Aircraft Cost Index and Carbon Emissions Reductions

Holly Edwards
PhD Researcher in Low Carbon Aviation
pmhae@leeds.ac.uk
Aviation responsible for around 2-3% of global greenhouse gas emissions

This proportion set to rise as carbon reduction solutions cannot keep up with demand growth

Likely scenario annual average growth rate:
• average growth rate 2010 to 2030 – 4.9% per annum
• 2030 to 2050 - 4% per annum

56,000 new aircraft required by 2040 (65% for growth)
Cost Index

\[ CI = \frac{\text{Time Cost} (\$/\text{min})}{\text{Fuel Cost} (\$/\text{kg})} \]

- CI value determines the speed of the aircraft
- The higher the CI the higher the speed. This leads to higher fuel use and carbon emissions.
- Time costs are the most complicated to calculate and include
  - Flight and cabin crew costs
  - Maintenance costs
  - Depreciation costs
  - Delay costs
Emissions Savings:

B767-300ER – 3.4%
B777-300ER – 3.4%
B787-8 – 4.5%
A300-600R – 1.1%
A340-600 – 12.3%
A380-800 – 6.9%
Future Impacts

Impacts can be divided into three main areas:

• Technology
• Policy
• Environment
Technology

Aircraft and Airframe
- Thermodynamic propulsion efficiency
- Propulsion efficiency
- Drag
- Structural weight
- Radical designs

Operational Technology
- ADS-B
- Datalink
- Other ground systems

Maintenance – design of aircraft
Expected Improvements in fuel efficiency: aircraft technology

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Single Aisle</th>
<th></th>
<th>Twin Aisle</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020</td>
<td>2030</td>
<td>2020</td>
<td>2030</td>
</tr>
<tr>
<td>TS1: Continuation</td>
<td>23%</td>
<td>29%</td>
<td>19%</td>
<td>26%</td>
</tr>
<tr>
<td>TS2: Increased Pressure</td>
<td>29%</td>
<td>34%</td>
<td>25%</td>
<td>35%</td>
</tr>
<tr>
<td>TS3: Further Increased Pressure</td>
<td>41%</td>
<td></td>
<td>41%</td>
<td></td>
</tr>
<tr>
<td>TS3 with open rotor</td>
<td>48%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Relative to year 2000 technology baseline
Expected Improvements in fuel efficiency: Operations

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>3.25%</td>
<td>6.75%</td>
<td>9.00%</td>
</tr>
<tr>
<td>Lower Confidence Interval</td>
<td>2.25%</td>
<td>4.50%</td>
<td>5.75%</td>
</tr>
</tbody>
</table>

Relative to 2010 levels
Technology

Biofuels

- Started to gain attention in late 2000s with high profile test flights
- Need to be at least second generation biofuels
- Still environmental and social issues attached to production of biofuels

Possible drop in fuel proportions:
- 2020 – 15%
- 2030 – 30%
- 2050 – 50%
Policy

- Operations
  - Airspace charging and restricted airspace

- Emissions Trading
  - Global agreement – carbon pricing

- Regulation on crew work times

- Airport Construction

<table>
<thead>
<tr>
<th>Zone</th>
<th>Unit Rate (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portugal</td>
<td>10.60</td>
</tr>
<tr>
<td>Belg.- Luxembourg</td>
<td>72.19</td>
</tr>
<tr>
<td>Germany</td>
<td>77.47</td>
</tr>
<tr>
<td>Finland</td>
<td>52.21</td>
</tr>
<tr>
<td>Netherlands</td>
<td>66.62</td>
</tr>
<tr>
<td>Ireland</td>
<td>30.77</td>
</tr>
<tr>
<td>Denmark</td>
<td>71.53</td>
</tr>
<tr>
<td>Norway</td>
<td>52.66</td>
</tr>
<tr>
<td>Poland</td>
<td>35.36</td>
</tr>
<tr>
<td>Malta</td>
<td>27.76</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>89.26</td>
</tr>
<tr>
<td>Switzerland</td>
<td>100.72</td>
</tr>
<tr>
<td>Austria</td>
<td>73.54</td>
</tr>
</tbody>
</table>
Climate Change Impacts on Aviation

<table>
<thead>
<tr>
<th>Climate Impact</th>
<th>Aviation Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Increase</td>
<td>Changes in demand; changes in climb performance; redistribution on noise impact; heat damage to tarmac surfaces.</td>
</tr>
<tr>
<td>Changes in Precipitation</td>
<td>Operational impacts: loss of capacity and efficiency; increased delay; increased de-icing requirements; structural issues due to changes in ground frost depth and duration.</td>
</tr>
<tr>
<td>Increase in intensity and frequency of convective weather</td>
<td>Operational impacts: loss of capacity and efficiency, increased delay.</td>
</tr>
<tr>
<td>Changes in wind patterns</td>
<td>Increased crosswinds and loss of runway capacity; redistribution of noise impact due to procedural change</td>
</tr>
<tr>
<td>Sea Level Rise</td>
<td>Loss of network capacity; increased delays, network disruption; temporary or permanent airport closure</td>
</tr>
</tbody>
</table>
Environment

Jet Fuel

- In general there is an expectation that oil prices will rise
- Have to be careful that CI represents the price at origin airport
- To convert crude oil price to jet fuel price a 25% crack spread is used
Calculating CI and Costs

- Piano-X used to model flights for B767-300ER
- Mach numbers from MRC (CI=0) and the maximum
- Fuel burn and flight time used to calculate CI for each Mach number
- Costs allocated for each CI – time costs from University of Westminster, fuel and carbon costs from DECC.
Impact on CO$_2$ Emissions

The graph illustrates the impact on CO$_2$ emissions across different scenarios and years. Various lines represent different conditions and scenarios, with colors and line styles indicating different data sets. The x-axis represents the cost index, while the y-axis shows CO$_2$ emissions in kg. The legend on the right side indicates the meaning of each line style and color.
Global Impact

AC $/RA: Airspace charging/restricted airspace

Severe Extreme Weather

Sea Level Rise

Polar Jet Stream

Subtropical Jet Stream

Busy/Congested/Airports
Conclusions

• Cost Index can provide a tool for assessing future impacts on aviation on a flight by flight basis

• Cost Index is also a tool for reducing emissions in itself

• Three main areas which will have an effect – policy and environment are still very uncertain.

• Questions over the impact of implementing a carbon price.

• Need policy that:
  A. Addresses both direct and indirect impacts on Cost Index
  B. Provides real incentives and solutions to reducing emissions

• Whole aviation system needs to be considered.