Airline Reservation Systems

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KLM – AMS/RX
Objective of the presentation

- To illustrate
  - what happens when passengers make a reservation
  - how airlines decide what fare to charge to passengers
Basic Disciplines

- Economics
  - supply / demand / fares

- Econometrics
  - models / optimization techniques

- Computer Science
  - process management
Travel Example (1)

- **Route**
  - Amsterdam → Houston → Amsterdam

- **Availability request**
  - airline office / website
    - biased
  - travel agent / website
    - neutral
5 Travel Example (2)

- Result
  - many alternatives
    - journey & fare
  - different journey (route or date) → different fare
    - airline / route
    - flights (different expected load factor)
  - same journey → different fares
    - fare conditions
      - cancellation / change / service level / ...
    - origin of availability request (point of sale)
6 System Components

• Reservation system (RS)
  - controls bookings based on flight statuses
  - global systems: Amadeus, Galileo, Worldspan, …
  - airline systems: Arco, Alpha3, Corda, …

• Revenue management system (RMS)
  - computes flight settings
  - sends the settings to the reservation system
  - systems: PROS, Sabre, AirFrance/KLM, …
Reservation Systems (RS)

- **Airline reservation system (ARS)**
  - airline owned
  - Arco, Alpha3, Corda, …

- **Central reservation system (CRS)**
  - airline independent
  - Amadeus, Galileo, Worldspan, …
Airline Reservation System (ARS)

- Responsible for the airline’s own data
  - flight schedule / fares / passenger data / …

- Decides whether or not to accept a passenger and determines the fare the passenger will have to pay

- Communication with
  - other airlines (ARS’s)
  - travel agents / passengers
  - central reservation systems (CRS’s)
  - …
Central Reservation System (CRS)

- Makes reservations for passengers in ARS’s

- Responsible for its bookings
  - reservation / ticketing / consistency with data in ARS

- Communication with
  - airlines (ARS’s)
  - travel agents / passengers
  - ...
Overview Picture
Availability Request

- Passenger (travel agent / website) connects to ARS / CRS

- ARS / CRS knows where the passenger is located

- Fare offered depends on location (point of sale) of passenger and path from passenger to ARS
  - passenger (Berlin) → United → United (flight IAH-FRA)
  - passenger (Berlin) → Lufthansa → United (flight IAH-FRA)
  - passenger (Oslo) → United → United (flight IAH-FRA)
  → United may (most likely will) offer different fares

- Travel websites (Priceline / CheapTickets) try several paths (by faking a change of location!)
Revenue Management Systems (RMS)

- Reservation systems
  - accept passengers and determine the fare to pay

- Revenue management system
  - computes settings to be used by reservation systems when accepting passengers
  - PROS, Sabre, AirFrance/KLM, …
Airline Passenger Revenue Management

- Process of maximizing seat revenue through:
  - pricing
    - market segmentation
    - “different products at different prices”
  - inventory control
    - limit the number of seats available to specific market segments
    - anticipate on future cancellations and no-shows
Pricing (1)

- Market segmentation
  - single fare class

![Diagram showing fare, revenue, dilution, untapped revenue, unaccommodated demand, and demand curve with expected seats sold on the x-axis.]
• Market segmentation
  - multiple fare classes with different restrictions
Inventory Control

- Maximize total revenue
  - compute the “optimal” passenger mix
    - number of passengers / fare
  - allow (limited) overbooking
    - number of denied boardings (close to) zero
    - yield of accepting extra passengers higher than denied boarding costs
Example

- Amsterdam (AMS) – Houston (IAH/HOU)
- Departure date: 13 December 2009
- Booking date: 8 December 2009
## (RS) Availability AMS - IAH / 13 DEC

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* AMS = Amsterdam, NL  
  IAH = Houston, TX

**Notes:**
- **KL 661** and **KL 663** are KLM flights.
- **J4C3I2X9S9B9M9K9H9** and **J9C9I9** are flight numbers.
- **74E** and **737** are aircraft types.
- **0001-0300** indicates departure times.
- **L9Q9T9V9** is a flight code.

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**Airline Logos:**
- **AIR FRANCE**
- **KLM**
**FLIGHT: KL661 13DEC09 SUN 10:50**

**LAST BID/BKT UPD: 08DEC/1614Z AMS–IAH**

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Expected Marginal Seat Revenue (EMSR)

- **Heuristic (Belobaba 1989)**
  - flight based, several variants
  - simple, fast, reliable
  - works well with any reasonable stochastic demand forecast

- **Idea**: reserve seats for higher valued demand

- **Steering mechanism**
  - bucket: set of fares
  - bucket protection: number of seats reserved for passengers paying at least a fare associated with that bucket
Towards Network-Optimization (1)

- Problem: How to deal with connecting passengers?

- Example:
  - 1 open seat on a flight from Geneva to Amsterdam
  - 2 passengers:
    - 1 passenger flying Geneva - Amsterdam willing to pay a high (business class) fare
    - 1 passenger flying Geneva - Amsterdam - Tokyo willing to pay a low (economy class) fare only
  - which passenger should get the seat on the flight from Geneva to Amsterdam?
Towards Network-Optimization (2)

- Flight oriented algorithms (like the one of Belobaba) are suboptimal for the global network

- Network carriers have >70% connecting traffic
  - Lufthansa, British Airways, Delta Airlines, KLM, …

- Huge data volumes
<table>
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<th>Origin</th>
<th>Dest.</th>
<th>Actual Seats Sold</th>
<th>Exp. Net Seats Sold</th>
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Network Inventory Control

- Maximize total revenue
  - compute the “optimal” passenger mix
    - number of passengers / route / fare
  - allow (limited) overbooking
    - number of denied boardings (close to) zero
    - yield of accepting extra passengers higher than denied boarding costs
Input (1)

- Schedule and capacity
  - flight departure and arrival times
  - cabin capacities
  - sales restrictions
Input (2)

• Demand and cancellation forecast
  
  - based on observed bookings in the past
  
  - low level:
    - route (origin / destination / flight list)
    - point of sale
    - passenger type
    - day of week / season
    - fare class
  
  - overrules for specific departure dates
Models

- **Notations**

  - **OD**: dated route (origin, destination, flight list) / fare class / point of sale / passenger type

  - for each **OD**
    - \( X_{OD} \): number of passengers to accept (booking limit)
    - \( D_{OD} \): probabilistic demand
    - \( F_{OD} \): fare

  - for each **flight j**
    - \( C_j \): remaining capacity (= capacity - actual seats sold)
      (single cabin flights only)
Stochastic Model

• Maximize

\[ E( \sum_{OD} F_{OD} \cdot \min \{ X_{OD}, D_{OD} \} ) \]

• Subject to

\[ \sum_{OD \supseteq \text{flight } j} X_{OD} \leq C_j \quad \text{(for all flights } j) \]

\[ X_{OD} \geq 0 \text{ and integer} \quad \text{(for all OD’s)} \]
Deterministic Model (1)

- Approximation of stochastic model

- Maximize
  \[ \sum_{OD} F_{OD} \cdot X_{OD} \]

- Subject to
  \[ \sum_{OD \ni \text{flight } j} X_{OD} \leq C_j \]  
  \[ 0 \leq X_{OD} \leq ED_{OD} \]
  (for all OD's)
Deterministic Model (2)

• Advantages
  - simple (linear programming)
  - well solvable (large instances)
  - easily extendable to multi-cabin flights

• Disadvantages
  - fractional solutions
  - deterministic (average demand)
  → how to handle unexpected booking behavior?
Dual Formulation (1)

• Decision variables
  - for each OD: $W_{OD} \geq 0$
  - for each dated flight $j$: $B_j \geq 0$

• Minimize
  $$\sum_{OD} D_{OD} \cdot W_{OD} + \sum_j C_j \cdot B_j$$

• Subject to
  $$W_{OD} \geq F_{OD} - \sum_{OD \geq \text{flight } j} B_j \quad \text{(for all OD’s)}$$
• $W_{OD} & B_j$
  - marginal values w.r.t. demand and capacity

• Terminology
  - $B_j$: bid price of flight $j$

  - $F_{OD} - \sum_{OD \supseteq vlucht j} B_j: OD$ (customer) contribution

→ notation: $CuCo_{OD}$
Unexpected Booking Behavior

- Acceptance strategy for passengers willing to fly a certain OD
  
  - accept the passengers if
    \[ CuCo_{OD} = F_{OD} - \sum_{OD \supseteq \text{flight } j} B_j > 0 \]
  
  - refuse the passengers if
    \[ CuCo_{OD} = F_{OD} - \sum_{OD \supseteq \text{flight } j} B_j < 0 \]
  
  - conditionally accept the passengers if
    \[ CuCo_{OD} = F_{OD} - \sum_{OD \supseteq \text{flight } j} B_j = 0 \]
Optimization Frequency

- **Best strategy**
  - after each accepted booking
  - if expected bookings fail to happen
  → practically infeasible

- **Second best strategy**
  - at regular time intervals: daily, weekly, …
  - on demand: heavy booking activity, schedule changes, …
  → how to avoid loss of revenue?
• Use Belobaba’s algorithm as secondary tool

• Create flight forecast based on customer contribution

• Steering mechanism
  - bucket: customer contribution values
  - bucket protection: number of seats reserved for passengers paying at least a fare associated with that bucket

• Availability request
  - return minimum bucket availability of all flights in the itinerary
Cancellations & No-shows (1)

- Overbooking of flights in order to prevent empty seats

- Risk based overbooking
  - limit expected number of denied boardings
    → increase the number of available seats

- Cost based overbooking
  - limit expected denied boarding costs
    → extra terms in the objective function
Cancellations & No-shows (2)

- Overbooking on bookings on hand
  - all passenger data are known
  - cancellation forecast model may be trusted

- Overbooking on demand to come
  - optimization model computes demand to accept
  - actual accepted demand may differ
  - to be applied with care
Issue: Buy-Down (1)

- Models assume market segmentation
  - passengers willing to pay a specific fare will actually buy a ticket at that fare

- Assumption is valid in case of (strict) fare restrictions
  - minimum / maximum stay
  - no rerouting
  - no refunds
  - ...
Issue : Buy-Down (2)

- Fare restrictions disappear gradually …

→ Passengers will buy cheapest ticket in the market
  → direct loss of revenue
  → lower demand forecast for higher fares
    → indirect loss of revenue in the future (spiral down)

- New sell-up models incorporate customer behavior
  - mixed integer / nonlinear / fare adjustments
Issue: Buy-Down (3)

→ Airlines will not always offer low fare tickets in order to fill up (empty) flights