Modeling Passenger Choice of Flight Options

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Strategic Planning
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Lecture Outline

• **Boeing Decision Window Model (DWM)**
  - Traveler Decision Process
  - Decision Windows
  - Passenger Choice of Path Options
  - Airline Image Factors
  - Schedule vs. Airline Decision Orientation

• **Passenger Origin-Destination Simulator (PODS)**
  - Simulation Process
  - Inputs and Assumptions – Demand by Passenger Type
  - Passenger Choice Representation
  - Disutility Model for Fare Restrictions
  - Total Generalized Cost
Boeing Decision Window Model (DWM)

- An approach for estimating passenger preference for different flight alternatives in a schedule
  - DWM assumes a model of the decision making process of individual travelers

- Given an estimate of the total daily demand for air travel in a directional O-D market
  - What is the expected share of this demand that will prefer each alternative “path” (itinerary)
  - Path preference based on time of day demand distributions and path quality of schedule alternatives (non-stop vs. connect, etc.)
  - Assume “all else equal” – competing airlines have same fares, same product quality, same aircraft preferences
The Traveler Decision Process

Travelers have some knowledge of the characteristics of their planned trips

Source: Boeing
Each Passenger has a Decision Window

- Bounded by earliest departure and latest arrival time
  - Window is situated on the preferred travel day
  - Window is wider than the perceived (actual) travel time required
  - All departure and arrival times in the window are acceptable to the traveler

Source: Boeing
**Decision Window Size**

- **“Delta-T”:** Difference between local departure time and local arrival time at destination
  - Represents perceived duration of flight

- **Schedule Tolerance:** Amount of flexibility in passenger’s preferred travel schedule
  - Will differ by passenger type (business vs. leisure)

*Source: Boeing*
**Airline Schedules Create Paths**

- Paths are flights and itineraries that are available for travel from the passenger’s origin to destination

<table>
<thead>
<tr>
<th>The Schedule</th>
<th>YY 08:00-10:00 0</th>
<th>ZZ 14:30-17:30 1</th>
<th>CC 12:00-12:30 0</th>
<th>CC 13:00-15:00 0</th>
<th>EE 20:30-21:30 0</th>
<th>CC 23:00-23:15 0</th>
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<td>SEA-SFO</td>
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<td></td>
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</tr>
</tbody>
</table>

Source: Boeing
Many Individuals Make Up Total Demand in a Market

- For example, a distribution of decision windows

Source: Boeing
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)
Decision Windows Capture Key
Characteristics of Airline Markets

• More frequencies are good
  ▪ More flight options at different times increase the likelihood each traveler will find at least one path in his decision window

• Frequency saturation exists
  ▪ At some point, adding more flights satisfies the same travelers that were willing to choose another flight

• Shorter paths (non-stop) are good
  ▪ Long (multiple stop or connecting) paths are less likely to fit into the decision window of most travelers

• Timing of flights is important
  ▪ Paths departing at popular times will be within the decision window of more travelers

Source: Boeing
Passenger Choice of Path Options

- Acceptable paths must fit within decision window
- Path choice based on path quality and airline image
Factors Affecting Airline Image

• Importance of different factors varies with distance of the trip being considered
Decision Orientation Affects Path Choice

Schedule Oriented

- Chooses the best path quality
- Chooses preferred airline

Airline Oriented

- Chooses preferred airline
- Chooses best path quality

Source: Boeing
Insights from Decision Window Model of Path Choice

• Path Quality is important
  ▪ Paths with lower PQI are less likely to be chosen
  ▪ Lower PQI means increased total travel time
  ▪ Lower PQI can also mean greater risk and lower image (e.g., missed connections, baggage problems)

• Trip Distance (range) determines the importance of different factors
  ▪ The longer the range, the more important are airline service quality and passenger environment (including aircraft type)
  ▪ Differences in path quality are less important at longer range

Source: Boeing
Passenger Origin Destination Simulator

- Passenger Origin Destination Simulator developed by Boeing in early 1990s
  - Originally simulated passenger choice based on Decision Window Model
  - MIT (Belobaba) helped to integrate pricing and airline Revenue Management models in mid-1990s

- PODS simulates interaction of RM and passenger choice in competitive markets:
  - Airlines must forecast booking demand from actual (previously simulated) historical data
  - RM systems set booking limits by leg/class or path/class (O+D) given demand forecasts and optimization/control scheme
  - Passengers choose among O-D paths/fare types and airlines based on prices, restrictions and RM availability
Overview of PODS Architecture

• Multiple iterations (samples) of pre-departure booking process and departure day:
  ▪ Stationary process (no trends)
  ▪ Initial input values for demands, then gradual replacement with direct observations
  ▪ “Burn” first n observations in calculating final scores

• Pre-departure process broken into time frames:
  ▪ RM system intervention at start of each time frame
  ▪ Bookings arrive randomly during time frame
  ▪ Historical data base updated at end of time frame
Basic Schematic

- **PASSENGER DECISION MODEL**
- **REVENUE MANAGEMENT OPTIMIZER**
- **FORECASTER**
- **HISTORICAL BOOKING DATA BASE**

**Connections:**
- Path/Class Availability
- Path/Class Bookings/Cancellations
- Current Bookings
- Future Bookings
- Update
- Historical Bookings
Passenger Choice Model

- Demand generation
  - Total demand for air travel per O-D market per passenger type per departure date

- Passenger characteristics
  - Passenger type, Decision window, WTP, disutilities

- Passenger choice set
  - Available travel alternatives
    - Advance purchase requirements
    - Affordable travel alternatives (Fare > WTP)
    - Path/class open/closed status

- Decision rule
  - Choose alternative (path/class) that has the lowest generalized cost (Fare + disutilities)
PODS Inputs and Parameters

• Total daily demand for an O-D market, by passenger type (business vs. leisure):
  ▪ Time of day demand and schedule tolerance
  ▪ Maximum out-of-pocket fare willingness to pay
  ▪ “Attributed costs” associated with path quality, fare restrictions, trip re-planning

• Maximum willingness to pay (WTP) and attributed costs modeled as Gaussian distributions:
  ▪ Means and variances (k-factors) specified as inputs

• Booking curves by passenger type over 16 booking periods before departure.
Booking Curves by Passenger Type

Days Out

Percent Booked

BUSINESS

LEISURE
Business vs. Leisure Passengers

- Two passenger types defined by:
  - Time of day demand and schedule tolerance
  - Maximum out-of-pocket fare willingness to pay
  - “Attributed costs” associated with path quality, fare restrictions, trip re-planning

- Maximum willingness to pay (WTP) and attributed costs modeled as Gaussian distributions:
  - Means and variances (k-factors) specified as inputs
  - Each simulated passenger has randomly drawn value from each distribution
Example of WTP Formulation

In the passenger choice model used in PODS, a passenger’s willingness-to-pay (WTP) is set according to:

\[
\text{Probability (pay at least } f \text{)} = \min[1, e^{-\frac{\log(2) \times (f - \text{basefare})}{(\text{emult} - 1) \times \text{basefare}}}] 
\]

With: \( \text{basefare} = Q \text{ fare for leisure passengers} = 2.5 \times Q \text{ fare for business passengers} \)

And: \( \text{emult} = 1.5 \text{ for leisure passengers} = 2.0 \text{ for business passengers} \)
Different WTP Curves

Business passengers

Emult = 3.5
Emult = 3.0
Emult = 2.5

Leisure passengers

Emult = 1.2
Emult = 1.4
Modeling Passenger Path Choice

• Define each passenger’s “decision window”:
  ▪ Earliest departure and latest arrival time
  ▪ Market time-of-day demand profile

• Eliminate paths with lowest available fare greater than passenger’s maximum willingness to pay

• Pick best path from remainder, trading off:
  ▪ Fare levels and restrictions
  ▪ Path quality (number of stops/connects)
  ▪ Other disutility parameters
Choice of Path/Fare Combination

- Given passenger type, randomly pick for each passenger generated:
  - Maximum “out-of-pocket” willingness to pay
  - Disutility costs of fare restrictions
  - Additional disutility costs associated with “re-planning” and path quality (stop/connect) costs

- Screen out paths with fares greater than this passenger’s WTP.

- Assign passenger to feasible (remaining) path/fare with lowest total cost.
Fare Class Restriction Disutilities

• Disutility costs associated with the restrictions of each fare class:
  ▪ added to the fare value to determine the choice sequence of a given passenger among the classes with fare values less than his/her WTP.

• The “traditional” restrictions are:
  ▪ R1: Saturday night stay (for B, M and Q classes),
  ▪ R2: cancellation/change penalty (for M and Q classes),
  ▪ R3: non-refundability (for Q class).
## EXAMPLE: Fare Structure

<table>
<thead>
<tr>
<th>Fare Code</th>
<th>Price Level</th>
<th>Advance Purchase</th>
<th>Sat. Night Min. Stay</th>
<th>Non-Refundable</th>
<th>Change Fee</th>
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<tr>
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<td>$400</td>
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<td>B</td>
<td>$200</td>
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<td>M</td>
<td>$150</td>
<td>14 day</td>
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<tr>
<td>Q</td>
<td>$100</td>
<td>21 day</td>
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</table>
Total Generalized Cost of Fare Options
Total Generalized Cost of Fare Options
Other Disutility Costs

- **PQI disutility cost**
  - Unit PQI disutility cost determined as function of market base fares
  - PQI: 1 for nonstop path, 3 for connecting path
  - PQI disutility cost = Unit PQI disutility cost * PQI

- **Replanning disutility cost**
  - Applies when a given path is outside of passenger’s decision window
  - Function of market base fares

- **Unfavorite airline disutility cost**
  - Applies when a given path is not a favorite airline
  - Function of market base fares
Total Disutility Costs

- **Passenger path choice criteria: Least total cost**
  - Total cost = Fare + Restriction disutility + PQI disutility + Replanning disutility + Unfavorite airline disutility

- **Impact of passenger disutilities**
  - With passenger disutility costs included in PODS simulations, passengers are able to differentiate the “attractiveness” of each path/fare combination, resulting in higher preference for “favorable” paths
Summary of Passenger Choice Model

DEMAND GENERATION

PASSENGER CHARACTERISTICS
(by passenger type – leisure or business)

AVAILABILITY

GENERALIZED COST
OF EACH FEASIBLE ALTERNATIVE

PASSENGER CHOICE

Willingness to pay

Disutility costs

Time window

Passenger arrival

Courtesy T. Gorin