Lecture Outline

• Schedule Development Process
  ▪ Principal decision steps
  ▪ Airline supply terminology
  ▪ Sequential schedule planning

• Frequency Planning
  ▪ Frequency share vs. load consolidation
  ▪ Additional frequency considerations

• Timetable Development
  ▪ Time of day demand distributions
  ▪ Operational and maintenance constraints
  ▪ Scheduled block times

• Schedule Map of Aircraft Rotations
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
SCHEDULE DEVELOPMENT

• Given a set of routes to be operated in a 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
Schedule Development Decisions

- Involves several interrelated decisions, which to date have not been fully integrated:

  - **Frequency Planning**: Number of departures to be offered on each route, non-stop versus multi-stop
  
  - **Timetable Development**: Flight departure and arrival times, including connections at airline hubs
  
  - **Fleet Assignment**: Aircraft type for each flight, based on demand and operating cost estimates
  
  - **Aircraft Rotation Planning**: Links consecutive flights to ensure balanced aircraft flows on the network.
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)
  - DL945 is a two-leg flight BOS-MSP-SEA operated with a B757

- **Route**
  - Consecutive links in a network served by single flight numbers
  - DL 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 (e.g., BOS-SEA via connection at DTW)
Integrated Scheduling Planning Process: Key Decisions

**Fleet Planning**
- Fleet allocation and resource planning

**Network Planning**
- Schedule Development
- Schedule revision

**Process Timing**
- **Network Plan** 24-60 months
- **Fleet Plan** 24-60 months
- **Network Plan** 12-60 months
- **Fleet Plan** adjustments
- **Schedule** 6-12 months
- **New Fleet allocation**
- **Fleet reallocation between Bases**
- **Schedule** 3-6 months
- **Operational Plan** 0-12 months
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
Frequency Planning

• Frequency of departures on a route reduces total trip times for passengers and increases market share:
  - In competitive markets, airline frequency share is most important to capturing time sensitive business travelers
  - Frequent departures reduce schedule displacement or “wait time” between flights
  - Frequency is more important in short-haul markets than for long-haul routes where actual flight time dominates “wait time”

• Path Quality also affects market share
  - Non-stop flights preferred over one-stop, one-connects, double-connects, interline connects
  - 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


Additional Frequency Considerations

• Seasonal variations in demand
  ▪ More frequent flights during peak seasons; require aircraft to be shifted from off-peak routes
  ▪ Some routes might only be served during peak season

• Business vs. leisure mix of demand
  ▪ Short-haul business routes typically require more frequency; usually with smaller aircraft

• Hub connections and network considerations
  ▪ Number of flights affected by connecting banks at hub
  ▪ Some flights provide one-stop service through hub
Timetable Development

• For a chosen frequency of service on each route, need 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

• Most airlines try 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
Time of Day Demand – Preferred Departure Times by Passengers

• Two peaks of preferred departure times (0900 and 1800) in this short-haul (1-2 block hours) example.

Source: Boeing Decision Window Model (DWM)
Timetable Development Constraints

- Hub networks require that flights arrive/depart within a prescribed time range, for connecting banks
- Time zone differences limit feasible departure and arrival times
- Airport slot times, noise curfews limit scheduling flexibility
- Minimum turn times and gate availability at airports
- Crew scheduling – availability and layover rules differ for cockpit and cabin crew
- Routine maintenance requirements
Maintenance Requirements

• Most airlines have different maintenance capabilities at different stations on their network:
  ▪ Major Maintenance Bases perform virtually all types of maintenance, from minor to complete aircraft overhauls
  ▪ Scheduled Maintenance Stations perform minor to intermediate scheduled maintenance
  ▪ Some stations have the airline’s own mechanics on duty
  ▪ Remaining stations limited to other airlines or sub-contractors
### Example: Narrow Body Aircraft Maintenance Program

<table>
<thead>
<tr>
<th>Type of Maintenance</th>
<th>Elapsed Time</th>
<th>Man-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily check (overnight)</td>
<td>1-4 hours</td>
<td>8</td>
</tr>
<tr>
<td>Weekly check (A)</td>
<td>8 hours</td>
<td>13</td>
</tr>
<tr>
<td>Monthly check (B)</td>
<td>12 hours</td>
<td>120</td>
</tr>
<tr>
<td>Annual base visit (C)</td>
<td>3 days</td>
<td>2,000-4,000</td>
</tr>
<tr>
<td>Four-year visit (D)</td>
<td>3-6 weeks</td>
<td>9,000-40,000</td>
</tr>
</tbody>
</table>
Scheduled Block Time

• Block time = from door closed to door open
  ▪ Can also be from brake release to brake set

• ACTUAL block time is variable, affected by
  ▪ Ground crews, pushback and taxi-out times at different airports
  ▪ Different airport runway configurations on different days
  ▪ Airport congestion, departure queues, ground holds
  ▪ Weather and wind speeds while airborne; specific route flown
  ▪ Arrival queues, descent patterns, taxi-in delays

• SCHEDULED block time involves trade-offs
  ▪ Longer planned schedules increase “on-time” performance
  ▪ But, increases operating costs, reduces utilization, gate issues
  ▪ Should buffer be applied to block time or turn-around time?
Variability in Actual Block Times

Average: 366.5
St. Deviation: 25.8

Courtesy: G. Skaltsas
Additional Timetable Considerations

• Increased planned block times can improve on-time arrival performance for airline, but has costs:
  ▪ Reduced utilization of aircraft and crew resources
  ▪ Lower position on GDS display screens
  ▪ Potential frustration for passengers with “early” arrivals

• Each timetable shift has multiple impacts
  ▪ Previous and subsequent flights operated by same aircraft might also have to be shifted
  ▪ Feasibility of crews, gates, maintenance, curfews, etc.
  ▪ Potential demand (and revenue) impacts via Time of Day Demand and GDS displays
Example of a Schedule Map
2 aircraft; 10 flight legs; 9 block-hr/aircraft-day

STO
0700

AMS
1500

FRA
1000

MA
0700

D
1330

Long Turnaround

Long Overnight
Revised Schedule Map
2 aircraft; 12 flight legs; 11 block-hr/aircraft-day
OR Models in Airline Scheduling

• Airline scheduling problems have received most operations research (OR) attention

• Use of schedule optimization models has led to impressive profit gains in:
  ▪ Aircraft rotations; fleet assignment
  ▪ Crew rotations; maintenance scheduling

• Current focus is on solving larger problems:
  ▪ Bigger aircraft fleets, more constraints, and more realistic representations of demand
  ▪ Optimized solutions minimize planned costs, not actual costs under conditions of operational uncertainty and disruptions