Why the APTS has Delays:
It’s the Economics, the Regulations, and the Technology (i.e. aircraft technology)

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CATSR/GMU
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

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

Slope = Price Elasticity
- $< -1$ elastic, do not fly as price goes up
- $>-1$ inelastic, do not care about price

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Airfare vs Demand Curve

IAD-DEN Demand vs. Price ($50 buckets)
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.

Cumulative # Passengers = \sum (q_i) = M \times \exp (\text{Coeff} \times (\sum (p_i q_i) / \sum (q_i)) )
Cumulative Demand vs Airfare

Theoretical # Pax at Airfare = Zero

Cumulative Demand = $M \times \exp(Price \times Coeff)$
Cumulative Demand = 1529 * exp (Avg Airfare * -0.007)

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

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# 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>
</tr>
<tr>
<td>JFK - ORD</td>
<td>344</td>
<td>-0.004</td>
<td>Low volume, very inelastic</td>
</tr>
</tbody>
</table>

Which Market Size, Airfare Elasticity would you rather have?
Cumulative Demand vs Airfare

- Passengers not scared-off by higher prices
- Passengers scared-off quickly by higher prices

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Relationship between Demand and Price

Demand = M \times \exp(\text{Price} \times \text{Coeff})

Solve for Price

Take natural log of both sides

\ln(\text{Demand}) = \ln(M) + \text{Price} \times \text{Coeff}

Solve for Price

\text{Price} = \frac{(\ln(\text{Demand}) - \ln(M))}{\text{Coeff}}
Maximizing Airline Revenue

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

$32,088
$80,258
$56,170
Maximum Airline Revenue

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

• Cost per Flight =
  Landing Fee +
  \{Average Block Hours *
    [Direct Operating Costs (not including fuel costs) +
     (Burn Rate * Fuel Price)] \} }

• Costs to Satisfy Demand = Cost per Flight *
  Number of Flights
# Differences in Aircraft Performance

<table>
<thead>
<tr>
<th>Aircraft Size</th>
<th>Fuel Burn Rate</th>
<th>Direct Operating Costs/Hour (not including fuel)</th>
<th>Landing Fees ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>201.87</td>
<td>639.53</td>
<td>111.90</td>
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<td>50</td>
<td>435.41</td>
<td>853.90</td>
<td>136.85</td>
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<td>75</td>
<td>457.86</td>
<td>778.96</td>
<td>217.63</td>
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<td>100</td>
<td>854.05</td>
<td>1153.85</td>
<td>330.25</td>
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<td>125</td>
<td>844.19</td>
<td>1073.76</td>
<td>355.91</td>
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<td>150</td>
<td>963.06</td>
<td>1150.46</td>
<td>367.08</td>
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<tr>
<td>175</td>
<td>1252.49</td>
<td>1276.66</td>
<td>686.17</td>
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<tr>
<td>200</td>
<td>1427.53</td>
<td>648.83</td>
<td>545.99</td>
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<tr>
<td>225</td>
<td>1723.43</td>
<td>1786.16</td>
<td>945.15</td>
</tr>
</tbody>
</table>
Airline Costs

Total Airline Costs are a function of (1) Airline Operating Costs per Block Hour and (2) Number of flights to Satisfy Demand. Note, the relationship between operating costs and aircraft size is NOT correlated.

Based on operating performance for each aircraft type, $2 gallon fuel. Why are 100 seats and 125 seats more expensive to operate?
Airline Decision-making

• Primary decision:
  – Profit = Revenue – Costs

• Secondary decision:
  – Market-share/Frequency-share S-Curve
    • When Frequency share is greater than 50%:
      – One unit increase in frequency, yields more than one unit increase in market share
      – One unit decrease in frequency, yields more than one unit decrease in market share
    • Leans towards increased frequency
Profit per Day Serving 3K Pax (i.e. pax for Max Revenue)

There are multiple profit points!

Profit = $48.3K

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Maximum Profit?

• Profit = Revenue – Cost

• Maximum Revenue does not always mean Maximum Profit
  – the cost of serving the passengers (associated with max revenue) may be excessive
Profit per Flight Hour Serving 3000 Pax
(i.e. Max Revenue)

Profit = $48.3K
Profit per Flight Hour Serving 2000 Pax
(i.e. < Max Revenue)
Profit per Flight Hour Serving 3400 Pax
(i.e. > Max Revenue)

No profit from volume sales!
Result of Airline(s) Decision

• Number of Flights to serve market
  – Time of day
  – Aircraft Size

• Cumulative Airline Schedule
  – Sum of all airlines flights
Cumulative Airline Schedule (e.g. Arrivals)

Time of Day (15 minute bins)

# of Flights

Capacity

<table>
<thead>
<tr>
<th>Airline</th>
<th>0-4</th>
<th>5-9</th>
<th>10-14</th>
<th>15-19</th>
<th>20-24</th>
<th>25-29</th>
<th>30-34</th>
<th>35-39</th>
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<tbody>
<tr>
<td>AAL 123</td>
<td>6</td>
<td>14</td>
<td>24</td>
<td>28</td>
<td>33</td>
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</tr>
<tr>
<td>USA078</td>
<td>8</td>
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<td>26</td>
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<tr>
<td>UAIL 456</td>
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<td>15</td>
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<td>29</td>
<td>34</td>
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<td></td>
<td>4</td>
<td>10</td>
<td>18</td>
<td>23</td>
<td>32</td>
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</tbody>
</table>
Over Scheduling Results in Flight Delays (and Cancellations)

<table>
<thead>
<tr>
<th>Time of Day (15 minute bins)</th>
<th># of Flights</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>15</td>
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<td>USA078</td>
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<td>UAIL 456</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>AAL 123</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

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Flight Delay Cost Model

Total Cost of Flight Delay = Gate + Taxi + Airborne

Cost of Flight Delay (phase of flight)=
\[(C_{\text{fuel}} \times \text{fuel burn rate} \times \text{fuel price}) + (C_{\text{crew}} \times \text{crew cost}) + (C_{\text{maintenance}} \times \text{maintenance cost}) + (C_{\text{other}} \times \text{other cost})\]

- Phase of flight (gate, taxi, airborne)
- \(C_n\) = coefficient derived from airline data

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Delay Cost Model

1. Gate Delay Costs
   – \( C_{\text{gate\_delay}} = c_{\text{crew}} \times \text{crew cost} + c_{\text{other}} \)
     • \( C_{\text{gate\_delay\_15}} = 0.03 \times \text{crew cost} + 0.21 \)
     • \( C_{\text{gate\_delay\_65}} = 0.46 \times \text{crew cost} + 0.21 \)

2. Taxi Delay Costs
   – \( C_{\text{taxi\_delay}} = (c_{\text{fuel}} \times \text{taxi burn rate} \times \text{fuel price}) + (c_{\text{crew}} \times \text{crew cost}) + c_{\text{other}} \)
     • \( C_{\text{taxi\_delay\_15}} = (1 \times \text{taxi burn rate} \times \text{fuel price}) + (0 \times \text{crew cost}) + 0.12 \)
     • \( C_{\text{taxi\_delay\_65}} = (1 \times \text{taxi burn rate} \times \text{fuel price}) + (0.43 \times \text{crew cost}) + 0.12 \)

3. Airborne Delay Costs
   – \( C_{\text{air\_delay}} = (c_{\text{fuel}} \times \text{taxi burn rate} \times \text{fuel price}) + (c_{\text{crew}} \times \text{crew cost}) + c_{\text{other}} \)
     • \( C_{\text{air\_delay\_15}} = (1 \times \text{burn rate} \times \text{fuel price}) + (0.01 \times \text{crew cost}) + 0.10 \)
     • \( C_{\text{air\_delay\_65}} = (1 \times \text{burn rate} \times \text{fuel price}) + (0.46 \times \text{crew cost}) + 0.10 \)
Effect of Over-Scheduling on Profit

JFK-ATL
- Average 4.5 flights per day
- Average 656 passengers per day
- $137 Average Fare
- $89.9K of Revenue per day
- $49.6K of Operational Cost per day

- Profit ~$89.9K-$49.6K = $40.3K per day

Profit Margin = Profit/Revenue = 44.8%

JFK-ATL with Delays

Average Daily Gate Delay costs = $11.2K
Average Daily Taxi out Delay costs = $19.2K
Average Daily Airborne Delay costs = $9.4K

Profit = $40.3K - $11.2K - $19.2K - $9.4K = $0.7K

Adjusted Profit Margin = .8%
Welcome to the “APTS Game”
## Airline Passenger Transportation System Game (Round 1)

<table>
<thead>
<tr>
<th>Airline</th>
<th>1 (Transcontinental)</th>
<th>2 (Regional)</th>
<th>3 (Feeder Hub)</th>
<th>4 (Transcontinental)</th>
<th>5 (Mid-range, mix pax)</th>
<th>6 (Transcontinental - Leisure)</th>
<th>7 (Fortress Hub)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Factor</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Hedged Fuel Price ($/gallon)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Block Hours</td>
<td>5.5</td>
<td>1.5</td>
<td>1.5</td>
<td>5.5</td>
<td>4.5</td>
<td>6</td>
<td>5</td>
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<tr>
<td>Elasticity Coefficient</td>
<td>-0.004</td>
<td>-0.011</td>
<td>-0.011</td>
<td>-0.004</td>
<td>-0.007</td>
<td>-0.0099</td>
<td>-0.004</td>
</tr>
<tr>
<td>Market Size Coefficient</td>
<td>3000</td>
<td>7884</td>
<td>7884</td>
<td>3000</td>
<td>5000</td>
<td>3500</td>
<td>3500</td>
</tr>
</tbody>
</table>

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Submit Form for Next Round

1. Come up with Airline name
2. Create spreadsheet tailored for your airline (Load Factors, Block Hours, Fuel Price, Market Size Coefficient, Airfare Elasticity Coefficient)
3. Generate Schedule for next round (Aircraft size, Flights per day)
4. Email to lsherry@gmu.edu with Subject “PEVS 0541 – APTS Game Round #X”

Be prepared for shifts in travel demand, changes in fuel prices, change in route structure (block hours), and miscellaneous unanticipated events!

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Aircraft Size</td>
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<tr>
<td>Load Factor</td>
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</tr>
<tr>
<td>Flights per Day</td>
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</tr>
<tr>
<td>Total Pax per Day</td>
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</tr>
<tr>
<td>Revenue per Day</td>
<td></td>
</tr>
<tr>
<td>Airfare</td>
<td></td>
</tr>
<tr>
<td>Block Hours</td>
<td></td>
</tr>
<tr>
<td>Fuel Price</td>
<td></td>
</tr>
<tr>
<td>Market Size Coefficient</td>
<td></td>
</tr>
<tr>
<td>Airfare Elasticity Coefficient</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Profit</td>
<td></td>
</tr>
<tr>
<td>Explanation (Why did you make this decision)</td>
<td></td>
</tr>
</tbody>
</table>

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Final Thoughts

1. Economic growth and demographics continue to drive pax travel demand

2. To meet pax demand, APTS (in current industry equilibrium) schedules flights in excess of airports capacity

If there is no change in the legal structure of the APTS then NextGen must fix ...

1. Capacity Coverage problem
   - Runway Configuration Problem
     • Crosswinds, noise abatement

2. Reduced Separation between departing flights/arriving flights
   - No safety method to allow “certification”
NextGen? If there is no change in the equilibrium point of the APTS industry (e.g. legal structure), then modernization (e.g. NextGen) must fix ...

**CAPACITY**

1. Capacity Coverage problem
   - Runway Configuration Problem
     - Crosswinds, noise abatement

2. Reduced Separation between departing flights/arriving flights
   - No safety method to allow “certification”

**DEMAND**

1. Passenger Willingness-to-Pay determines demand
   - Shape demand through economic policy

2. APTS network design
   - Design flaw
     - No seat reservoir for disruptions
     - High Load Factors and Poor On-time Performance = Perfect Storm

3. Aircraft Technologies
   - more operationally efficient aircraft (100 seaters)