Aviation Integrated Modelling (AIM) Project

ANCAT MITG/12
The Hague, 19 May 2009
Background

• Goal: Develop integrated assessment tool for aviation, environment & economic interactions at local & global levels, now and into the future
  - Assess policies to strike appropriate balances between economic benefits and environmental impact mitigation
  - Independent & transparent tool for mediating between stakeholders

• Duration: 3-year “Phase 1” initiated in October 2006

• Funding from:
  EPSRC
  Engineering and Physical Sciences Research Council
  NATURAL ENVIRONMENT RESEARCH COUNCIL
AIM Policy Assessment

- Aircraft Movement
  - Sample policy: ATC evolution
  - Sample policy: Regulation
  - Sample policy: Economic instruments

- Airport Activity
  - Aircraft Technology & Cost
  - Air Transport Demand

- Global Environment Impacts
  - Global Climate
  - Air Quality & Noise

- Local Environment Impacts
  - Regional Economics

- Local/National Economic Impacts
AIM Detailed Architecture

Version: 14 September 2007
AIM Architecture Benefits

• Integration
  - Captures interdependencies, data transfer & feedback
  - Examination of trade-offs (e.g. local environment vs. global environment vs. economic impacts)

• Modularity
  - Resolution of modules tailored to application
  - Subset of modules run independently
  - Substitution of models from other groups

• Extendability
  - Natural expansion in sophistication or number of modules

• Policy assessment potential
AIM Team

Core team:
- Dr. Andreas Schäfer (Principal Investigator)
- Steven Barrett (Air Quality & Noise)
- Dr. Lynnette Dray (Air Transport Demand)
- Antony Evans (Airport Activity)
- Dr. Helen Rogers (Global Climate)
- Dr. Maria Vera Morales (Aircraft Technology and Cost)

IAE co-investigators:
- Prof. Bill Dawes (Engineering)
- Dr. Chez Hall (Engineering)
- Prof. Peter Haynes (DAMTP)
- Prof. Roderic Jones (Chemistry)
- Prof. John Pyle (Chemistry)

Affiliated researchers:
- Prof. Rex Britter (Air Quality, MIT)
- Dr. Marcus Köhler (Global Climate, King’s College London)
- Dr. Tom Reynolds (Air Traffic Control/Management, MIT/Lincoln Labs)
- Dr. Zia Wadud (Regional Economics, Bangladesh University of Engineering and Technology)
The First 3 Years…

- Output: Journal publications, Conference papers, PhD theses

- Collaborations
  - Omega projects (2 lead, 3 partner)
  - PARTNER (2 workshops)
  - MIT
  - IIT Bombay
  - FP7
  - UK Climate Change Committee

- Recent Research:
  - Omega Integration Study: Opportunities for Reducing Aviation-Related GHG Emissions – a Systems Analysis for Europe
  - PhD Research – Antony Evans: Modelling Airline Responses to Policy Measures and Constraints that may alter the Environmental Impact of Aviation
Omega Integration Study

• Omega Project 41, “Opportunities for Reducing Aviation-Related GHG Emissions – a Systems Analysis for Europe”

• Use modular AIM structure to interface with the results of other Omega projects

• Goals:
  - Investigate interaction between different technological, operational and economic CO₂ emission mitigation measures
  - Assess which measures would be most useful in achieving aviation CO₂ emission reductions
How might different policies/scenarios interact?

- Simulate by combining a range of Omega study results with a systems model for European Aviation:

  - Marginal Abatement Costs
  - Fleet Turnover
  - Climate-related ATM
  - Airspace Charging
  - Sustainable Fuels
  - EU ETS

Aviation Integrated Model (Cambridge)

Scenario inputs for future population, GDP, carbon/oil price (CCSP)
Omega Integration Study

Global Environment Impacts

Global Climate

Local Environment Impacts

Air Quality & Noise

Local/National Economic Impacts

Regional Economics

Aircraft Technology & Cost

Airport Activity

Air Transport Demand

SESAR

Winglets, Open Rotors, Engine upgrades, Aero/Engine maintenance

Airport capacity

EU ETS

Institute for Aviation and the Environment

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Future Scenarios (CCSP 2007):

**IGSM:** High GDP growth, high oil price

**MERGE:** medium GDP growth and oil price, higher carbon price

**MiniCAM:** low GDP growth, low oil price
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**IGSM:** High GDP growth, high oil price

**MERGE:** medium GDP growth and oil price, higher carbon price

**MiniCAM:** low GDP growth, low oil price
ETS-only vs. Reference (no ETS) case

- Without other mitigation measures, emissions reductions come mainly from lowered demand.
- Reference case demand requires ~doubling in capacity at LHR, CDG to 2050.
Uptake of abatement measures

- <190 Seats
- 190–300 Seats
- >300 Seats

MERGE with ETS and biofuels

- Total Fleet
- Engine Upgrade
- Winglet Retrofit
- Aero Maintenance
- Engine Maintenance
- Open Rotor
- SESAR
- Biofuel
ETS with abatement measures

- Now include abatement measures airlines can take to reduce emissions
  - Largest effects on emissions from SESAR, biofuels
  - Open rotors in high-cost scenarios only
  - Airlines can reduce fuel/carbon costs so RPKM decrease is smaller than ETS-only case
Conclusions of Study

- Complex interactions - uptake of one mitigation measure can lower future uptake of other measures
- Depending on the scenario and assumptions, reductions in airborne CO₂ over reference case seem possible by 2050
  - 8-15% (ETS only)
  - 20-30% (ETS+non-biofuel abatement measures)
- Strongest reduction in lifecycle aviation emissions (under assumptions used here) is ETS+biofuels
  - Lifecycle CO₂ emissions below 2005 levels in 2050
  - However, noise, local and airborne emissions will be little-changed from reference case
  - Cellulosic biomass fuel → land area problems?
How would likely airline responses to policy measures and constraints affect the environmental impact of aviation?
Objectives & Methodology

• **Objective**: Develop model of airline responses to changes in cost and demand caused by policy measures and constraints
  - Routing network changes (e.g. avoid congested hubs)
  - Changes in aircraft size
  - Changes in flight frequency

• **Methodology**: Select each airline’s routing network, flight frequencies, and aircraft to maximize individual profit
  - Simulate game between airlines to capture effects of competition endogenously
  - Model effects of policies and constraints on airline costs and demand endogenously
Sample Airline Response Modelling

Model 5 airlines in 14 cities / 22 airports / 9 hubs in the domestic US in 2005

<table>
<thead>
<tr>
<th>Flights per day</th>
<th>1</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>&gt;15</th>
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Actual Network Operated, 2005

Airline Game Theoretical Equilibrium Network

System Optimal Network

Tripling of 2005 fuel cost

<table>
<thead>
<tr>
<th>O-D Seats</th>
<th>O-D Flt Freq.</th>
<th>Segment Flt Freq.</th>
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<tbody>
<tr>
<td></td>
<td>% diff. System</td>
<td>R²</td>
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<tr>
<td>25% high</td>
<td>0.858</td>
<td></td>
</tr>
<tr>
<td>9% low</td>
<td>0.703</td>
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AIM 2

- Greater consideration of supply side effects
  - Aircraft fleet planning model
  - Global location of aircraft
  - More advanced marginal abatement modelling
- Integrate airline response modelling
- Further sophistication of aircraft performance modelling
- Contrails and regional non-CO$_2$ climate impacts
- Cruise related air pollutant emissions
- Further development of economic impacts modelling