Airline Economics
101

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SYST 660/OR750
Fundamental Questions

• What are the “physics” underlying the transportation service provider (i.e. airline) decisions?
• Are there quasi-stable economic “operating points”? 
• Where are the “operating points” in the state-space?
• How can “operating points” be shifted to maximize utility?
Airlines Choose Flights to Maximize Profits

Boston Arrivals for one day in 15 minute epochs, ordered by profit

| Markets by decreasing profit | JFK(-253) 25 | RDU(2049) 50 | RDU(-178) | ACK(222) | RIC(3825) 150 | BHB(876) | SFO(2443) | LGA(4950) 50 | PBI(2134) | MDW(3630) | ATL(6517) 75 | JAX(3273) | ATL(4942) 75 | TPA(6690) | LGA(3839) 75 | PHL(6364) | FLL(6984) | CLT(6432) | LAX(6969) | IAD(7444) | SLC(6640) | MKE(7918) | DCA(12822) | IAD(7235) | CVG(17954) | DCA(13827) | BNA(12509) | DTW(8153) | ATL(15864) 150 |
|----------------------------|-------------|-------------|-----------|---------|-------------|---------|-----------|-------------|----------|----------|-------------|---------|-------------|---------|-------------|-----------|---------|-----------|---------|---------|-------------|---------|-------------|-----------|---------|-------------|---------|-------------|
| 49                         | 50          | 51          | 52        | 53      | 54          | 55      | 56        |

- Scheduled Arrivals into Boston in 15 minute epochs, listed by profit
- ATL-BOS (34 flights per day, 75-150 seats per flights, Seat efficiency = 92.5 seats per flight)
- PHF-BOS (4, 125 seats per flight)

- Flights below profit threshold, do not make the cut (e.g. smaller markets)
Airlines Choose Flights to Maximize Profits

- Flights in a time period are ranked by profit
- Non-profitable flights are eliminated
- When resources are limited, least profitable flights are eliminated
  - Low Profitability flights
    - Low demand
      - O/D linking to small communities
    - Elastic markets
      - O/D linking to small communities
      - Unpopular times of day (all links) with passengers with low airfares
    - Unpredictable fluctuations in demand

Profit = Revenue - Cost
Model Airline Economics – Assumptions

• Assumptions:
  – Airline are rational economic agents
    • Select aircraft type and schedule to maximize profit
      – Profit maximized across network (e.g. connecting)
  – Profit = Revenue – Costs
    • Revenue = (Airfare + Fees) * Pax
    • Costs = (Non-fuel Costs Rate * Block-hours)
      + (Fuel Burn Rate * Fuel Price * Block Hours)
  – Revenue is driven by (economic health sensitive) demand
  – Cost is driven by fuel prices, labor, aircraft performance (i.e. technology)
Airline Economics

Willingness-to-Pay (Demand vs Airfare)

- Passenger Demand
- Airfare

Direct Operating Costs for each Aircraft

Aircraft Size

Revenue

Max Profit

Congestion: # Flights

Economic Access: # Pax Afford to Travel

Airspace/Airport Capacity

Non-Fuel DOC

Fuel Burn Rate

Hedged Fuel Price

Max Profit

Passenger Throughput; total pax
Every Market Pair has a Travel Demand

Number of passengers that have an interest in travelling from Market A to Market B during each time period.
Passengers Have Willingness-to-Pay

Passengers in each group will have an interest in travelling based on the airfare – Willingness-to-Pay.
Willingness-to-Pay & Elasticity

Airfare vs Demand Curve: Number of passengers that will travel at each Airfare point

Slope = Airfare Elasticity
• < -1 elastic, do not fly as Airfare goes up
• > -1 inelastic, do not care about Airfare
Daily Willingness-to-Pay

Assumption:
• Uniform demand across day
Cumulative Demand vs Airfare

Airfare-Demand Curve

# Passengers

\[ Q_{\text{Low}} \]

\[ Q_{\text{High}} \]

Individual Airfare

P_{\text{Low}}

P_{\text{High}}

Willingness-to-Pay Curve

Cumulative # Passengers

Convert to Cumulative Willingness-to-Pay:

Start with P-Low to P-High, compute the Cumulative Pax Demand, and then compute the Weighted Average Airfare. Plot this point. Increase P-Low, and repeat. The result is an exponential function.

Weighted Average Airfare from \( P_{\text{High}} \) to \( P_{\text{Low}} \)

\[
\text{Cumulative # Passengers} = \sum (q_i) = M \ast \exp (\text{Coeff} \ast (\sum (pi \ast q_i) / \sum (q_i)) \)
\]
Cumulative Demand vs Airfare

Theoretical # Pax at Airfare = Zero

Cumulative Demand = M * exp(Airfare * Coeff)
Cumulative Demand = 1529 * exp (Avg Airfare * -0.007)

Shape of exponential curve ~ elasticity
- less negative = inelastic
- more negative = elastic
## Example Coefficients

<table>
<thead>
<tr>
<th>Market</th>
<th>Market Size Coefficient</th>
<th>Airfare Elasticity Coefficient</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>JFK - ATL</td>
<td>1529</td>
<td>-0.007</td>
<td>Medium volume, inelastic</td>
</tr>
<tr>
<td>JFK - MCO</td>
<td>7884</td>
<td>-0.011</td>
<td>High volume, very elastic</td>
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<tr>
<td>JFK - ORD</td>
<td>344</td>
<td>-0.004</td>
<td>Low volume, very Inelastic</td>
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</table>

Which Market Size, Airfare Elasticity preferred?
Cumulative Demand vs Airfare

JFK – ATL for different Airfare Sensitivity Coefficients

- **Passengers not scared-off by higher Airfares**
- **Passengers scared-off quickly by higher Airfares**

- **Example**
- **Large Markets - Inelastic**
- **Small Markets - more elastic**
Relationship between Demand and Airfare

Cumulative Demand = M * exp(Airfare*Coeff)

**Solve for Airfare**

Take natural log of both sides

\[ \ln(\text{Cumulative Demand}) = \ln(M) + \text{Airfare} \times \text{Coeff} \]

**Solve for Airfare**

\[ \text{Airfare} = \frac{(\ln(\text{Cumulative Demand}) - \ln(M))}{\text{Coeff}} \]
Maximizing Airline Revenue

What combination of Airfare and Cumulative Passenger Demand yields the greatest Revenue

Maximum Revenue

$32,088

$80,258

$56,170
Maximum Airline Revenue

Max Revenue:
2950 Pax, $196K Rev, $66.51 Airfare
Sensitivity to Airfare

Max Revenue:
2950 Pax, $196K Rev, $66.51 Airfare

- Asymmetric
- Spills more pax and revenue as airfare increases (to left of max Revenue)
Airline Costs

• Number of Flights = Pax Demand/Aircraft Size

• Costs to Satisfy Pax Demand = Cost per Flight (Aircraft Size) * Number of Flights

• Cost per Flight (Aircraft Size) =
  
  \[
  \{ \\
  \text{Average Block Hours} * \\
  \left(\text{Non-Fuel Direct Operating Costs per Hour}\right) + \\
  \left(\text{Hourly Fuel Burn Rate} * \text{Hedged Fuel Price}\right) \}
  \]
Non-Fuel Operating Costs by Seat Size

Marginal economies-of-scale
Fuel Burn Rate by Seat Size

No economies-of-scale by year of introduction
Gallileo’s Square-Cubed Law

\[ W_T (SL, Pax) = W_P + W_S + W_F \]

\[ W_T (SL, Pax+\Delta Pax) = W_P + W_{\Delta P} + W_F + W_{\Delta F+\Delta P} + W_{\Delta F+\Delta F} + W_S + W_{\Delta S+\Delta P+\Delta F} \]

Kroo, 1995
Total Cost per Seat-Hour is Sensitive to Fuel Price

Cost per Seat Hour = -0.3875Aircraft Seat Size + 21.145

Economies-of-scale at $1/gallon

No economies of scale at $4/gallon

Cost per Flight (Aircraft Size) = Average Block Hours *
(Non-Fuel Direct Operating Costs per Hour) +
(Hourly Fuel Burn Rate * Hedged Fuel Price)
Seats per Day = A/C Size * Frequency

<table>
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<tr>
<th>ze/Freq</th>
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Symmetry in Seats per Day
Daily Cost is $f(Freq, Aircraft Size)$

<table>
<thead>
<tr>
<th>AC Size (Seats)</th>
<th>Frequency</th>
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<tr>
<td>25</td>
<td>1  2  3  4  5</td>
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<td>25</td>
<td>2,493 4,986 7,478 9,971 12,464</td>
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<td>50</td>
<td>4,824 9,936 14,904 19,872 24,839</td>
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<td>75</td>
<td>7,425 14,851 22,276 29,702 37,127</td>
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<td>100</td>
<td>9,865 19,731 29,596 39,461 49,326</td>
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<tr>
<td>125</td>
<td>12,288 24,575 36,863 49,150 61,438</td>
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<tr>
<td>150</td>
<td>14,692 29,384 44,077 58,769 73,461</td>
</tr>
<tr>
<td>175</td>
<td>17,079 34,158 51,238 68,317 85,396</td>
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<tr>
<td>200</td>
<td>19,449 38,897 58,346 77,794 97,243</td>
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<tr>
<td>225</td>
<td>21,800 43,601 65,401 87,201 109,002</td>
</tr>
<tr>
<td>250</td>
<td>24,134 48,269 72,403 96,538 120,672</td>
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</table>

3 Block Hours, $3/gallon
Daily Cost is $f(Freq, Aircraft Size)$

$\text{Daily Cost is non-monotonic with Aircraft Size due to frequency of service required to transport total pax demand per day}$

$3/$gallon

3 Block Hours

Linear Functions $LF = 0.8$
Min Cost Increases with Pax Transported

Min Daily Cost = (12,225 * Pax per Day) + 93.906
R² = 0.9999

Min Daily Costs to Transport Passengers = 12,225 * Daily Pax + 93.906
R² = 0.9999

$3/gallon
3 Block Hours
Linear Functions
Daily Revenue and Airfare

![Graph showing daily revenue and average airfare per day. The x-axis represents total passengers per day, ranging from 100 to 2000, and the y-axis represents revenue and average airfare, ranging from $0 to $200,000. The graph includes two curves: one for revenue and one for average airfare. At 900 passengers per day, the revenue and average airfare intersect.](image-url)
Daily Revenue & Cost & Profit

MS = 2000
AS = -0.004
$3/gallon
3 Block Hours
LF = 0.8
Key “Operating” Points

- MS = 2000
- AS = -0.004
- $3/gallon
- 3 Block Hours
- LF = 0.8
What can be exploited to shift Max Profit point closer to Max Revenue point

MS = 2000
AS = -0.004
$3/gallon
3 Block Hours
LF = 0.8
Summary – Economics of Airline Operations

- **O/D Markets Served** determined by profitability of flights from that market
  - New O/D markets added only when exceed profitability threshold

- **Frequency of Service and Aircraft Size**
  - Economies-of-Density in Non-Fuel Direct Operating Costs
  - **No** economies of density in Fuel-burn Rate
  - **No** economies-of-density (for increasing aircraft size) when Fuel Price > $3/gallon
  - Symmetry in Cost of Seats per Day
    - Seats per Day can be achieved by Freq * Seat Size without cost penalty
    - High frequency with small aircraft costs the same as low frequency with bigger aircraft
  - Max Profit Operating Point transports fewer passengers at higher airfares than Max Revenue Operating Point