Network Schedule Optimization Extensions

Dr. Peter Belobaba

Istanbul Technical University

Air Transportation Management

M.Sc. Program

Network, Fleet and Schedule

Strategic Planning

Module 14 : 12 March 2014

Lecture Outline

- **Itinerary-based Network Fleet Assignment**
  - Network Effects on Evaluating Spill
  - IFAM Definition and Formulation
  - Opportunities for Further Model Improvement

- **Dynamic Fleet Assignment**
  - Demand Driven Dispatch
  - Requirements and Implementation Issues

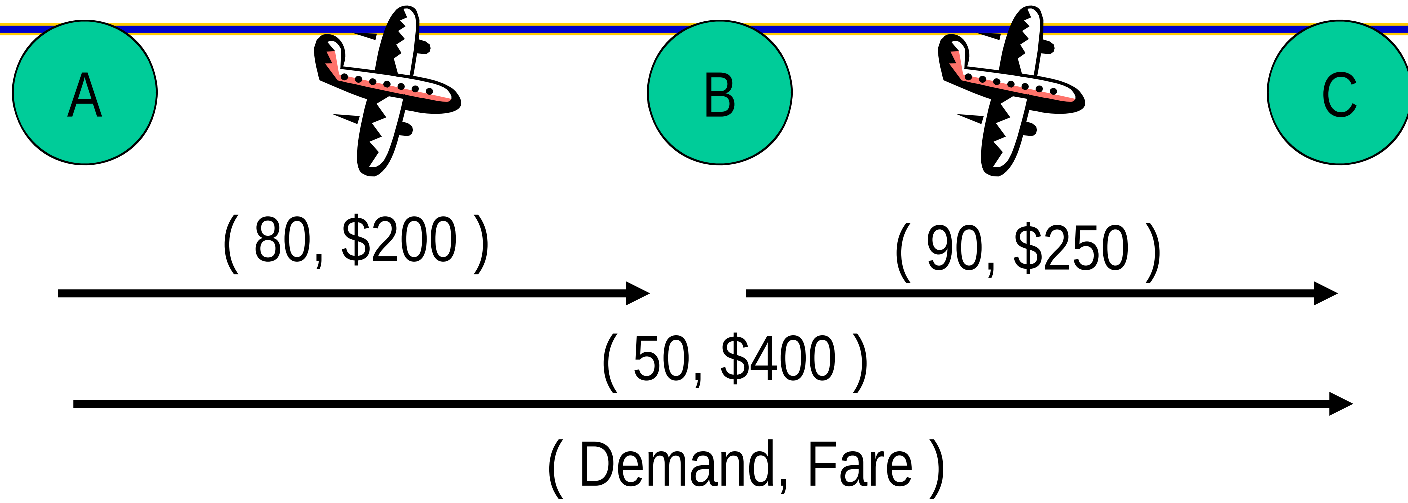
- **Crew Scheduling Optimization**
  - Definitions and Constraints
  - Crew Pairing Problem

Leg-Based Fleet Assignment Optimization

- **The fleet assignment models examined thus far have assumed independent demand and spill on each leg**
  - In essence, all demand on each leg assumed to be local
  - Changing capacity assumed to affect only demand on that leg, and revenue impact based on fares paid by local demand
  - Certainly not true in a large connecting hub network

- **Several network optimization models were presented, but leg independence was still assumed**
  - "Network" fleet assignment optimization referred to ensuring a balance of aircraft types and feasible rotations of aircraft

Fleet Assignment: Network Effects



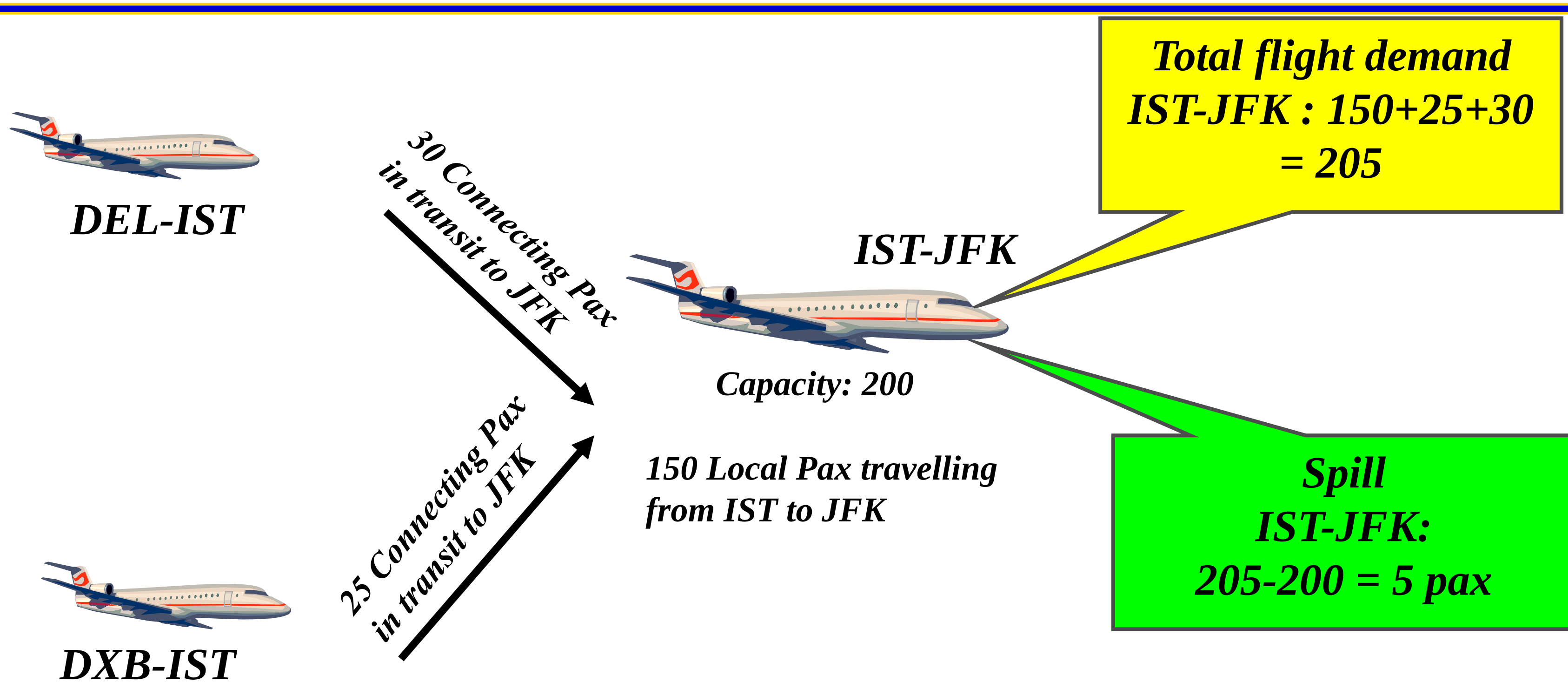
Fleet Type	Capacity	Spill Cost
i	80	?
ii	100	?
iii	120	?
iv	150	$0

Leg Interdependence

Network Effects

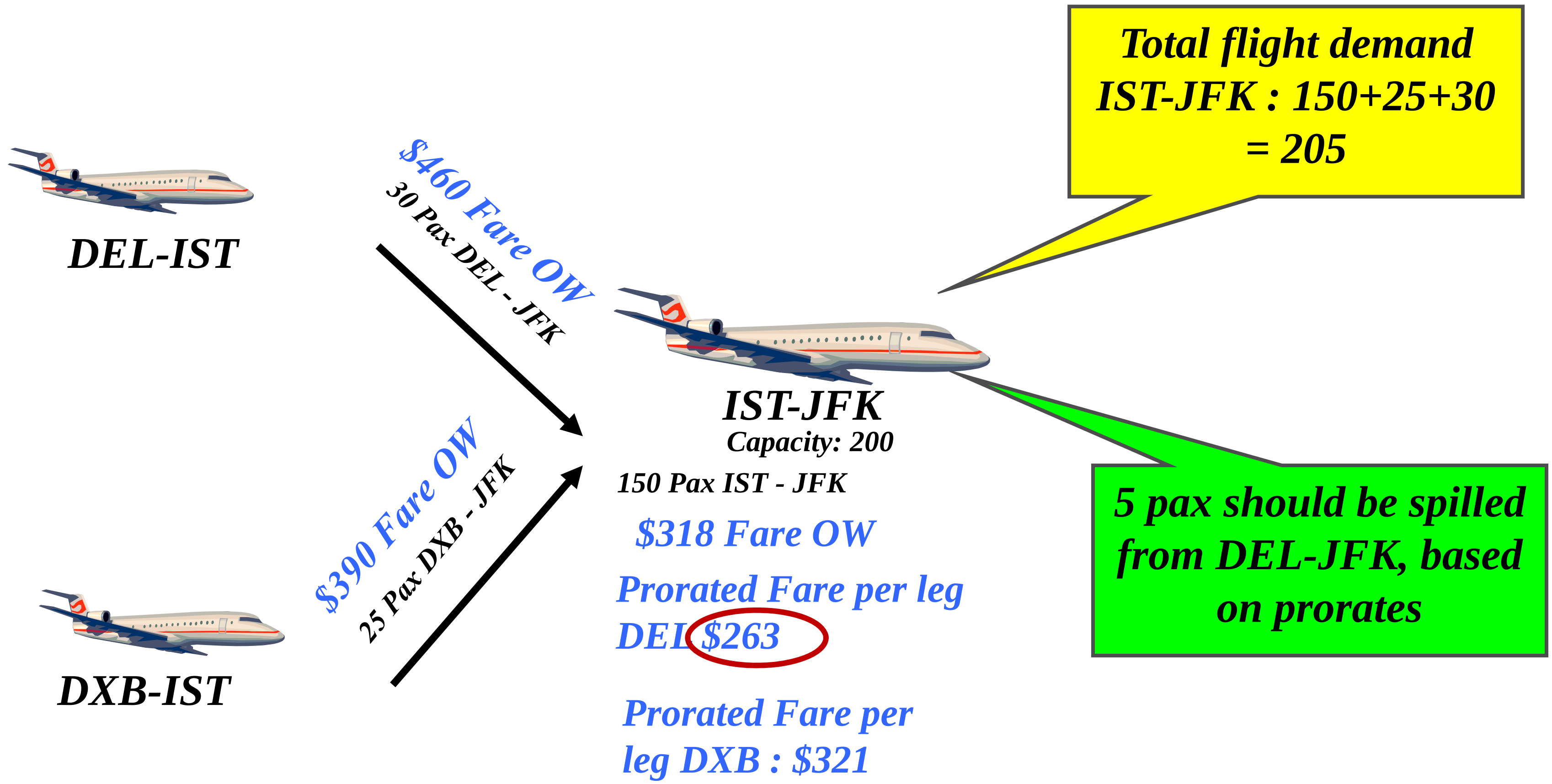
SOURCE: Prof. C. Barnhart

Calculation of Network Spill



Which 5 passengers should be spilled on the IST-JFK flight leg?

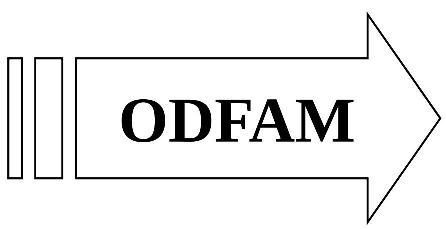
Prorated Calculation of Network Spill



Itinerary-based Fleet Assignment Definition

- **Given**
  - a fixed schedule,
  - number of available aircraft of different types,
  - unconstrained passenger demands by itinerary, and
  - recapture rates,

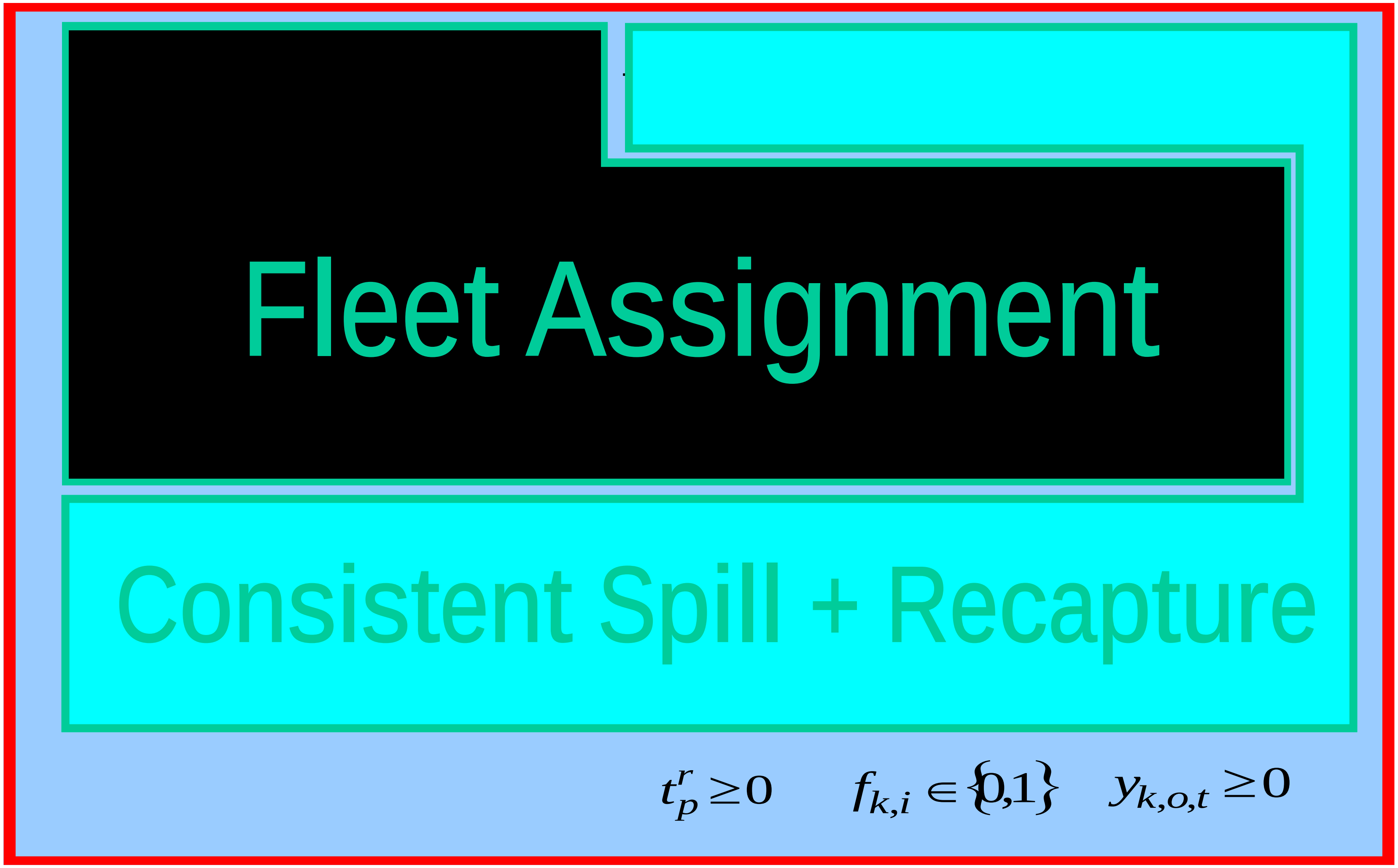
Find maximum contribution



Network effects

SOURCE: Prof. C. Barnhart

Itinerary-Based FAM (IFAM)



Kniker (1998)

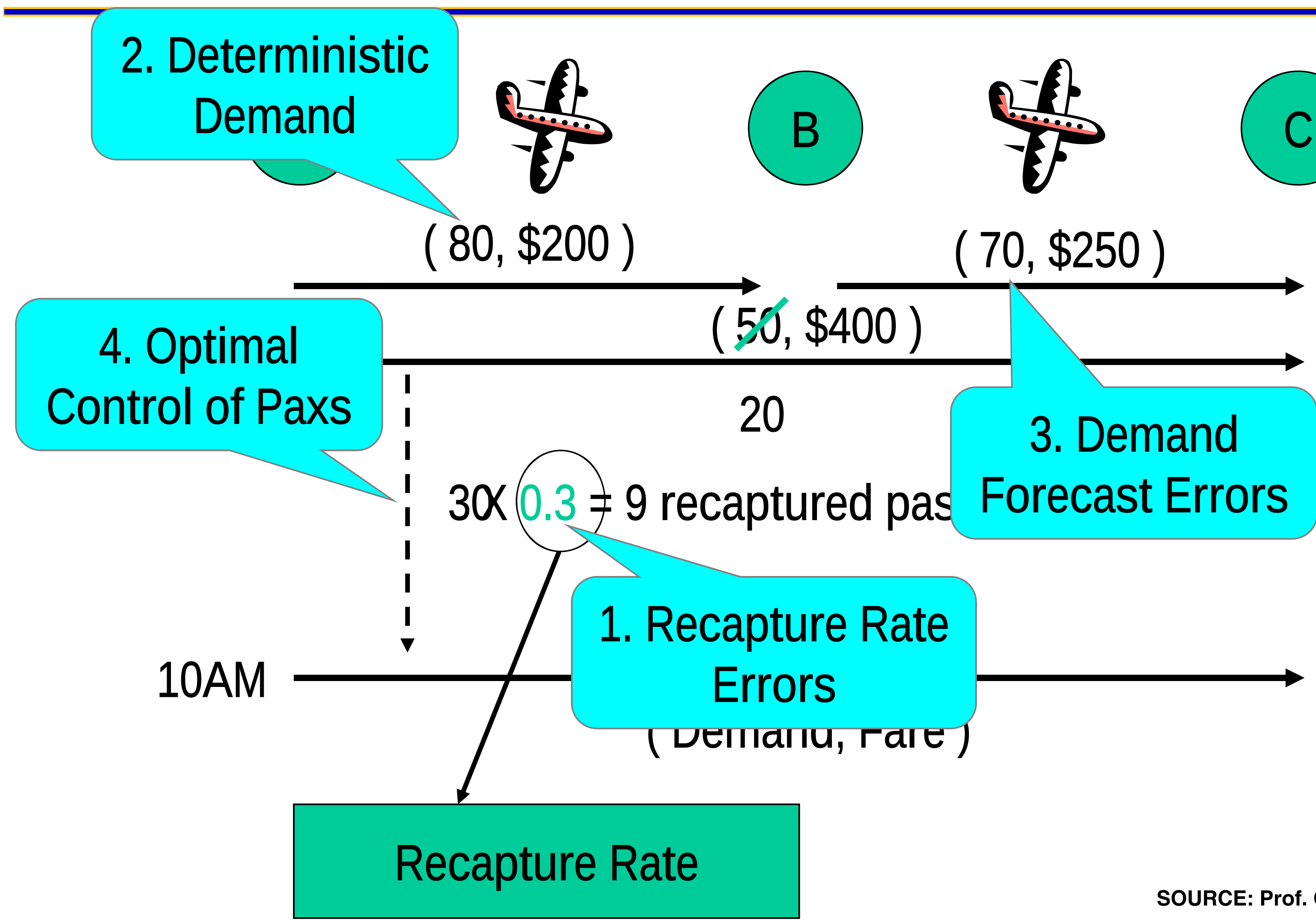
SOURCE: Prof. C. Barnhart

Moving from FAM to IFAM: Challenges

- **IFAM, unlike FAM, has:**
  - Extensive data requirements
    - → Itinerary-specific demands
    - → Recapture rates
  - Immense model size
    - → One decision variable for every pair of itineraries for which spill can occur
    - → One constraint for each itinerary
  - Tractability issues associated with model
    - → Constraints linking supply (provision of seat capacity) with demand for seats

SOURCE: Prof. C. Barnhart

Opportunities for Improvement: FAM



SOURCE: Prof. C. Barnhart

Dynamic Fleet Assignment

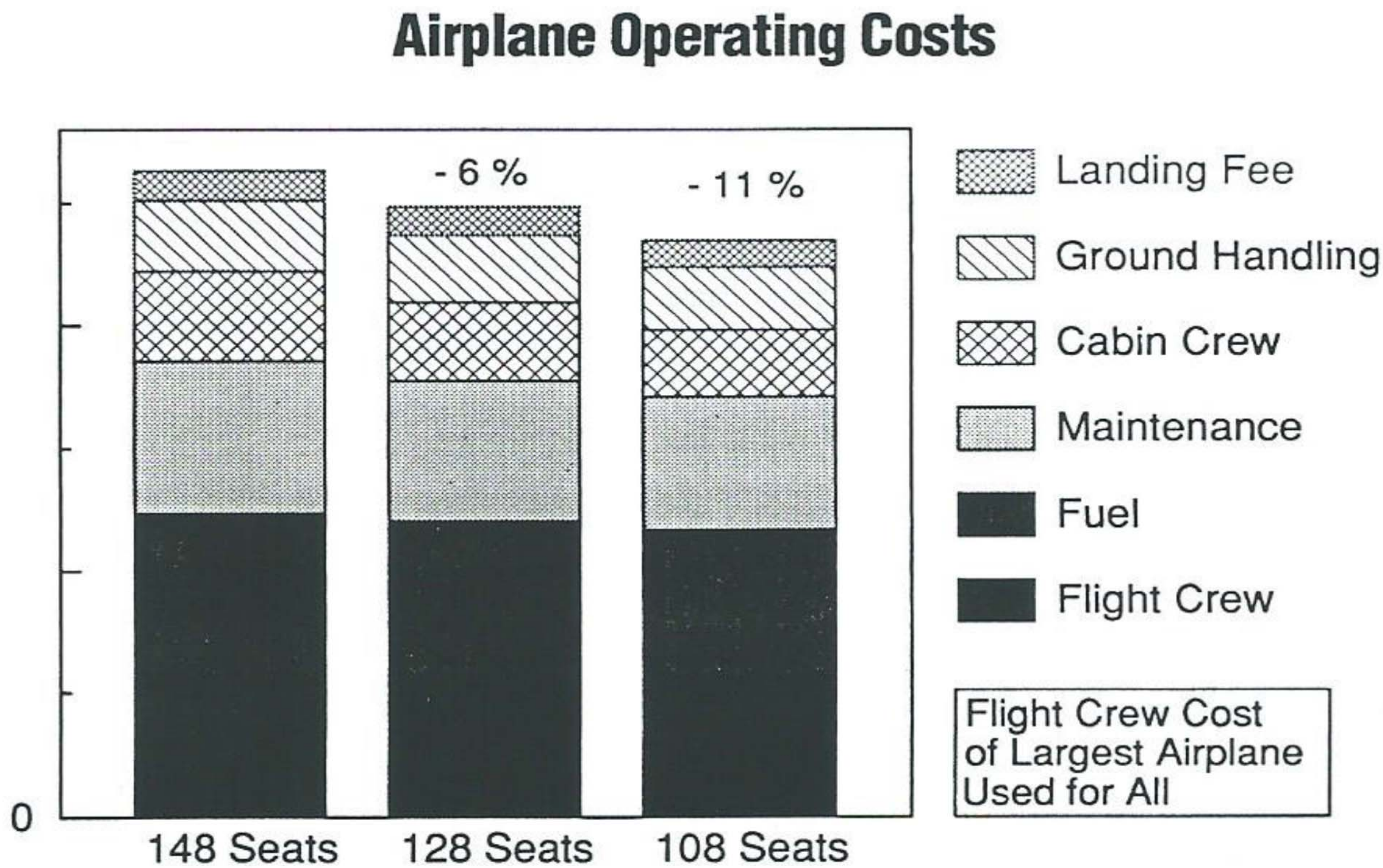
- **Adjust the capacity on flight legs during the booking process to better match actual bookings with supply by “swapping” aircraft**
- **Re-assigning available aircraft within the same fleet family**
  - Maintaining crew feasibility
  - Maintaining conservation of flow (or balance) by fleet type
  - Maintaining satisfaction of maintenance constraints
- **Also known as “Demand Driven Dispatch”**
  - Concept developed by Boeing in search of “elastic” airplane
  - Made practical by fleet commonality in aircraft families

Demand Driven Dispatch

- **Dynamic fleet assignment when demand varies daily on each flight leg during a schedule period**
  - Assign the right size airplane to each departure based on actual booking patterns
  - If bookings are forecast to be higher than average, opportunity to increase capacity for that departure
  - If bookings are forecast to be much lower than planned, reducing aircraft size can reduce total operating costs

- **Requirements for Demand Driven Dispatch (or D^3)**
  - RM system that generates accurate forecasts of demand for each future flight departure date
  - Common-rated family of aircraft allows for swapping of aircraft assignments closer to departure without disturbing crew schedules

Operating Costs Differ by Aircraft Size



Source: Boeing

Demand Driven Dispatch Process

- **Identify potential swaps based on RM forecasts**
  - One flight with excess demand (greater than capacity) and another with excess capacity expected at departure
  - Both flights scheduled to depart at approximately the same time from the same airport – connecting hubs increase this potential

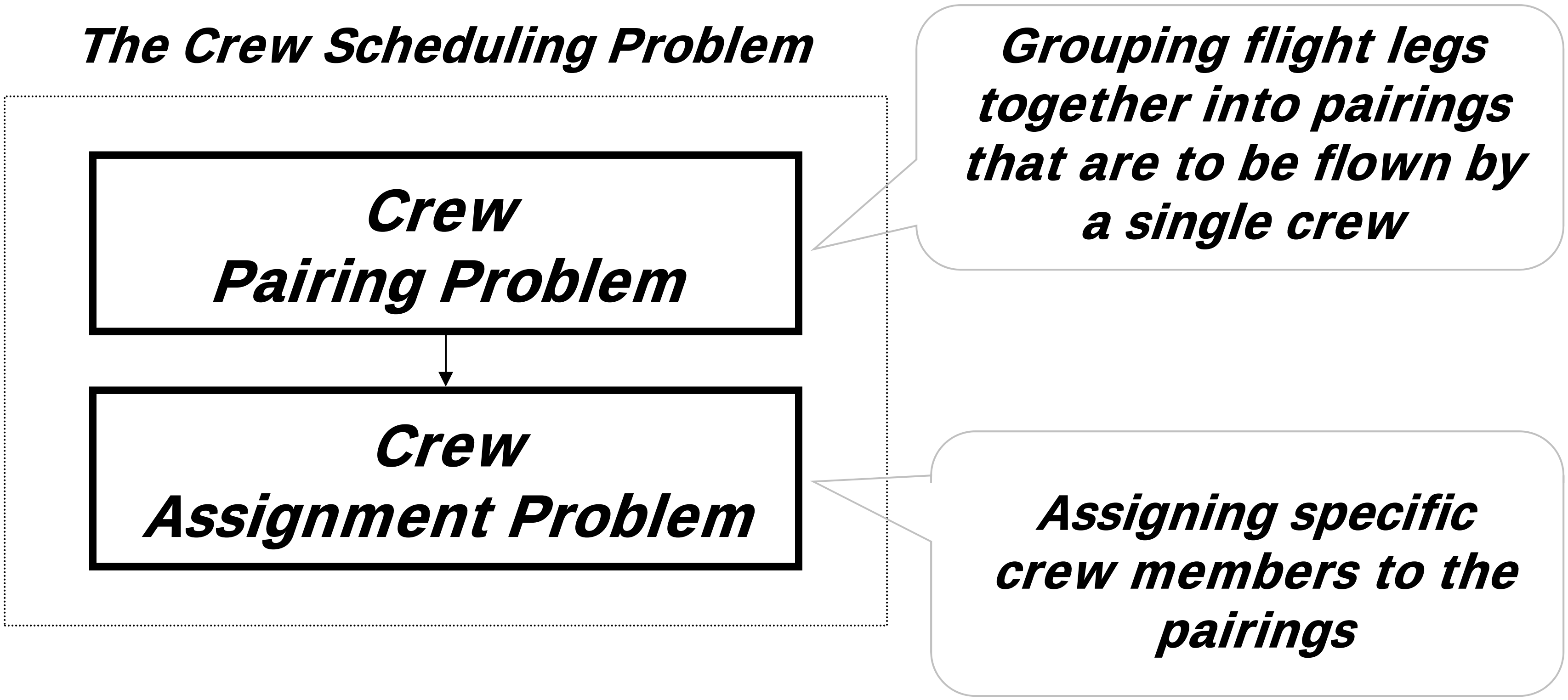
- **Assess benefits of executing the swap**
  - Revenue gain from assigning a larger aircraft to the flight with excess demand vs. possible spill on flight with smaller aircraft
  - Even if no revenue gains, reductions in operating costs can be achieved if both flights have excess capacity – assign smaller aircraft to the longer flight

Implementation Issues for D³

- **Crew scheduling problems can be overcome with common-rated fleet families**
  - But, larger aircraft might require additional flight attendant
- **Maintenance plans need to be maintained**
  - Swapped aircraft must return to maintenance base as scheduled
- **Ground handling and catering issues**
  - Close-in swaps tend to disrupt gate assignments and ground operations routines
- **Passenger service issues**
  - Specific aircraft type not specified until a few days before departure
  - Imposes constraints on advance seat assignment

Airline Crew Scheduling

The Crew Scheduling Problem



Reference: C. Barnhart, A. Cohn, E. Johnson, D. Klabjan, G. Nemhauser, and P. Vance. 2003. "Airline Crew Scheduling". Randolph W. Hall, ed. Handbook of Transportation Science, 2nd ed.

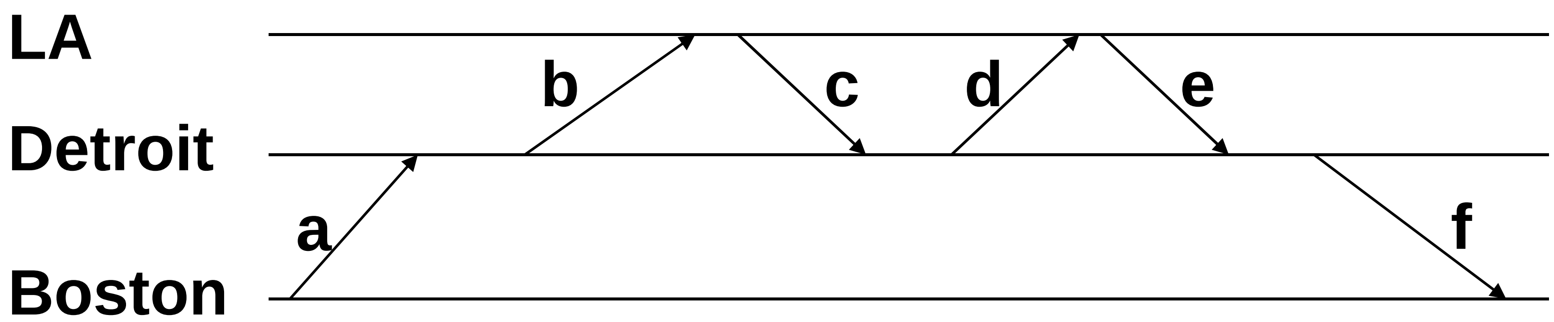
SOURCE: Prof. C. Barnhart

Definitions

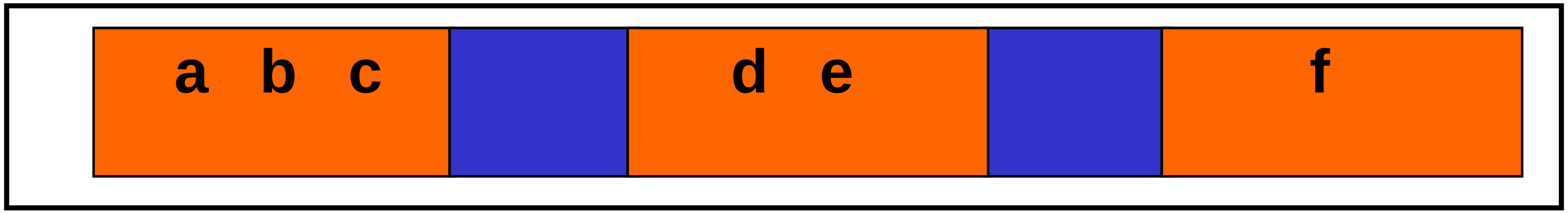
- **A *duty period* (or *duty*) is a sequence of flight legs comprising a day of work for a crew**
- **A *crew pairing* is a sequence of *duties* separated by rest periods:**
  - beginning and ending at a crew base
  - spanning one or more days
  - satisfying regulations and collective bargaining agreements, such as:
    - → maximum flying time in a day
    - → minimum rest requirements
    - → minimum connection time between two flights

SOURCE: Prof. C. Barnhart

Example: Duty Periods



Pairing = DP1(a,b,c) + rest + DP2(d,e) + rest + DP3(f)



SOURCE: Prof. C. Barnhart

Airline Crew Scheduling

- **2-stage process:**
- **Crew Pairing Optimization**
  - Construct minimum cost work schedules, called pairings, spanning several days
- **Bidline Generation/ Rostering**
  - Construct monthly work schedules from the pairings generated in the first stage
    - ➔ Bidlines
    - ➔ Individualized schedules
  - Objective to balance workload, maximize number of crew requests granted, etc.

SOURCE: Prof. C. Barnhart

Crew Pairing Costs

- **Duty costs: *Maximum* of 3 elements:**
  - *f1**flying time cost
  - *f2**elapsed time cost
  - *f3**minimum guarantee
- **Pairing costs: *Maximum* of 3 elements:**
  - *f1**duty cost
  - *f2**time-away-from-base
  - *f3**minimum guarantee

SOURCE: Prof. C. Barnhart

Crew Pairing Problem

- **Constraints on feasible pairings**
  - Flights connect in space and time
  - Minimum/Maximum connection times
  - Regulatory constraints
    - Maximum duty duration
    - Minimum rest duration between duties
    - 8-in-24 rule
    - Maximum time-away-from-base (TAFB)

- **Potentially, many billions of pairings**

SOURCE: Prof. C. Barnhart

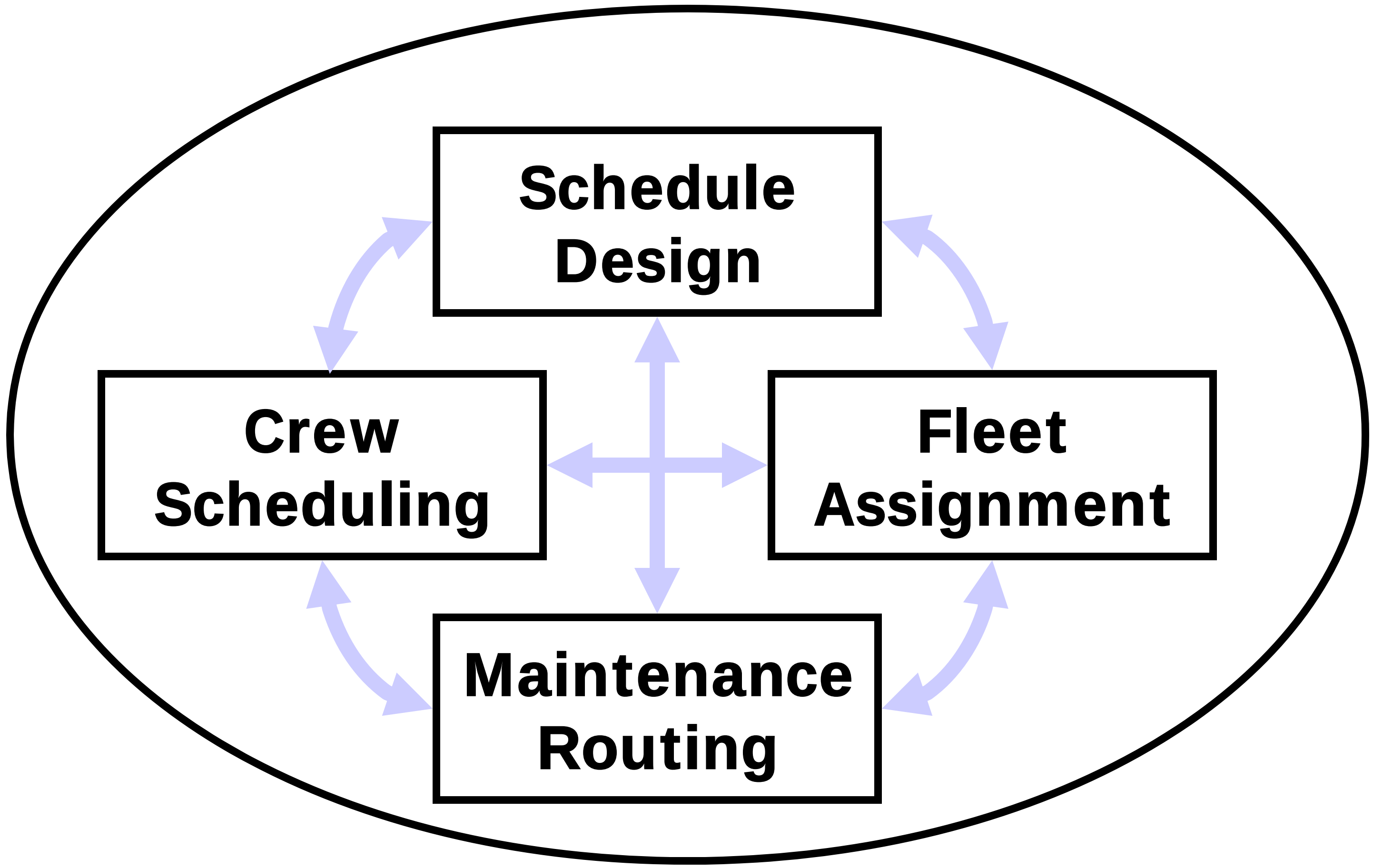
Problem Size and Solutions

- **A typical global airline (hub-and-spoke) has millions (or billions) of potential pairings**
  - 150 daily flights 90,000 pairings
  - 250 daily flights 6,000,000 pairings
- **Crews are the second highest component of aircraft operating costs (after fuel).**
- **The introduction of OR decision support tools has reduced the amount of pay & credit at some airlines by 50%.**

SOURCE: Prof. C. Barnhart

Integration of Schedule Optimization Models

A challenge…



SOURCE: Prof. C. Barnhart

Future Research Challenges

1. **Integrating decisions involving schedule design and aircraft and crew routing and scheduling**
2. **Expanding schedule planning models to include pricing and revenue management decisions**
3. **Robust schedule planning to allow for disruptions and delays**
4. **Operations recovery after schedule disruptions**

SOURCE: Prof. C. Barnhart