Airline Schedule Development

16.75J/1.234J Airline Management

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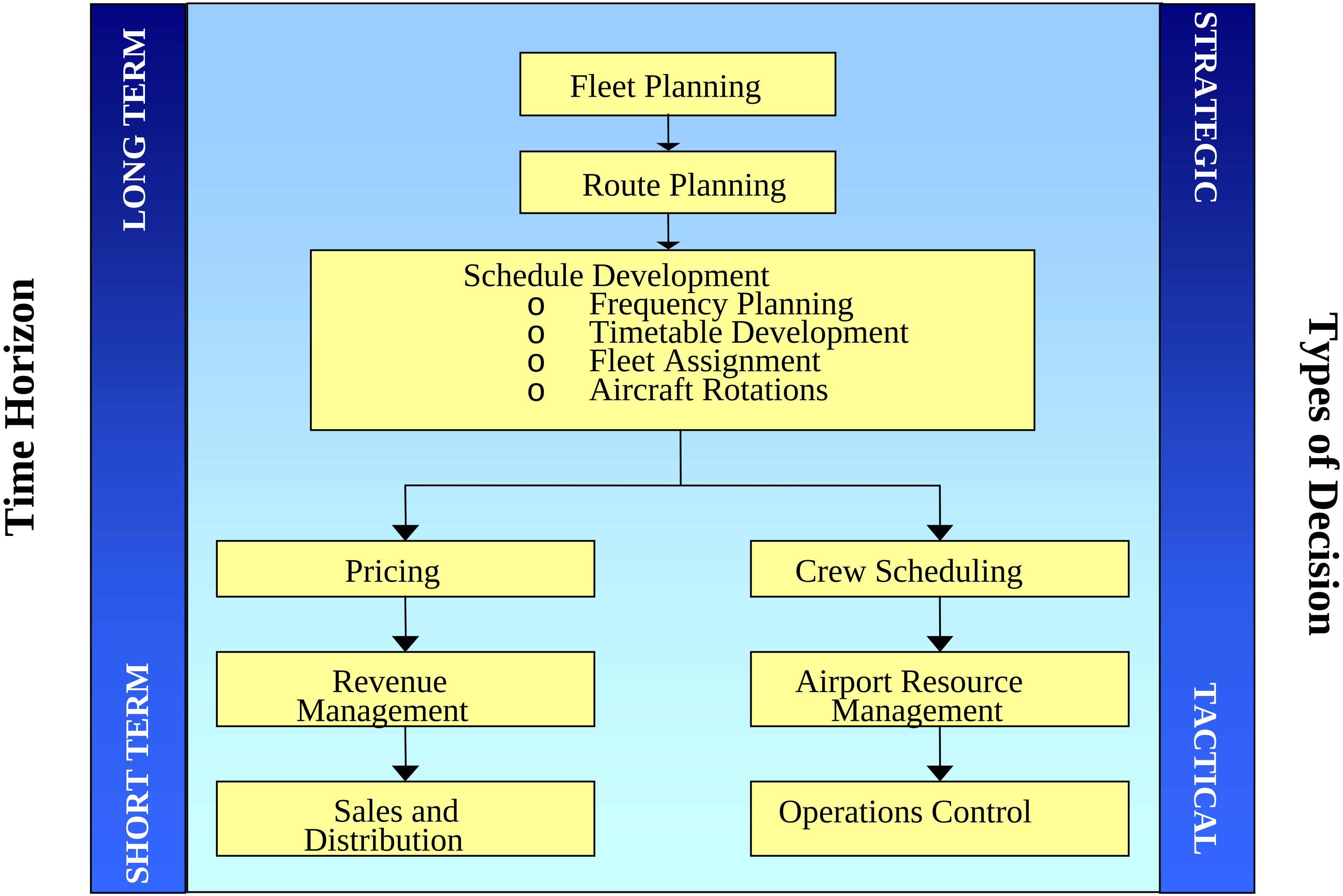
1. **Schedule Development Process**
   - Airline supply terminology
   - Sequential approach to schedule planning
2. **Frequency Planning**
   - Market share / frequency share
3. **Timetable Development**
   - Aircraft rotations and timetable constraints
4. **Fleet Assignment Optimization**
   - Problem definition and objective
   - Network modeling and solution
   - Constraints and limitations

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

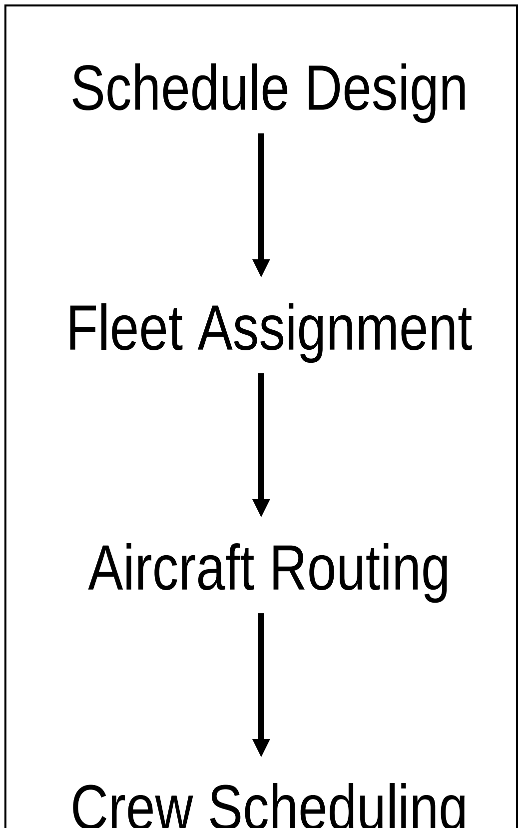


SOURCE: Prof. C. Barnhart

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



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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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

Fleet Type	Capacity	Spill Cost	Op. Cost	Assignment Cost
i	80	$2,000	$5,000	$7,000
ii	100	$0	$6,000	$6,000
iii	120	$0	$7,000	$7,000
iv	150	$0	$8,000	$8,000

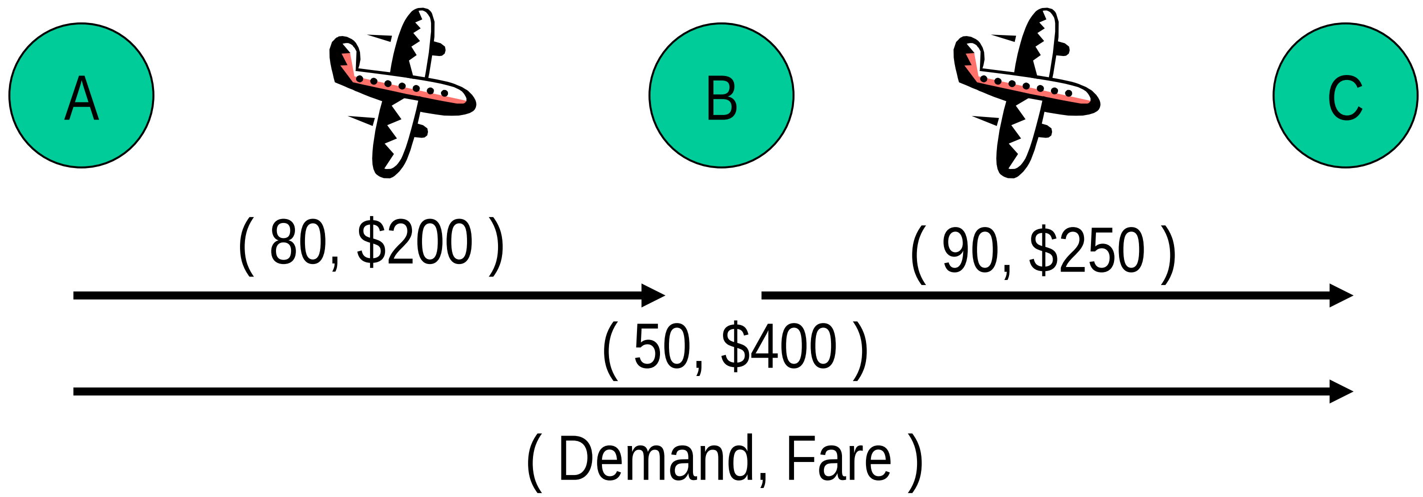
Objective Function

- **For each fleet - flight combination: Cost $\equiv$ Operating cost + 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* * MAX(0, unconstrained demand for *j* – 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**

- **Hane, et al. "The Fleet Assignment Problem, Solving a Large Integer Program," *Mathematical Programming*, Vol. 70, 2, pp. 211-232, 1995**

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**