Airline Schedule Development

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Airline Schedule Development

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   - Sequential approach to schedule planning

2. Frequency Planning
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3. Timetable Development
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1. Schedule Development Process

- Given a set of routes to be operated in an airline network, and a fleet of aircraft, schedule development involves:
  - Frequency planning (how often?)
  - Timetable development (at what times?)
  - Fleet assignment (what type of aircraft?)
  - Aircraft rotation planning (network balance)

- The process begins a year or more in advance and continues until actual departure time:
  - Frequency plans established first, based on routes and aircraft
  - Timetables and aircraft rotations defined 2-6 months in advance
  - Final revisions and “irregular operations” until the flight departs
Fleet Planning

Route Planning

Schedule Development
- Frequency Planning
- Timetable Development
- Fleet Assignment
- Aircraft Rotations

Pricing

Crew Scheduling

Revenue Management

Airport Resource Management

Sales and Distribution

Operations Control

SOURCE: Prof. C. Barnhart
Airline Supply Terminology

• **Flight Leg** (or “flight sector” or “flight segment”)
  – Non-stop operation of an aircraft between A and B, with associated departure and arrival time

• **Flight**
  – One or more flight legs operated consecutively by a single aircraft (usually) and labeled with a single flight number (usually)
  – NW945 is a two-leg flight BOS-MSP-SEA operated with a B757

• **Route**
  – Consecutive links in a network served by single flight numbers
  – NW operates 2 flights per day on one-stop route BOS-MSP-SEA

• **Passenger Paths or Itineraries**
  – Combination of flight legs chosen by passengers in an O-D market to complete a journey (e.g., BOS-SEA via connection at DTW)
Aircraft and Crew Schedule Planning: Sequential Approach

- Schedule Design
  - Fleet Assignment
    - Aircraft Routing
      - Crew Scheduling
  - Select optimal set of flight legs in a schedule
- A flight specifies origin, destination, and departure time
- Contribution = Revenue - Costs
- Assign crew (pilots and/or flight attendants) to flight legs
2. Frequency Planning

- Frequency of departures on a route improves convenience of air travel for passengers and increases market share:
  - Peak departure times (early morning and late afternoon) are most attractive to a larger proportion of travelers in many markets
  - More frequent departures further reduce schedule displacement or “wait time” between flights, reducing travel inconvenience
  - Frequency is much more important in short-haul markets than for long-haul routes where actual flight time dominates “wait time”
  - In competitive markets, airline frequency share is most important to capturing time sensitive business travelers
  - Frequency of departures can be as important as path quality (non-stop vs. connection) in many cases
Frequency Planning Process

• Demand forecasts and competition drive the frequency of flights on a route:
  – Estimates of total demand between origin and destination
  – Expected market share of total demand, which is determined by frequency share relative to competitors
  – Potential for additional traffic from connecting flights

• “Load consolidation” affects frequency and aircraft size decisions:
  – Single flight with multiple stops provides service to several origin-destination markets at the same time
  – Allows airline to operate higher frequency and/or larger aircraft
  – A fundamental reason for economic success of airline hubs
3. Timetable Development

• For a chosen frequency of service on each route, next step is to develop a specific timetable of flight departures:
  – Goal is to provide departures at peak periods (0900 and 1700)
  – But, not all departures can be at peak periods on all possible routes, given aircraft fleet and rotation considerations
  – Minimum “turn-around” times required at each stop to deplane/enplane passengers, re-fuel and clean aircraft
  – For example, 0900 departure from city A with 1100 arrival at B results in possible departure of aircraft from B at 1200
  – If this aircraft is to return to A, 1200 departure will be off-peak and have potentially lower demand, but keeping the aircraft on the ground until the next peak period reduces aircraft utilization (block hours per day)
Timetable Development Constraints

• Most airlines choose to maximize aircraft utilization:
  – Keep ground “turn-around” times to a minimum
  – Fly even off-peak flights to maintain frequency share and to position aircraft for peak flights at other cities
  – Leaves little buffer time for maintenance and weather delays

• Numerous constraints affect timetable development:
  – Hub networks require that flights arrive from spoke cities within a prescribed time range, to facilitate passenger connections
  – Time zone differences limit feasible departure times (e.g., flights from US to Europe do not depart before 1700, as passengers do not want to arrive at their destination before 0600)
  – Airport slot times, noise curfews limit scheduling flexibility
  – Crew scheduling and routine maintenance requirements also affect timetable development
Timetable Development Process

• Complexity and size of timetable development problem make most schedule changes incremental:
  – A single change in departure time of a flight from A can have major impacts on down-line times, connections, aircraft rotations, and even number of aircraft required to operate the schedule
  – Further complicated by crew and maintenance schedule needs, requiring coordination with several airline operational departments
  – There are no computer models that can determine “optimal” timetable, given huge combination of departure/arrival times, demand and market share estimates, and thousands of constraints
  – However, interactive computer scheduling databases and decision support tools allow for much faster “what-if” analysis
  – Substantial decision support progress in fleet assignment and aircraft rotation optimization
4. Fleet Assignment Optimization

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Massachusetts Institute of Technology

Outline:
- Problem Definition and Objective
- Fleet Assignment Network Representation
- Fleet Assignment Models and Algorithm
**Fleet Assignment Problem**

- **Given:**
  - Flight Schedule
    - Each flight covered exactly once by one fleet type
  - Number of Aircraft by Equipment Type
    - Can’t assign more aircraft than are available, for each type
  - Turn Times by Fleet Type at each Station
  - Other Restrictions: Maintenance, Gate, Noise, Runway, etc.
  - Operating Costs, Spill and Recapture Costs, Total Potential Revenue of Flights, by Fleet Type

- **What is the optimal (contribution/ profit maximizing) assignment of aircraft to flights?**
Definitions

• Spill
  – Passengers that are denied booking due to capacity restrictions

• Recapture
  – Passengers that are recaptured back to the airline after being spilled from another flight leg

• For each fleet and flight combination:
  Assignment Cost ≡ Operating cost + (Spill Cost – Recapture Cost)
**Fleet Assignment Example**

Demand = 100  
Fare = $100

<table>
<thead>
<tr>
<th>Fleet Type</th>
<th>Capacity</th>
<th>Spill Cost</th>
<th>Op. Cost</th>
<th>Assignment Cost</th>
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<td>i</td>
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<td>$2,000</td>
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<td>ii</td>
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<td>$6,000</td>
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<tr>
<td>iv</td>
<td>150</td>
<td>$0</td>
<td>$8,000</td>
<td>$8,000</td>
</tr>
</tbody>
</table>
Objective Function

• For each fleet - flight combination: \( \text{Cost} \equiv \text{Operating cost} + \text{Spill cost} \)

• Operating cost associated with assigning a fleet type \( k \) to a flight leg \( j \) is relatively straightforward to compute
  – Can capture range restrictions, noise restrictions, water restrictions, etc. by assigning “infinite” costs

• Spill cost for flight leg \( j \) and fleet assignment \( k \) = average revenue per passenger on \( j \) * \( \text{MAX}(0, \text{unconstrained demand for } j - \text{number of seats on } k) \)
  – Unclear how to compute revenue for flight legs, given revenue is associated with itineraries
Constraints

• Cover Constraints
  – Each flight must be assigned to exactly one fleet type

• Balance Constraints
  – Number of aircraft of a fleet type arriving at a station must equal the number of aircraft of that fleet type departing

• Aircraft Count Constraints
  – Number of aircraft of a fleet type used cannot exceed the number available
FAM Example: Network Effects

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

Leg Interdependence

Network Effects
Solution

• Solve fleet assignment problems for large domestic carriers (10-14 fleets, 2000-3500 flights) within 10-20 minutes of computation time on workstation class computers

A Look to the Future: Robust Scheduling

- **Issue:** Optimizing “plans” results in minimized *planned* costs, not *realized* costs
  - Optimized plans have little *slack*, resulting in
    - Increased likelihood of plan “breakage” during operations
    - Fewer recovery options

- **Challenge:** Building “robust” plans that achieve minimal realized costs

- **Challenge:** Building re-optimized plans in real-time