Airline Revenue Management: Impacts of Fare Simplification on RM Systems

1.201 Transportation Systems Analysis: Demand & Economics

Dr. Peter P. Belobaba
Changing Fare Structures Worldwide

• Major shifts in airline pricing strategies since 2000
  ▪ Growth of low-fare airlines with relatively unrestricted fares
  ▪ Matching by legacy carriers to protect market share and stimulate demand
  ▪ Increased consumer use of internet search engines to find lowest available fare options
  ▪ Greater consumer resistance to complex fare structures and huge differentials between highest and lowest fares offered

• Recent moves to “simplified” fares overlook the fact that pricing segmentation contributes to revenues:
  ▪ Fare simplification removes restrictions, resulting in reduced segmentation of demand
Fare Simplification Reduces Segmentation

<table>
<thead>
<tr>
<th>Fare Code</th>
<th>Dollar Price</th>
<th>Advance Purchase</th>
<th>Round Trip?</th>
<th>Sat. Night Min. Stay</th>
<th>Percent Non-Refundable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>$500</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>B</td>
<td>$375</td>
<td>7 day</td>
<td>--</td>
<td>--</td>
<td>50 %</td>
</tr>
<tr>
<td>M</td>
<td>$250</td>
<td>14 day</td>
<td>--</td>
<td>--</td>
<td>100 %</td>
</tr>
<tr>
<td>Q</td>
<td>$190</td>
<td>21 day</td>
<td>--</td>
<td>--</td>
<td>100 %</td>
</tr>
</tbody>
</table>

- With fewer restrictions on lower fares, some Y (business) passengers are able to buy B, M and Q.
- Keeping B, M, Q classes open results in “spiral down” of high fare passengers and total revenues.
## BOS-SEA Fare Structure
**American Airlines, October 1, 2001**

<table>
<thead>
<tr>
<th>Roundtrip Fare ($)</th>
<th>Cls</th>
<th>Advance Purchase</th>
<th>Minimum Stay</th>
<th>Change Fee?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>458</td>
<td>N</td>
<td>21 days</td>
<td>Sat. Night</td>
<td>Yes</td>
<td>Tue/Wed/Sat</td>
</tr>
<tr>
<td>707</td>
<td>M</td>
<td>21 days</td>
<td>Sat. Night</td>
<td>Yes</td>
<td>Tue/Wed</td>
</tr>
<tr>
<td>760</td>
<td>M</td>
<td>21 days</td>
<td>Sat. Night</td>
<td>Yes</td>
<td>Thu-Mon</td>
</tr>
<tr>
<td>927</td>
<td>H</td>
<td>14 days</td>
<td>Sat. Night</td>
<td>Yes</td>
<td>Tue/Wed</td>
</tr>
<tr>
<td>1001</td>
<td>H</td>
<td>14 days</td>
<td>Sat. Night</td>
<td>Yes</td>
<td>Thu-Mon</td>
</tr>
<tr>
<td>2083</td>
<td>B</td>
<td>3 days</td>
<td>none</td>
<td>No</td>
<td>2 X OW Fare</td>
</tr>
<tr>
<td>2262</td>
<td>Y</td>
<td>none</td>
<td>none</td>
<td>No</td>
<td>2 X OW Fare</td>
</tr>
<tr>
<td>2783</td>
<td>F</td>
<td>none</td>
<td>none</td>
<td>No</td>
<td>First Class</td>
</tr>
</tbody>
</table>
BOS-SEA Simplified Fare Structure  
Alaska Airlines, May 1, 2004

<table>
<thead>
<tr>
<th>Roundtrip Fare ($)</th>
<th>Cls</th>
<th>Advance Purchase</th>
<th>Minimum Stay</th>
<th>Change Fee?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>374</td>
<td>V</td>
<td>21 days</td>
<td>1 day</td>
<td>Yes</td>
<td>Non-refundable</td>
</tr>
<tr>
<td>456</td>
<td>L</td>
<td>14 days</td>
<td>1 day</td>
<td>Yes</td>
<td>Non-refundable</td>
</tr>
<tr>
<td>559</td>
<td>Q</td>
<td>14 days</td>
<td>1 day</td>
<td>Yes</td>
<td>Non-refundable</td>
</tr>
<tr>
<td>683</td>
<td>H</td>
<td>7 days</td>
<td>1 day</td>
<td>Yes</td>
<td>Non-refundable</td>
</tr>
<tr>
<td>827</td>
<td>B</td>
<td>3 days</td>
<td>none</td>
<td>No</td>
<td>2 X OW Fare</td>
</tr>
<tr>
<td>929</td>
<td>Y</td>
<td>none</td>
<td>none</td>
<td>No</td>
<td>2 X OW Fare</td>
</tr>
<tr>
<td>1135</td>
<td>F</td>
<td>none</td>
<td>none</td>
<td>No</td>
<td>First Class</td>
</tr>
</tbody>
</table>
In Retrospect, the Airline RM Problem was Relatively Simple

- **Fundamental assumptions of traditional RM models:**
  - Multiple fare levels offered on same flight, same itinerary
  - Each has different restrictions and characteristics
  - Demand for each fare class is independent and identifiable
  - Passengers will only buy their preferred fare product

- **Implications for forecasting:**
  - Future demand can be predicted based on historical bookings in each fare class
  - Time series statistical methods used by most RM systems

- **Implications for optimization:**
  - Given independent demand forecasts and remaining capacity, optimize booking limits for each fare class by flight or network
“Spiral-Down” in Traditional RM Systems

• Simplified fare structures characterized by
  ▪ One-way fares with little or no product differentiation, priced at different fare levels
  ▪ Without segmentation, passengers buy the lowest available fare

• Fare class forecasts based on historical bookings will under-estimate demand for higher fare levels
  ▪ Previous “buy-down” is recorded as lower fare demand
  ▪ EMSRb under-protects based on under-forecasts of high-fare demands
  ▪ Allowing more buy-down to occur, and the cycle continues
Revenue Impacts of Fare Simplification with Traditional RM Models

- Fully Restricted: -0.5%
- Remove AP: -16.8%
- Remove Sat Night Min Stay: -29.6%
- Remove All Restr, Keep AP: -45%
- Remove All Restr and AP: -45%

Revenue changes for different fare simplification scenarios.
Traditional RM Models “Spiral Down” without Product Differentiation

- Fully Restricted: 81.6
- Remove AP: 87.8
- Remove Sat Night Min Stay: 79.8
- Remove All Restr, Keep AP: 82.7
- Remove All Restr and AP: 88.1
Airline RM Systems Are Struggling Under Fare Simplification

• Primary responsibility for revenue maximization has shifted from pricing to RM
  ▪ Simplified fares still offer just as many price levels, but segmentation restrictions have been removed
  ▪ Existing RM systems still employed to control number of seats sold at each fare level

• Current RM system limitations are negatively affecting airline revenues
  ▪ Existing systems, left unadjusted, generate higher load factors but lower yields
  ▪ Many legacy carriers are using “rule-based” RM practices, for lack of a systematic approach to revenue maximization
US Network Carrier Yields and Load Factors 1995-2006

- **US Network Carrier Yields and Load Factors 1995-2006**

  - **US Cents/RPM**
  - **LOAD FACTOR**

  - **1995**
  - **1996**
  - **1997**
  - **1998**
  - **1999**
  - **2000**
  - **2001**
  - **2002**
  - **2003**
  - **2004**
  - **2005**
  - **2006**

  - **PAX YIELD**
  - **LOAD FACTOR**

  - **11.0**
  - **11.5**
  - **12.0**
  - **12.5**
  - **13.0**
  - **13.5**

  - **65%**
  - **67%**
  - **69%**
  - **71%**
  - **73%**
  - **75%**
  - **77%**
  - **79%**
  - **81%**
  - **83%**
Can Existing RM Systems be Saved?

- For traditional RM systems, what tools can reclaim revenues lost to simplified fares?
  - Focus on models tested in PODS simulation research at MIT

- Is development of Network RM (O+D control) still worthwhile?
  - Comparison of Network RM revenue gains to Leg-based RM enhancements

- How much of the revenue lost to simplification can be recouped with these models?
Current RM Challenge: Changing and Different Fare Structures

1. Fully Undifferentiated Fare Structures
   - Multiple fare levels with no differentiation of fare products, with only one fare level available at a given point in time

2. Semi-Restricted (“Simplified”) Fare Structures
   - Combination of differentiated fare products and loosely restricted undifferentiated fares in same market

3. Mixed Networks with Multiple Fare Structures
   - How to control seat availability in unrestricted fare LCC markets while managing seats in more traditional fare markets
   - Seats on a flight leg shared by passengers in both types of markets
New Developments in RM Modeling

• Forecasting and optimization methods to reverse and prevent spiral down in different fare structures
  ▪ Incorporate willingness to pay (WTP) or “sell-up” probabilities

• Several new approaches show promising results
  ▪ “Q-forecasting” by WTP (Hopperstad and Belobaba)
  ▪ Hybrid Forecasting (Boyd and Kallesen)
  ▪ Fare Adjustment in Optimization (Fiig and Isler)

• Methods developed and/or tested in MIT PODS research consortium
  ▪ Funded by seven large international airlines
  ▪ Passenger Origin Destination Simulator used to evaluate revenue impacts of RM models in competition markets
Q-Forecasting of Price-Oriented Demand

- Q forecasting assumes fully undifferentiated fares

Conversion of historical bookings to equivalent Q-bookings

Detruncation is applied to equivalent Q-bookings

Forecast of Q-bookings to come

Forecast of potential demand to come by fare class

Apply \textit{sell-up rates} to generate forecasts for higher fare classes

Scale historical bookings by \(1/(\text{sell-up rate})\)
Hybrid Forecasting For Simplified Fare Structures

• Hybrid Forecasting generates separate forecasts for price and product oriented demand:

  ➤ **Price-Oriented:**
  - Passengers will only purchase lowest available class
  - Generate conditional forecasts for each class, given lower class closed
  - Use “Q-Forecasting” by WTP

  ➤ **Product-Oriented:**
  - Passengers will book in their desired class, based on product characteristics
  - Use Traditional RM Forecasting by fare class

Forecast of total demand for itinerary/class
Change in Fare Class Mix – EMSRb+HF

- Load Factor drops from 86.7% to 83.7%, but yield increases as fewer bookings are taken the lowest fare class.
Fare Adjustment Methods

• Modify fare inputs to optimizer to prevent buy-down
  ▪ Incorporates sell-up into optimization logic when higher-class bookings depend entirely on closing down lower classes
  ▪ Developed by Fiig (SAS) and Isler (Swiss)
  ▪ Mathematically similar to previous EMSR “sell-up” models (Belobaba and Weatherford)

• Fare Adjustment in existing leg/class RM systems
  ▪ Average fare for each bucket is the weighted average of adjusted fares for path/classes in bucket
  ▪ Fare adjustment reduces availability to lowest fare classes in LCC markets
Leg-Based Fare Adjustment Principle

Instead of feeding the EMSR optimizer with fare values, optimize with:

\[
\text{O-D Fare} - \text{Price Elasticity Cost}
\]

- **Net Fare**
- **Reduction due to risk of buy-down**

Decreases the adjusted fares of LCC markets

Changes the fare ratios in EMSR optimizer

Increases seat protection for higher fare classes with sell-up potential

Reduces availability to lowest fare classes and encourages sell-up

Different ways to compute the Price Elasticity Cost:
- Thomas Fiig’s MR (continuous)
- Karl Isler’s KI (discrete)
### EMSRb Controls with Fare Adjustment

#### NO FARE ADJUSTMENT

<table>
<thead>
<tr>
<th>FC</th>
<th>Average Fares</th>
<th>Mean Demand</th>
<th>Std Dev</th>
<th>Booking Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$350.00</td>
<td>15</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>$225.00</td>
<td>13</td>
<td>8</td>
<td>87</td>
</tr>
<tr>
<td>3</td>
<td>$190.00</td>
<td>16</td>
<td>7</td>
<td>76</td>
</tr>
<tr>
<td>4</td>
<td>$160.00</td>
<td>20</td>
<td>9</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>$110.00</td>
<td>30</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>$90.00</td>
<td>38</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

#### WITH FARE ADJUSTMENT

<table>
<thead>
<tr>
<th>FC</th>
<th>Adjusted Fares</th>
<th>Mean Demand</th>
<th>Std Dev</th>
<th>Booking Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$350.00</td>
<td>15</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>$193.49</td>
<td>13</td>
<td>8</td>
<td>84</td>
</tr>
<tr>
<td>3</td>
<td>$128.20</td>
<td>16</td>
<td>7</td>
<td>71</td>
</tr>
<tr>
<td>4</td>
<td>$96.13</td>
<td>20</td>
<td>9</td>
<td>54</td>
</tr>
<tr>
<td>5</td>
<td>$54.42</td>
<td>30</td>
<td>11</td>
<td>28</td>
</tr>
<tr>
<td>6</td>
<td>$21.66</td>
<td>38</td>
<td>6</td>
<td>-13</td>
</tr>
</tbody>
</table>

- Fare Adjustment takes into account the probability of sell-up, and the “price elasticity” opportunity cost.

- Fewer seats allocated to the lower fare classes; lowest class 6 is closed down.
Network RM with Hybrid Forecasting and Fare Adjustment

- Greatest revenue gains of existing RM methods for less restricted fare structures come from:
  - **O-D Control**: Path-based forecasting and network optimization, with availability controlled by virtual buckets (DAVN) or bid prices (ProBP)
  - **Hybrid Forecasting**: Separate forecasting of price- vs. product-oriented demand in all markets (LCC and traditional) requires explicit WTP forecasts for price-oriented demand
  - **Fare Adjustment Optimization Logic**: Price-oriented demands subject to fare adjustment which maps availability to lower buckets and/or below bid price.

- These 3 components combine to provide Airline 1 with 3.86% revenue gain over standard Leg RM.
The Price Elasticity is estimated.

\[ PE_{cost} = ODFare \, P - MR \]
Hybrid Forecasting and Fare Adjustment

- Leg RM Hybrid Fcst and FA: 2.59%
- O+D Control: 1.89%
- O+D Control w/ Hybrid Fcst: 3.43%
- O+D w/Hybrid Fcst and FA: 3.86%
Existing RM Systems Are Inadequate for Changing Fare Structures

• Forecasters and optimizers need to be modified
  ▪ Mismatch between RM model assumptions and fare structures

• Price/product hybrid forecasting of demand
  ▪ Gains come from higher forecasts in upper/middle classes, increasing protection and helping to reduce “spiral down”

• Fare adjustment in optimization models
  ▪ Passenger values adjusted to reflect risk of buy-down and willingness to pay (WTP)

• But, both new methods require estimates of passenger WTP by time to departure for each flight
Sell-up Rates Must Be Estimated from Historical Observations

- On a single flight departure, bookings in each class observed only when lower class was closed down.

- With information about class closures and observed bookings, need to estimate WTP and sell-up rates
Willingness to Pay Relative to Lowest Fare Changes over the Booking Process

BOOKING PERIODS (DCPs)
Bringing OR Back to Airline RM

• OR contributed to the great success in airline RM:
  ▪ Good acceptance of RM models by management and users alike enabled a shift away from judgmental approaches

• Recently, RM systems have suffered setbacks:
  ▪ Return to “rule-based” decision-making due to lack of faith in existing (and inappropriate) RM forecasters and optimizers
  ▪ Self-perpetuating – users become more comfortable with rules, less willing to test new scientific solutions

• Challenge is to bring science back to RM:
  ▪ Development, testing and acceptance of new models for forecasting, optimization and estimation of willingness to pay
Can Existing RM Systems Be Saved?

• Our research results suggest the answer is “YES”
  ▪ Available RM enhancements described here can increase revenues by 3-4% over traditional leg-based RM systems
  ▪ O+D Control with Hybrid Forecasting and Fare Adjustment combine to successfully reverse and prevent dilution

• Yet, many airlines have not implemented RM model enhancements to respond to fare simplification
  ▪ Doing almost anything to reverse spiral down is better than doing nothing, and more systematic than user overrides
  ▪ Biggest research/development challenge is estimation of willingness to pay and consumer choice models