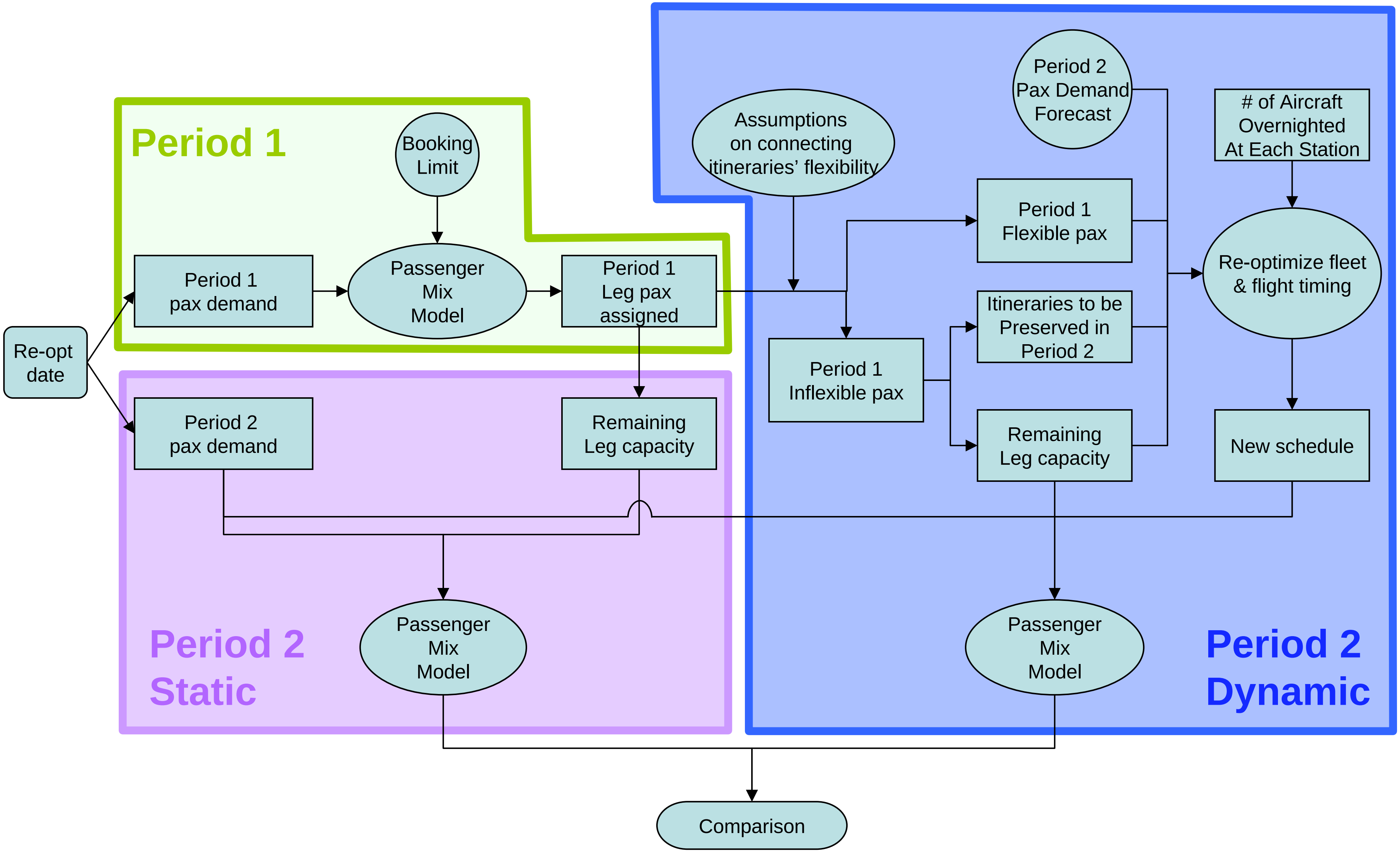
Dynamic Airline Scheduling

- 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
Booking Limit
Period 1 pax demand
Passenger Mix Model
Period 1 Leg pax assigned
Re-opt date
Period 2 pax demand
Remaining Leg capacity
Passenger Mix Model
Period 2 Static
Assumptions on connecting itineraries' flexibility
Period 2 Pax Demand Forecast
# of Aircraft Overnighted At Each Station
Period 1 Flexible pax
Re-optimize fleet & flight timing
Itineraries to be Preserved in Period 2
Period 1 Inflexible pax
Remaining Leg capacity
New schedule
Passenger Mix Model
Period 2 Dynamic
Comparison

Experiment Setup

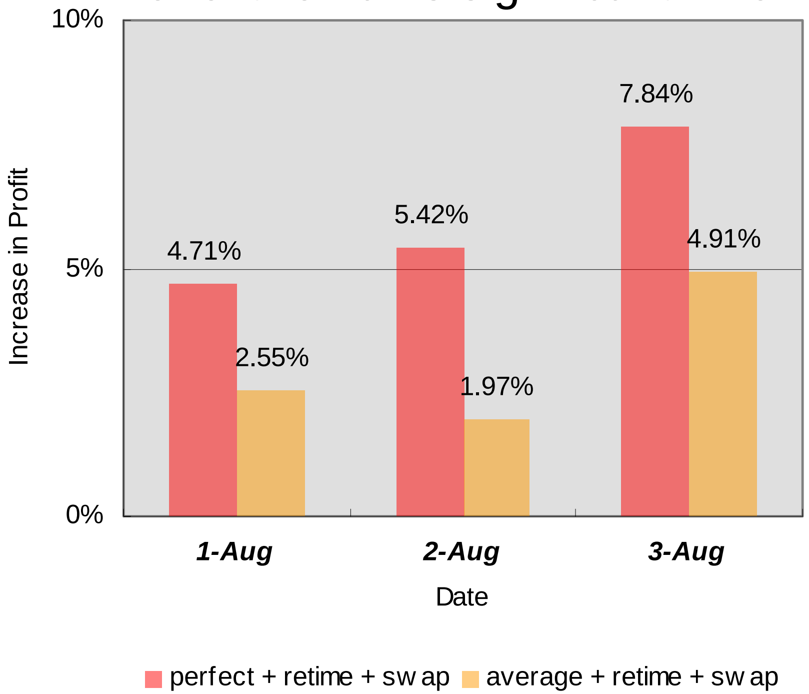
- Airline statistics
  - 832 flights daily
  - 50k path passengers/70k leg passengers daily
  - 302 inbound and 302 outbound flights at hub daily
- Retime window
  - +/- 15 minutes
- Refleet
  - A320 & A319
  - CRJ & CR9
- We experimented with three dates, when daily total demand is:
  - higher than 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

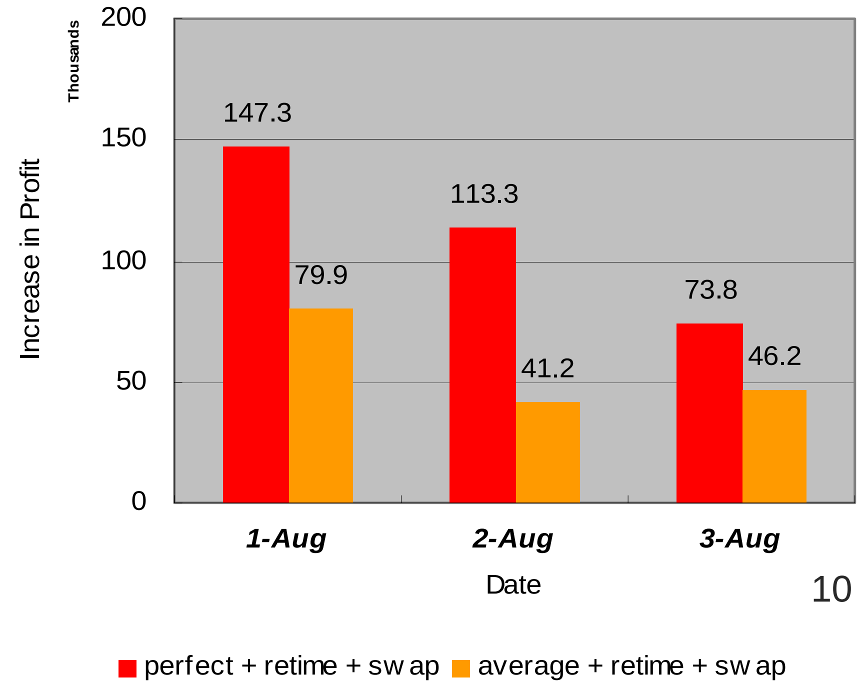
Summary of Findings

- 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

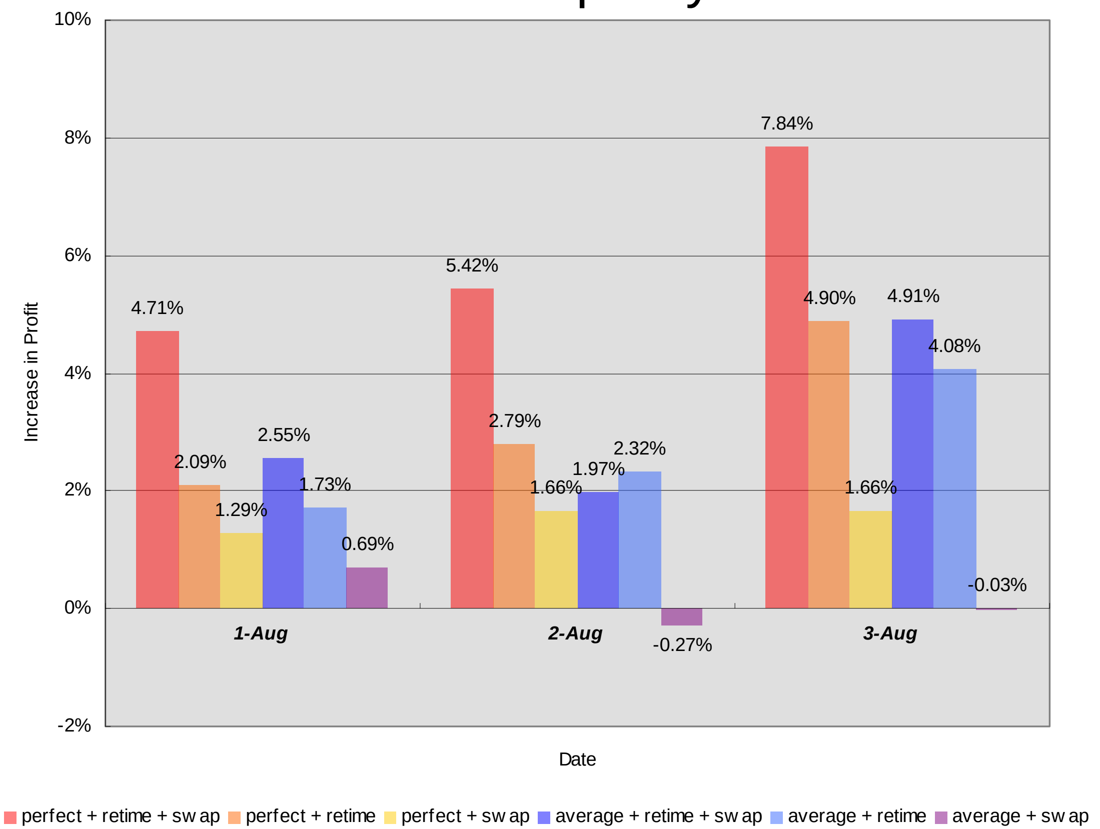
- Consistent improvement in profitability
  - Perfect information
    - 4-8% improvement in profit
    - 70-150k daily (25-55 million annually)
  - Average information
    - 2-5% improvement in profit
    - 40-80k daily (15-30 million annually)
  - not including benefit from aircraft savings, reduced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





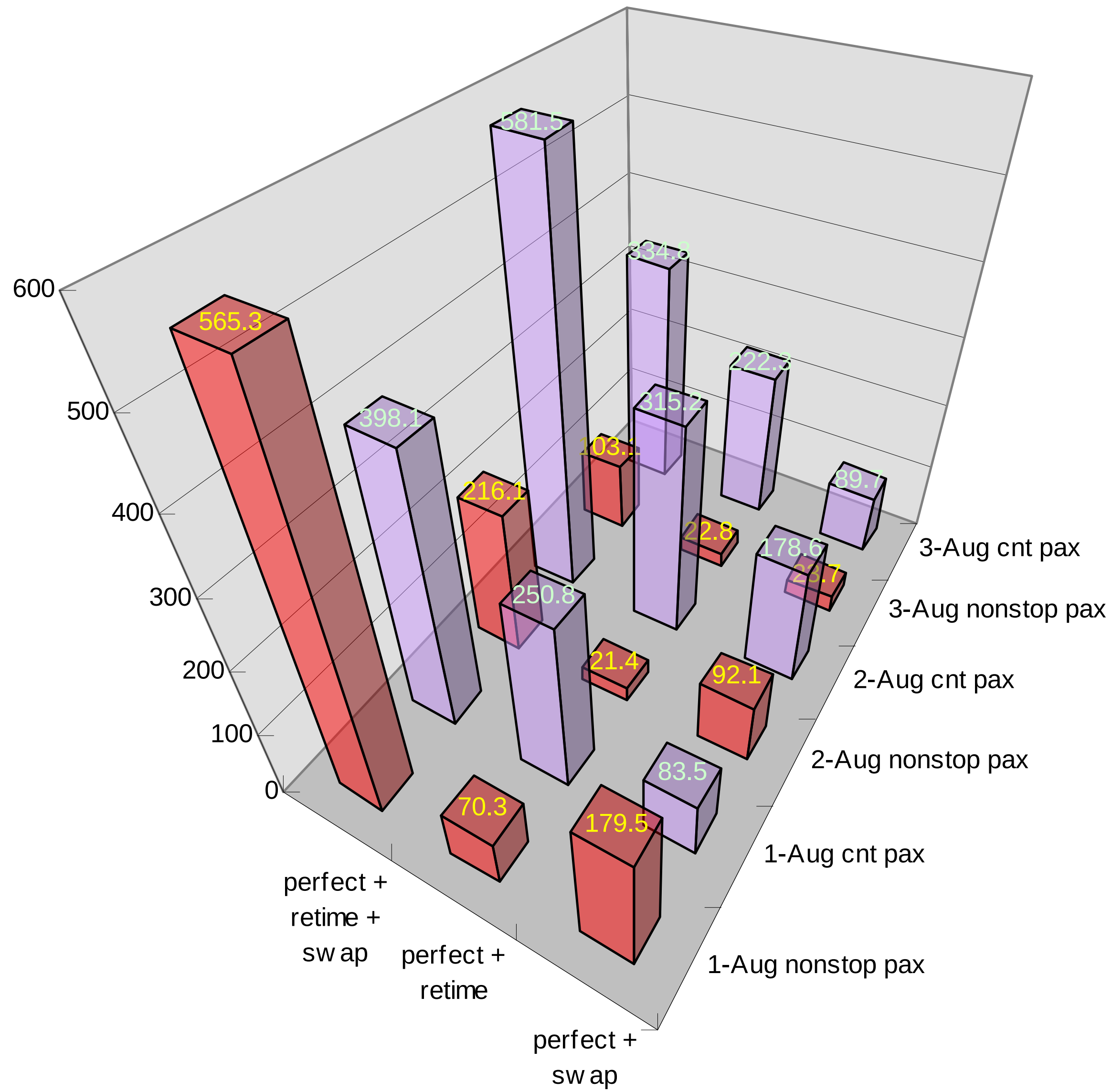
Comparison between Retime and Swap

- 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



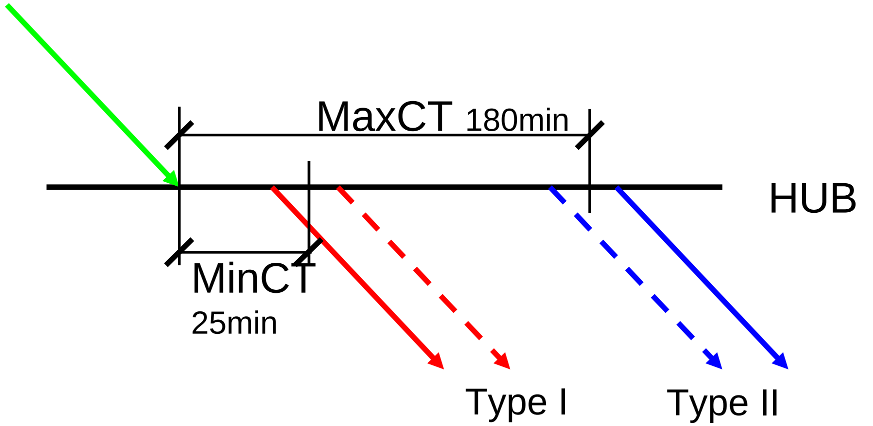
Increases in Passengers

- Retiming effectively captures connecting passengers

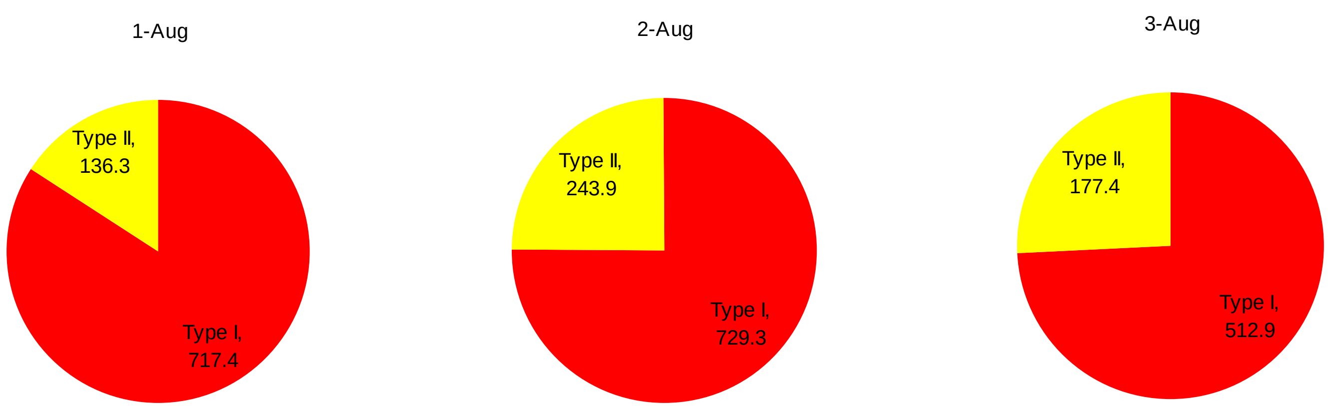


Properties of New Itineraries

- 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

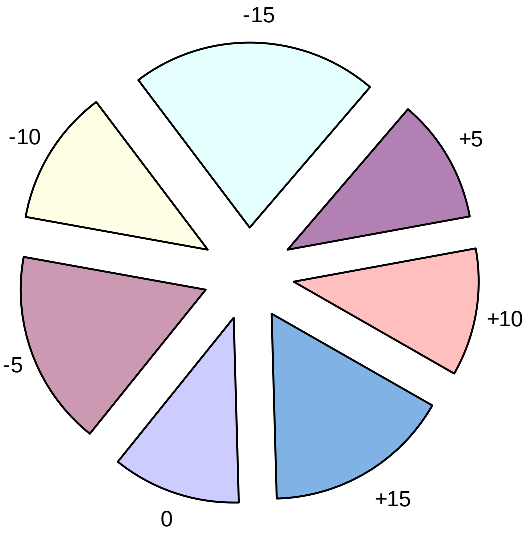


Other Statistics

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

	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 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