Assessing the Role of Operating, Passenger, and Infrastructure Costs in Fleet Planning under Fuel Price Uncertainty

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New considerations in planning air transportation services

• Organizations involved with aviation system planning are facing a mix of challenges and opportunities

• Challenges
  – Fuel price uncertainty
  – Future Air Traffic Management (ATM) charging mechanisms uncertainty

• Opportunities: The introduction of new and redesigned aircraft
Fuel price uncertainty

Fuel Price
Energy Information Agency (2009)
New considerations in planning air transportation services

• Organizations involved with aviation system planning are facing a mix of challenges and opportunities

• Challenges
  – Fuel price uncertainty
  – Future Air Traffic Management (ATM) charging mechanisms uncertainty

• Opportunities: The introduction of new and redesigned aircraft
ATM Charges
Robyn (2008)
Marchi (2007)
Odoni and de Neufville (2003)

• Evaluate the merits of collecting ATM fees as a percentage tax of each ticket sold and a fee based on aircraft weight
• The structure of fees which both capture revenue and use congested airports more efficiently are discussed
• Review airports that have implemented alternative ATM charges, such as flat landing fees or minimum landing fees
Research objective, method, and previous work

• Objective: Determine how short haul fleet mixes might be configured in response to changing fuel costs and ATM charging mechanisms

• Method: Evaluate the minimum cost fleet composition to serve a single origin-destination pair under varying travel distance and fuel price combinations

Cost Modeling
Douglas and Miller (1974)
Oster and McKey (1994)
Levinson et al (1996)

• Parametrically evaluate aircraft operating cost over varying distances
• Compare interregional vehicle operating costs, passenger costs, and environmental costs over a corridor
Presentation roadmap

- Research background and motivation
- Research objective
- Literature review
- Research approach
- Cost comparison for specific aircraft
- Conclusions
# Aircraft details

<table>
<thead>
<tr>
<th>Details of Representative Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft Category</td>
</tr>
<tr>
<td>Aircraft Model</td>
</tr>
<tr>
<td>Manufacturer</td>
</tr>
<tr>
<td>Number of Seats</td>
</tr>
<tr>
<td>Runway Length Requirement</td>
</tr>
<tr>
<td>Maximum Takeoff Weight (lb)</td>
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</table>
Cost calculation for specific aircraft

• Consider three key cost groups for each aircraft
  – Operating cost
    • Fuel consumption relationship
    • Crew, maintenance averages
  – Passenger cost
    • Travel time relationship
    • Disutility of flying on turboprops
    • Schedule delay
  – Air Traffic Management charges
• Compare fleets of homogeneous aircraft types and evaluate if differences arise in minimum cost fleet due to fuel price and distance
  – Operating costs alone
  – Operating and passenger costs
  – Operating and passenger costs with varying ATM fees
Cost calculation for specific aircraft

• Consider three key cost groups for each aircraft
  – Operating cost
    • Fuel consumption relationship
    • Crew, maintenance averages
  – Passenger cost
    • Travel time relationship
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      • Schedule delay
  – Air Traffic Management charges

• Compare fleets of homogeneous aircraft types and evaluate if differences arise in minimum cost fleet due to fuel price and distance
  – Operating costs alone
  – Operating and passenger costs
  – Operating and passenger costs with varying ATM fees
Fuel consumption and flying time per passenger

\[ FC \text{ or } FT = \alpha + \beta \times SL \]

<table>
<thead>
<tr>
<th>Aircraft Model</th>
<th>Aircraft Category</th>
<th>Alpha</th>
<th>Beta</th>
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<tr>
<td>Turboprop</td>
<td>Turboprop</td>
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Fuel Consumption per Passenger

<table>
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<tr>
<th>Aircraft Model</th>
<th>Block Time per Passenger</th>
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<td>Narrow Body</td>
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<tr>
<td>Regional Jet</td>
<td>1</td>
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<tr>
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<td>3</td>
</tr>
</tbody>
</table>

Relate fuel and travel time to stage length (up to 1000 miles)
Example presentation of results

Percent difference in cost contour plot

- Red line represents equal cost per passenger
- Below the red line represents the fuel price-stage length region where a turboprop has a lower cost per passenger
- Above the red line represents the fuel price-stage length region where the “incumbent aircraft” has a lower cost per passenger
Presentation roadmap

- Research background and motivation
- Research objective
- Literature review
- Research approach
- Cost comparison for specific aircraft
  - Operating Cost Alone
  - Operating and Passenger Cost
  - Operating, Passenger, and ATM Cost
- Conclusions
First comparison: operating cost alone

- Regional jet and turboprop
- Narrow body and turboprop
Operating cost per passenger
Regional jet and turboprop

Distance vs. Fuel Price Comparing Regional jet (RJ) and Turboprop (PR) Operating Cost per Passenger

RJ Total Cost is 50% higher than PR
Operating cost per passenger
Narrow body and turboprop

Distance vs. Fuel Price Comparing Narrow Body (NB) and Turboprop (PR) Operating Cost per Passenger

- NB Total Cost is 10% higher than PR
- NB Total Cost is equal to PR
- NB Total Cost is 10% lower than PR

Stage Length (miles)
Fuel Price ($/Gallon)
Operating cost per passenger
Narrow body and turboprop

Distance vs. Fuel Price Comparing Narrow Body (NB) and Turboprop (PR) Operating Cost per Passenger

- NB Total Cost is 10% higher than PR
- NB Total Cost is equal to PR
- NB Total Cost is 10% lower than PR

Stage Length (miles) vs. Fuel Price ($/Gallon)

- November 2008 fuel price
- July 2008 fuel price
Second comparison: operating cost and passenger costs (without schedule delay) combined

- Regional jet and turboprops
- Narrow body and turboprops
Passenger preference cost

- Passenger disutility for flying turboprops (compared with jets)
- Passenger value of time cost for flying time

<table>
<thead>
<tr>
<th>Passenger Segment</th>
<th>Percent of Passengers</th>
<th>Disutility for Turboprops ($/Flight)</th>
<th>Cost of Flying Time ($/hour)</th>
<th>Cost of Schedule Delay ($/hour)</th>
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<tbody>
<tr>
<td>Business</td>
<td>43%</td>
<td>40.0</td>
<td>69.7</td>
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<tr>
<td>Non-Business</td>
<td>57%</td>
<td>21.0</td>
<td>31.2</td>
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</table>

Source: Adler et al., 2005

- The passenger costs are added to the operating cost
Operating and passenger cost per passenger
Regional jet and turboprop

Distance vs. Fuel Price Comparing Regional Jet (RJ) and Turboprop (PR)
Operating and Passenger Cost per Passenger

- RJ Total Cost is 20% higher than PR
- RJ Total Cost is equal to PR
- RJ Total Cost is 20% lower than PR
Operating and passenger cost per passenger
Regional jet and turboprop

Distance vs. Fuel Price Comparing Regional Jet (RJ) and Turboprop (PR)
Operating and Passenger Cost per Passenger

- RJ Total Cost is 20% higher than PR
- RJ Total Cost is equal to PR
- RJ Total Cost is 20% lower than PR

Fuel Price ($/Gallon)
Stage Length (miles)
November 2008 fuel price
July 2008 fuel price

- 0%
- 20%
Operating and passenger cost per passenger
Narrow body and turboprop

Distance vs. Fuel Price Comparing Narrow Body (NB) and Turboprop (PR)
Operating and Passenger Cost per Passenger

- NB Total Cost is 10% higher than PR
- NB Total Cost is equal to PR
- NB Total Cost is 10% lower than PR
Third comparison: operating cost and passenger costs (with schedule delay) combined

- Regional jet and turboprops
- Narrow body and turboprops
Operating and passenger cost per passenger including schedule delay
Regional jet and turboprop

- The regional jet has a smaller seat capacity, its use necessitates more frequency service than the turboprop
- As market density increases the region where the turboprop offers a lower cost per passenger increases because discrepancy in frequency delay is decreased

Distance vs. Fuel Price Comparing Regional Jet (RJ) and Turboprop (PR)
Operating and Passenger Cost per Passenger
Operating and passenger cost per passenger including schedule delay
Narrow body and turboprop

- The narrow body has almost twice the seats of a turboprop, it serves the same market density with less frequent service
- As market density increases, the cost impact of frequency delay decreases and the region where a turboprop offers a lower cost per passenger shrinks and tends toward higher fuel prices

Distance vs. Fuel Price Comparing Narrow Body and Turboprop
Operating and Passenger Cost per Passenger
Fourth comparison: operating cost, passenger costs (with schedule delay), and ATM charges (fixed and variable)

- Regional jet and turboprops
- Narrow body and turboprops
## Air Traffic Management costs

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<thead>
<tr>
<th>En route air traffic navigation charges</th>
<th>Terminal airspace air traffic navigation charges</th>
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<tbody>
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<td>Variable Ticket Tax (Current)</td>
<td>Variable Landing Fee (Current)</td>
</tr>
<tr>
<td>Fixed Ticket Tax (Future)</td>
<td>Flat Landing Fee (Future)</td>
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<td>Flat Landing Fee (Future)</td>
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<td></td>
<td>Based on vehicle size and vehicle weight</td>
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<tr>
<td>Fixed Ticket Tax (Future)</td>
<td>Flat Landing Fee (Future)</td>
</tr>
<tr>
<td></td>
<td>Based on narrow body size and narrow body weight</td>
</tr>
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</table>
Total cost per passenger with ATM Charges

Regional jet and turboprop

Distance vs. Fuel Price Comparing Regional Jet and Turboprop
Equal Operating, Passenger, and ATM Cost per Passenger Curves

Market Density of 125 passengers/day

Market Density of 2000 passengers/day
Total cost per passenger with ATM Charges

Regional jet and turboprop

• Both infrastructure charging schemes increase the fuel price – stage length space where the turboprop offers a lower cost per passenger
• Variable: Turboprop gains an advantage due to similar landing fees
• Fixed: Turboprop has the largest lowest cost region due to a greater capacity
• High market densities diminish the importance of schedule delay

Distance vs. Fuel Price Comparing Regional Jet and Turboprop
Equal Operating, Passenger, and ATM Cost per Passenger Curves

Market Density of 125 passengers/day

Market Density of 2000 passengers/day
Total cost per passenger with ATM Charges

Narrow body and turboprop

- Variable: Turboprop gains an advantage due to smaller landing fees
- Fixed: Narrow body has an advantage due to greater capacity
- High market densities diminish the importance of schedule delay

Distance vs. Fuel Price Comparing Narrow body and Turboprop
Equal Operating, Passenger, and ATM Cost per Passenger Curves

Market Density of 125 passengers/day

Market Density of 2000 passengers/day
Conclusions: Fuel price
Regional jets and turboprops

• At summer 2008 record level fuel prices, regional jets have a *higher* operating cost and operating and passenger cost per passenger for all stage lengths compared with turboprops

• In contrast, at fuel prices seen in late 2008, there are many routes for which the regional jet has a lower cost per passenger

• For certain stage lengths, it is only a spike in fuel price that makes the turboprop a more attractive option over regional jets

• At fuel prices below $3.00/gallon, airlines are encouraged to adopt less fuel efficient aircraft (regional jets) in order to keep passenger costs low
Conclusions: Fuel price
Narrow body jets and turboprops

• At summer 2008 record level fuel prices, narrow body jets have a *higher* operating cost per passenger for all stage lengths compared with turboprops

• When passenger preference cost is considered, the narrow body jet has a lower cost per passenger over almost all fuel price-stage length combinations

• If operating cost is the principle concern, the turboprop will minimize cost
Conclusions: ATM charges

• Fixed ATM charges would favor larger jets as well as a move toward turboprops

• Variable ATM charges would encourage smaller aircraft, especially in the absence of a fuel price increase, because smaller jets would continue to have an advantage under variable charging schemes
Final conclusions

• The fleet selection decision is sensitive to fuel price, passenger costs, market density, and ATM charging

• Results of this study indicate that the following rationalize the adoption of fuel efficient aircraft, despite higher passenger cost
  – High fuel prices
  – Fixed ATM charges

• Implications for greenhouse gas emissions and other environmental policy
Thank you for your interest and attention.

“Nothing re-ignites interest in new turboprops faster than a good old-fashioned ‘fuel crisis.’” Aviation international News

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• Backup Slides
## Aircraft Differences

<table>
<thead>
<tr>
<th>Aircraft Model</th>
<th>(\gamma_j) (Standard Error)</th>
<th>(\delta_j) (Standard Error)</th>
<th>Adjusted R-Square</th>
<th>Observations</th>
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<tbody>
<tr>
<td><strong>Fuel Consumption</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrow Body</td>
<td>265.29 (20.67)</td>
<td>2.11 (0.022)</td>
<td>0.99934</td>
<td>7</td>
</tr>
<tr>
<td>Regional Jet</td>
<td>188.62 (7.56)</td>
<td>1.91 (0.010)</td>
<td>0.99985</td>
<td>6</td>
</tr>
<tr>
<td>Turboprop</td>
<td>44.66 (0.19)</td>
<td>0.646 (0.00015)</td>
<td>0.99999</td>
<td>7</td>
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<tr>
<td><strong>Block Time</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrow Body</td>
<td>0.6657 (0.071)</td>
<td>0.001989 (6.79E-05)</td>
<td>0.972796</td>
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<tr>
<td>Regional Jet</td>
<td>0.7429 (0.069)</td>
<td>0.001883 (0.00013)</td>
<td>0.941697</td>
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<tr>
<td>Turboprop</td>
<td>0.3090 (0.00207)</td>
<td>0.004895 (2.2E-06)</td>
<td>0.999999</td>
<td>7</td>
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</table>

<table>
<thead>
<tr>
<th>Aircraft Model</th>
<th>Fuel Consumption per Passenger</th>
<th>Block Time per Passenger</th>
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<tbody>
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<td>Alpha</td>
<td>Beta</td>
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<tr>
<td>Narrow Body</td>
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<td>Regional Jet</td>
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<tr>
<td>Turboprop</td>
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# Aircraft Operating Cost

<table>
<thead>
<tr>
<th>Aircraft Model</th>
<th>Fuel Price (FP) Coefficient</th>
<th>SL*FP Coefficient</th>
<th>Stage Length (SL) Coefficient</th>
<th>Constant</th>
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</thead>
<tbody>
<tr>
<td><strong>Per Operation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrow Body</td>
<td>2.7*10²</td>
<td>2.1</td>
<td>2.6</td>
<td>8.8*10²</td>
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<tr>
<td>Regional Jet</td>
<td>1.9*10²</td>
<td>1.9</td>
<td>1.2</td>
<td>4.8*10²</td>
</tr>
<tr>
<td>Turboprop</td>
<td>4.5*10¹</td>
<td>6.5*10⁻¹</td>
<td>3.8</td>
<td>2.4*10²</td>
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<tr>
<td><strong>Per Passenger</strong></td>
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</tr>
<tr>
<td>Narrow Body</td>
<td>2.5</td>
<td>2.0*10⁻²</td>
<td>2.5*10⁻²</td>
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<td>5.6</td>
<td>5.7*10⁻²</td>
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<td>1.2*10⁻²</td>
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## Operating and passenger cost

<table>
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<tr>
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<td>1.9</td>
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<td>1.7*10^3</td>
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<tr>
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<td>6.5*10^-1</td>
<td>1.7*10^1</td>
<td>2.6*10^3</td>
</tr>
<tr>
<td><strong>Per Passenger</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Narrow Body</td>
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Operating, passenger, and variable ATM cost

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<th>Aircraft Model</th>
<th>Aircraft Category</th>
<th>FP Coeff.</th>
<th>SL*FP Coeff.</th>
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<td></td>
<td>Per Passenger</td>
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<tr>
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## Operating, passenger, and fixed ATM cost

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