

---

# Environmental Outlook

Aerospace 2009: Facing up to the future

21-23 April 2009

Royal Aeronautical Society, London

Andreas Schäfer

University of Cambridge

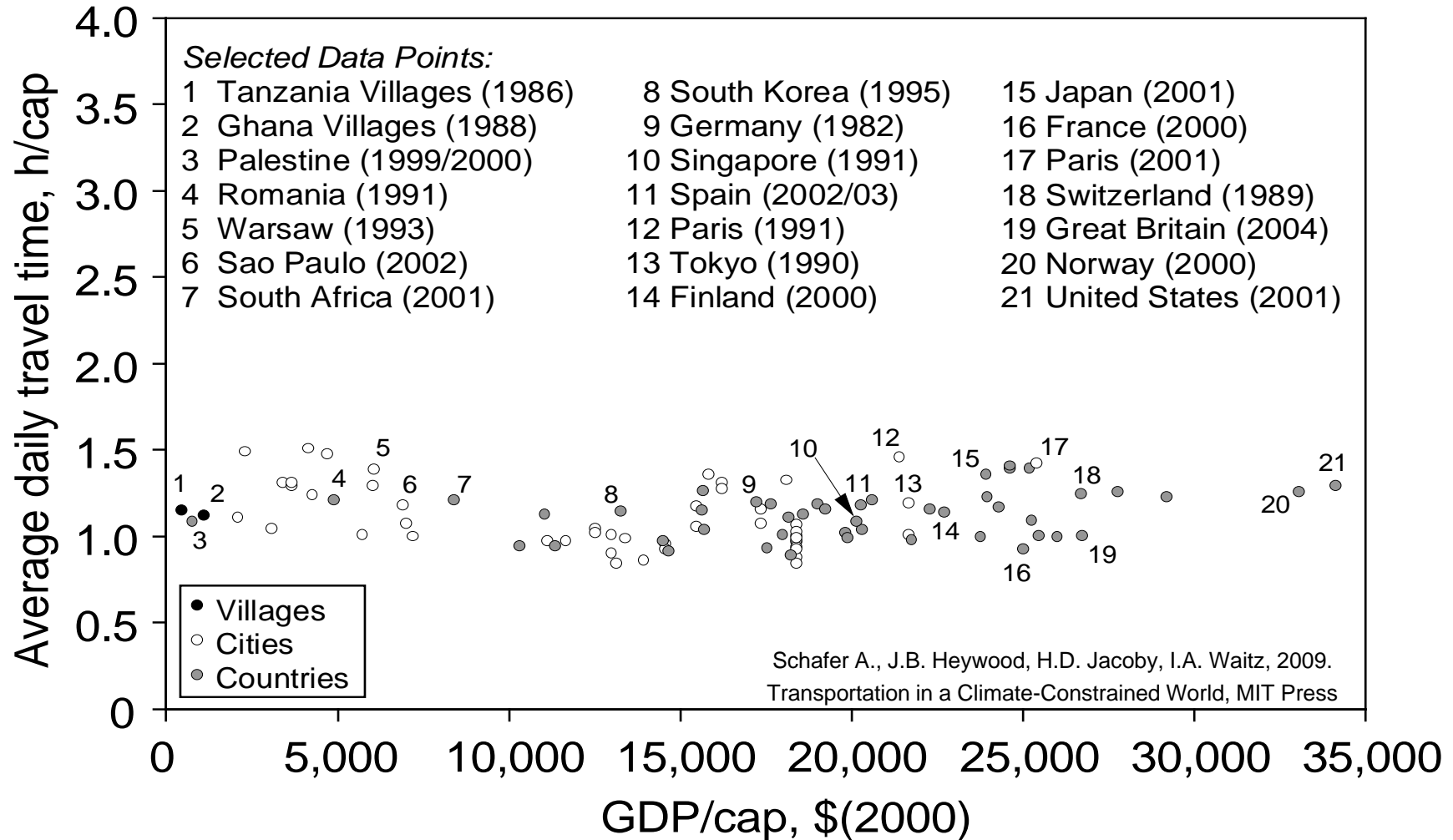
as601@cam.ac.uk

# Contents

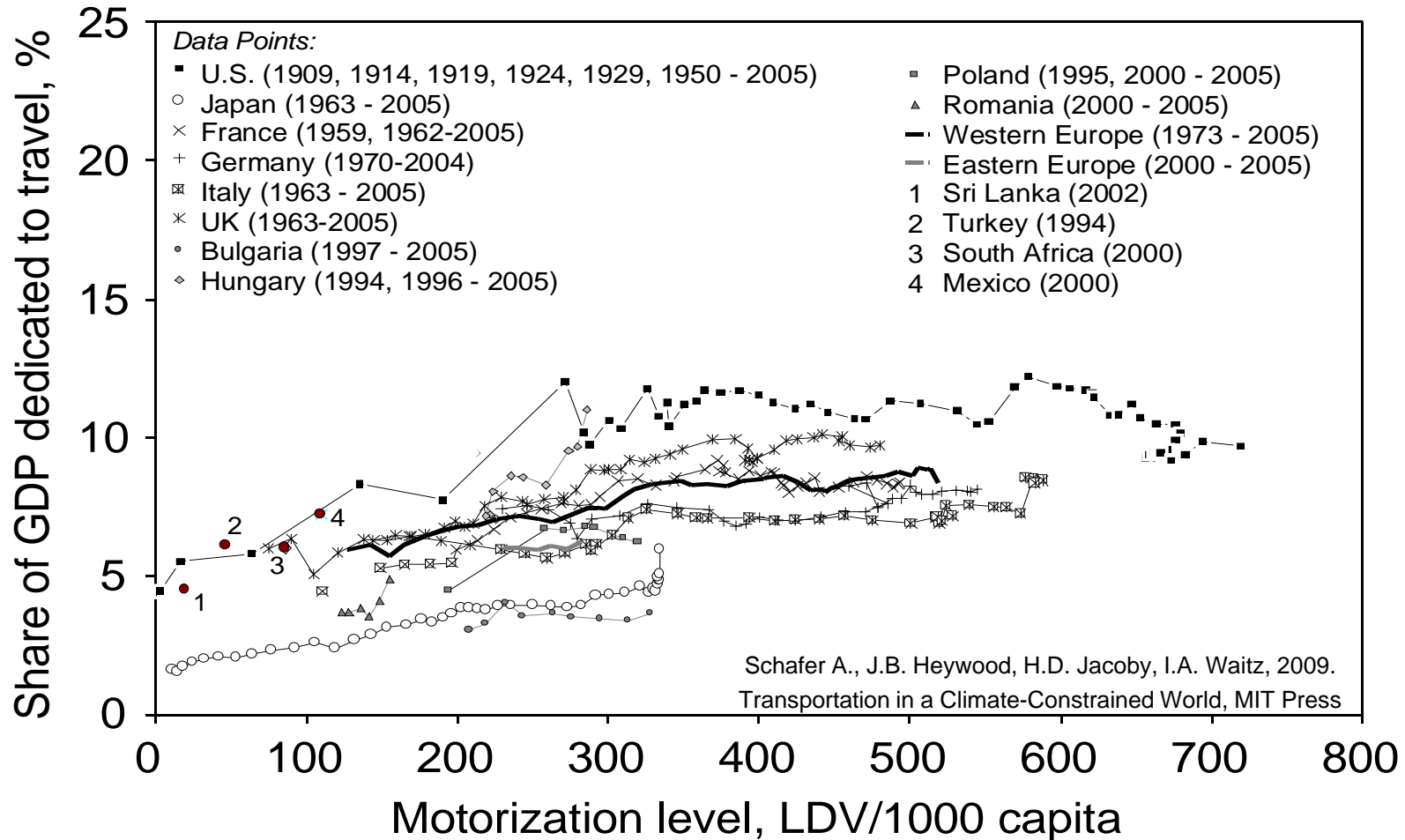
---

- ❑ Demand for passenger mobility
- ❑ A closer look at air travel
  - ❑ Omega “integration study”
  - ❑ Flight frequency study

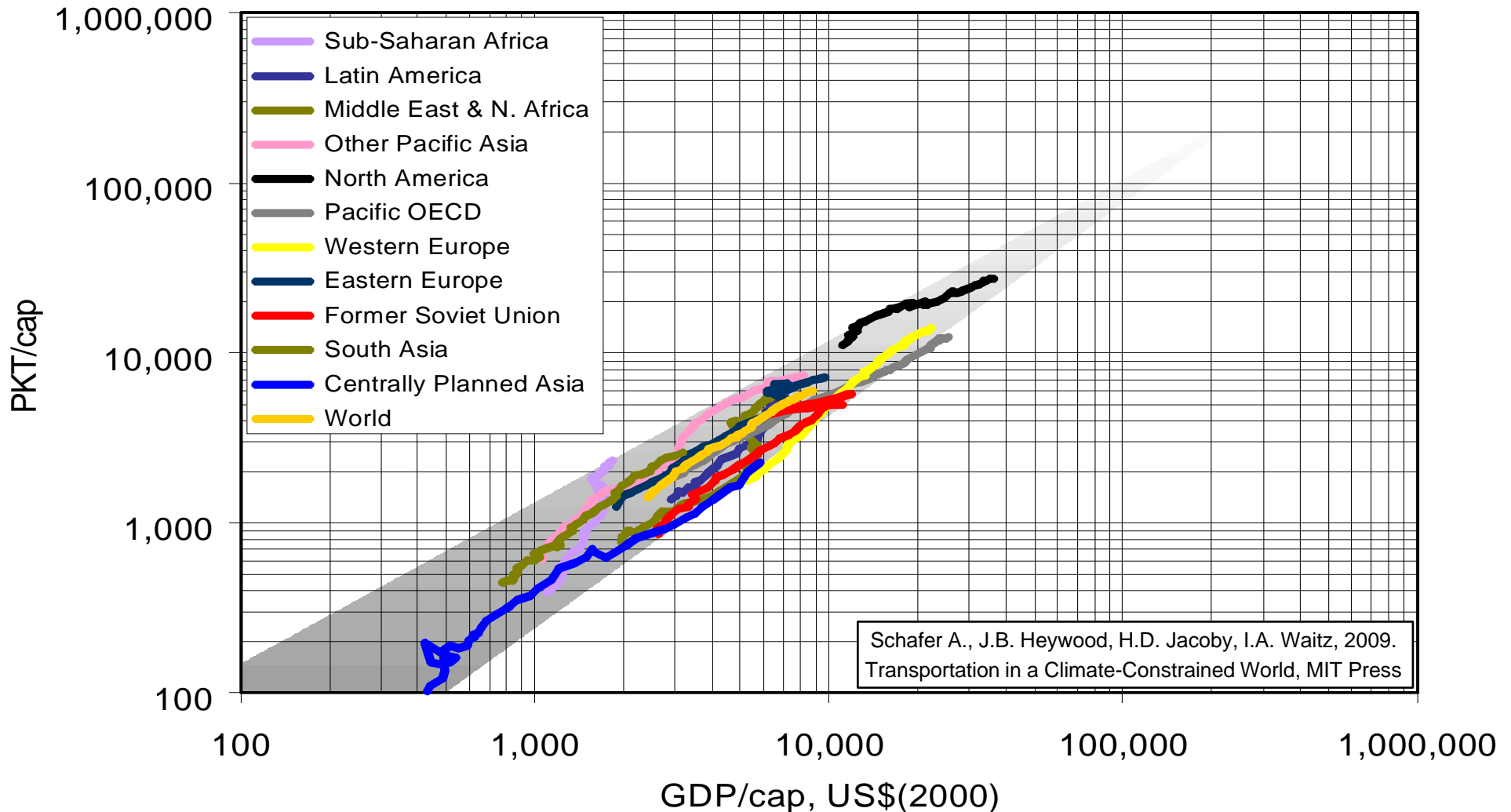
# Determinants of travel demand: TTB



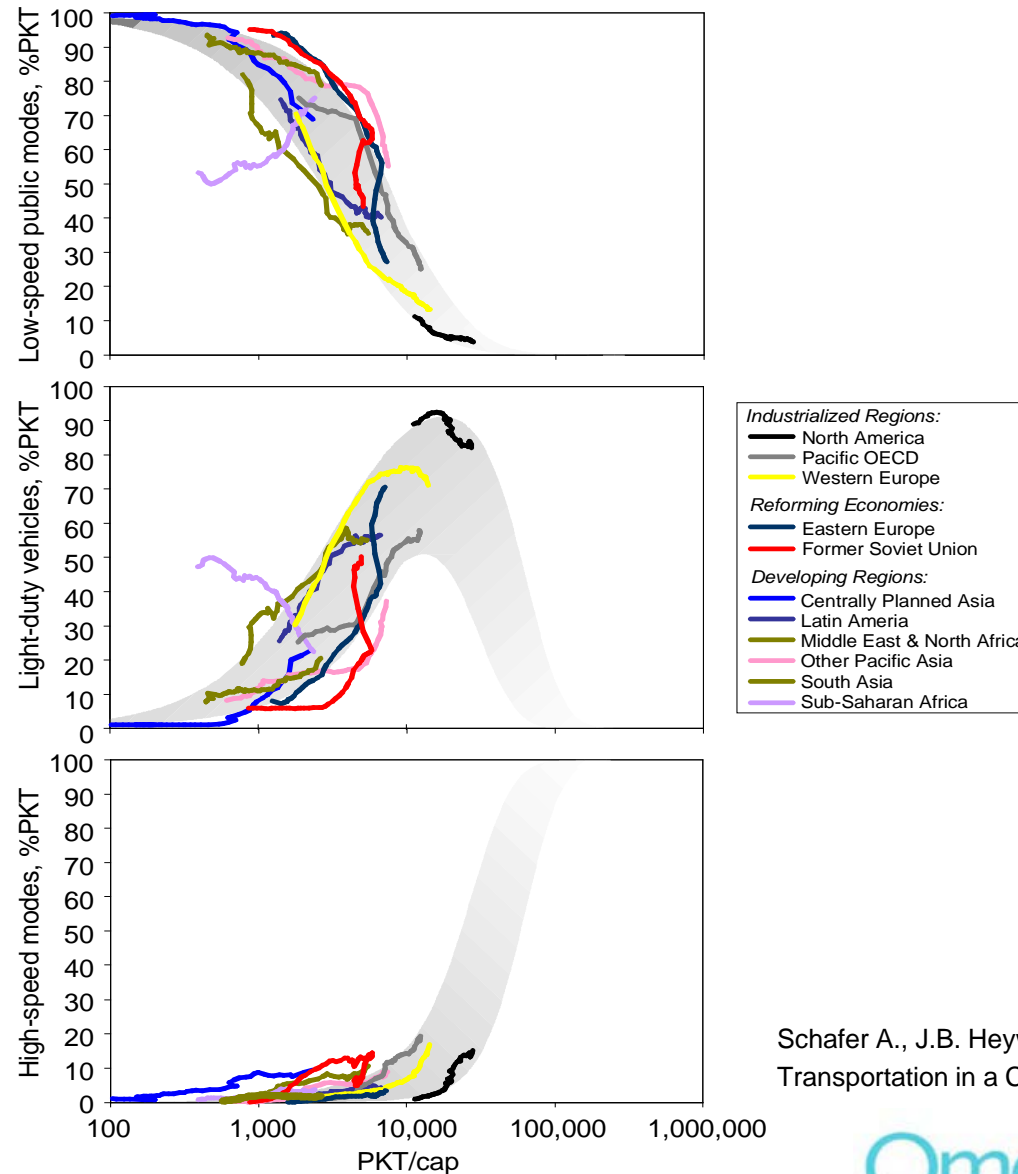
# Determinants of travel demand: TMB



# Growth in global mobility (1950-2005)

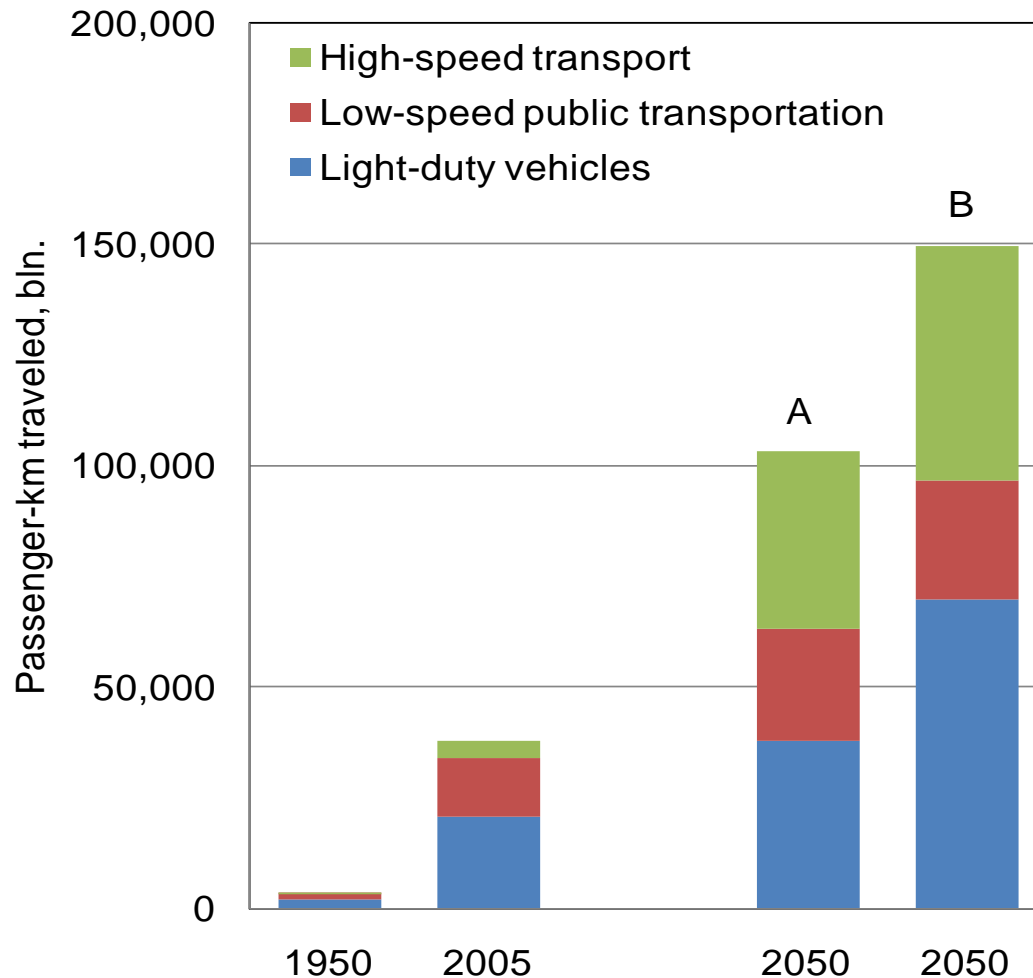


# Shift from slow to fast (1950-2005)



Schafer A., J.B. Heywood, H.D. Jacoby, I.A. Waitz, 2009.  
 Transportation in a Climate-Constrained World, MIT Press

# Global mobility by mode (1950-2050)



## 2050 Projections:

A: Annual average growth in gross world product per capita corresponds to 2.2% per year; moderate income growth in the developing world.

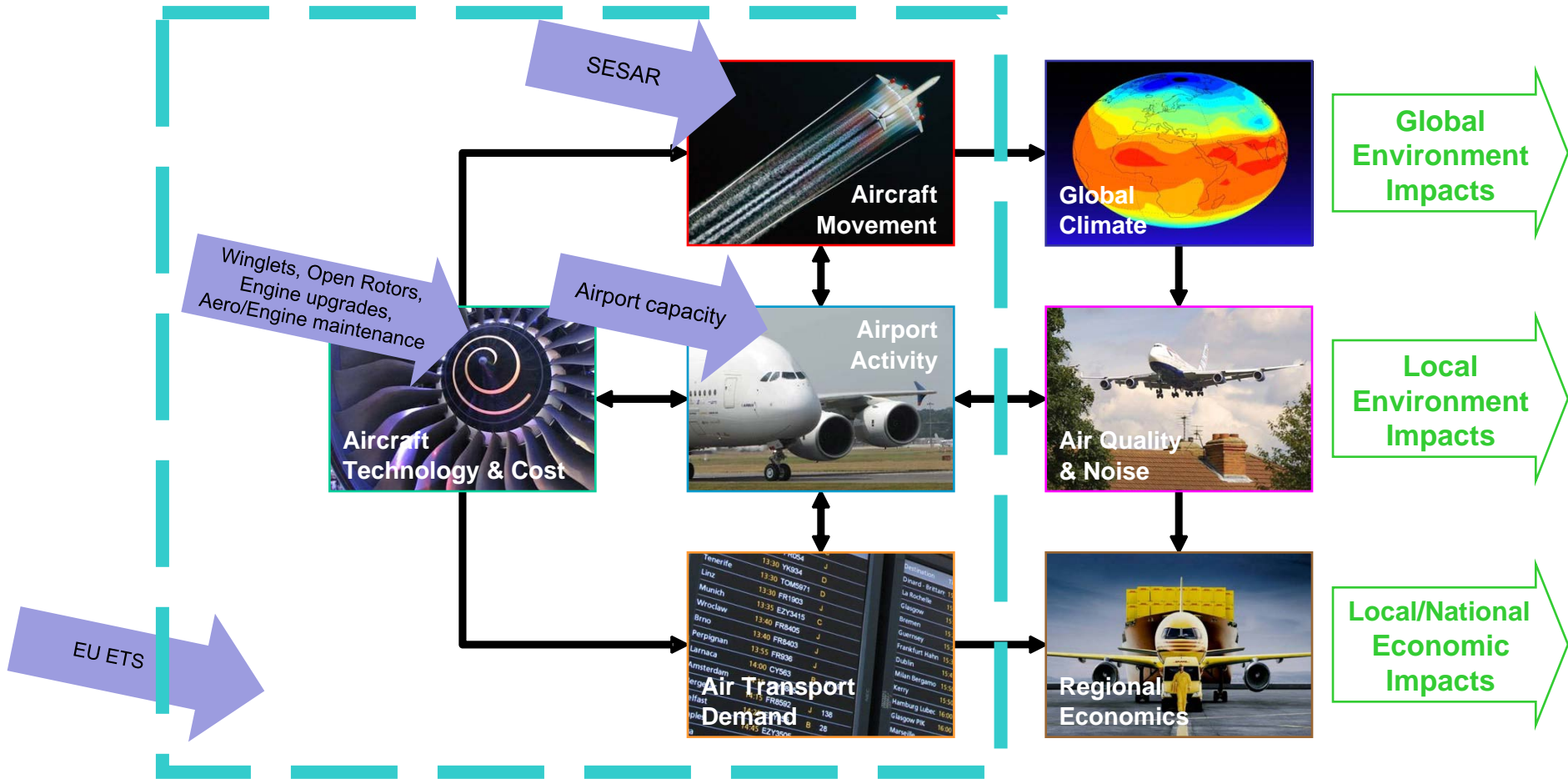
B: Annual average growth in gross world product per capita corresponds to 2.6% per year; strong income growth in the developing world.

A & B: Travel time budget per person assumed to be 1.2 h per day, on average.

## *Source:*

Schäfer A., J.B. Heywood, H.D. Jacoby, I.A. Waitz, 2009. *Transportation in a Climate-Constrained World*, MIT Press.

# Aviation integrated modelling



[www.AIMproject.aero](http://www.AIMproject.aero)

# Study mitigation options

---

Study title	Key outputs used for this study
Climate Related Air Traffic Management	Aircraft fuel efficiency improvement potential due to advanced ATM
Sustainable Fuels for Aviation	Fuel-cycle characteristics of second-generation (cellulosic) synthetic oil products
Marginal Costs of Environmental Abatement for Aviation	Main economic and technological char. of selected mitigation technologies
Environmental Aspects of Fleet Turnover, Retirement and Life Cycle	Retirement of existing aircraft and market penetration characteristics of new aircraft
Environmental Effects of Aircraft Operations and Airspace Charging Regimes	Capacities of European Airports
Air Transport in the European Emissions Trading Scheme	Range of carbon prices to prioritize emissions trading scenarios

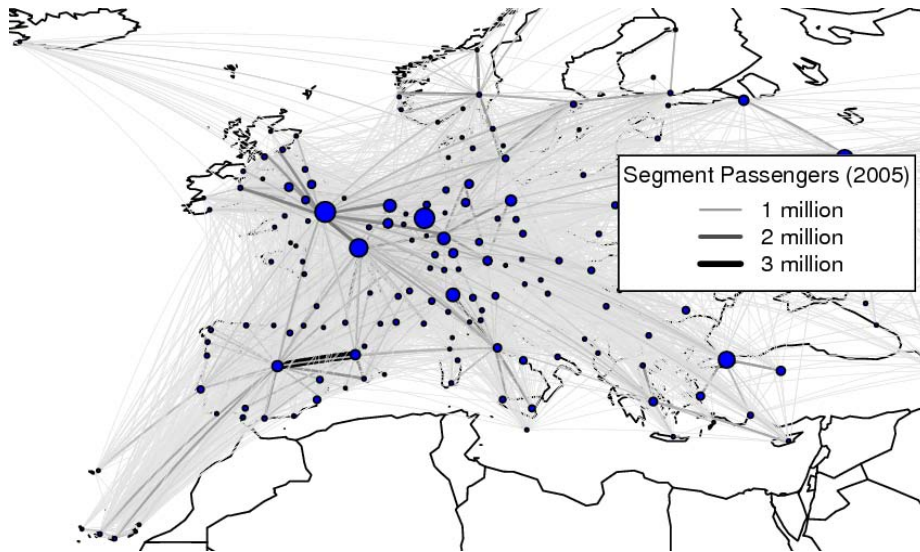
# Study approach

---

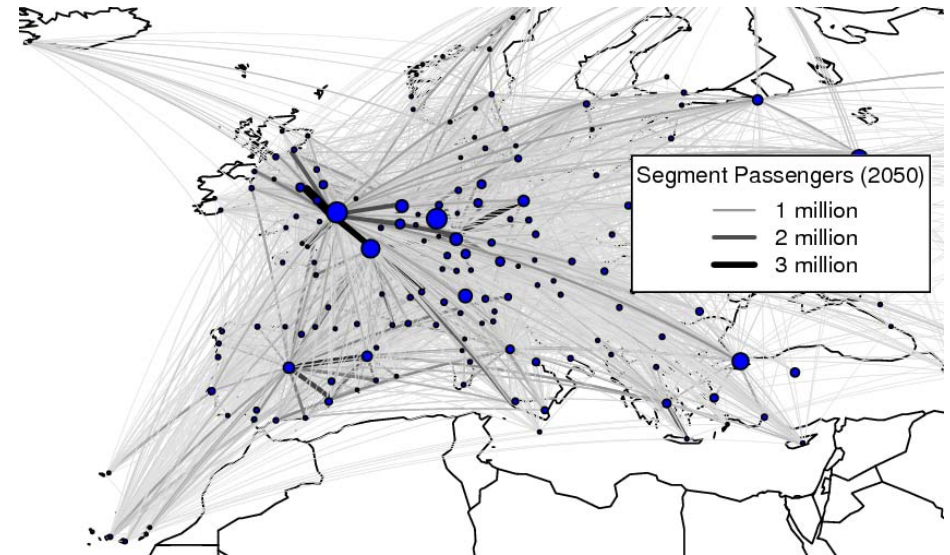
- Socio-economic variables, oil price development, carbon price trajectory from three internally consistent scenario families (U.S. Climate Change Science Program)
- Selected scenarios are consistent to carbon prices in Omega study and would lead to 450/550 ppm CO<sub>2</sub>-eq atmospheric stabilization
- Adoption of Omega study mitigation technologies: airlines choose among competing technologies based upon cost-effectiveness (payback period = 7 years for new technology)

# European air transport system evolution

2005

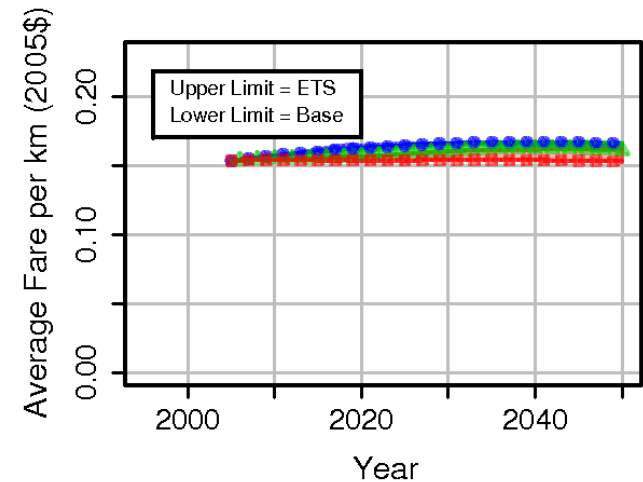
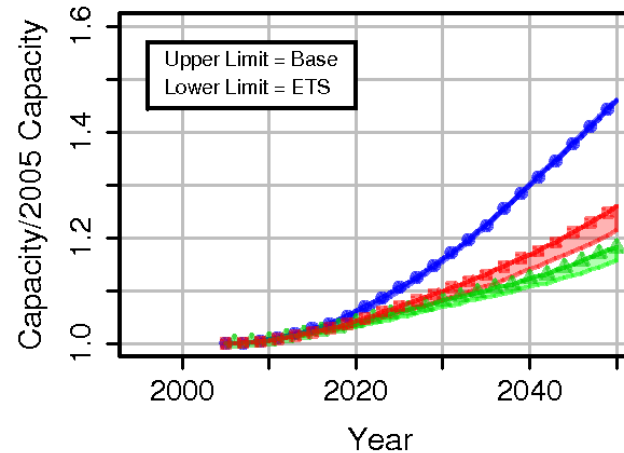
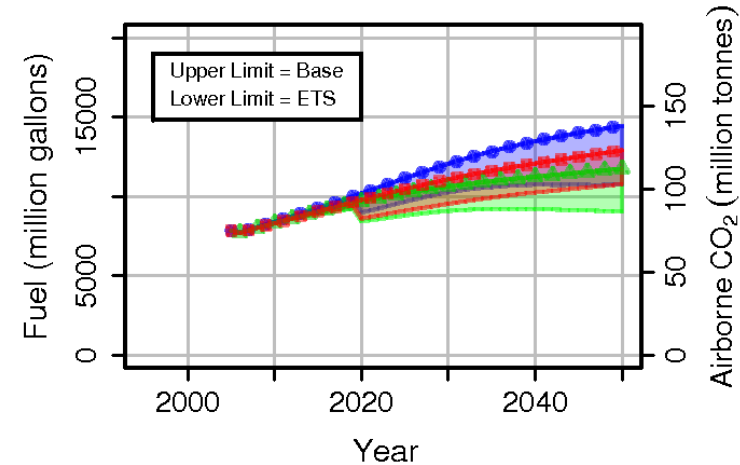
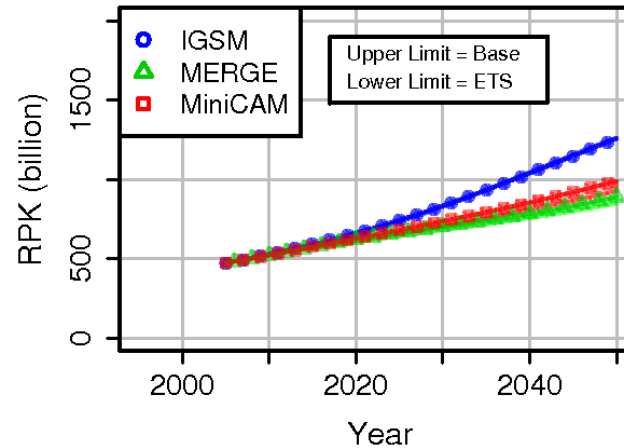


2050

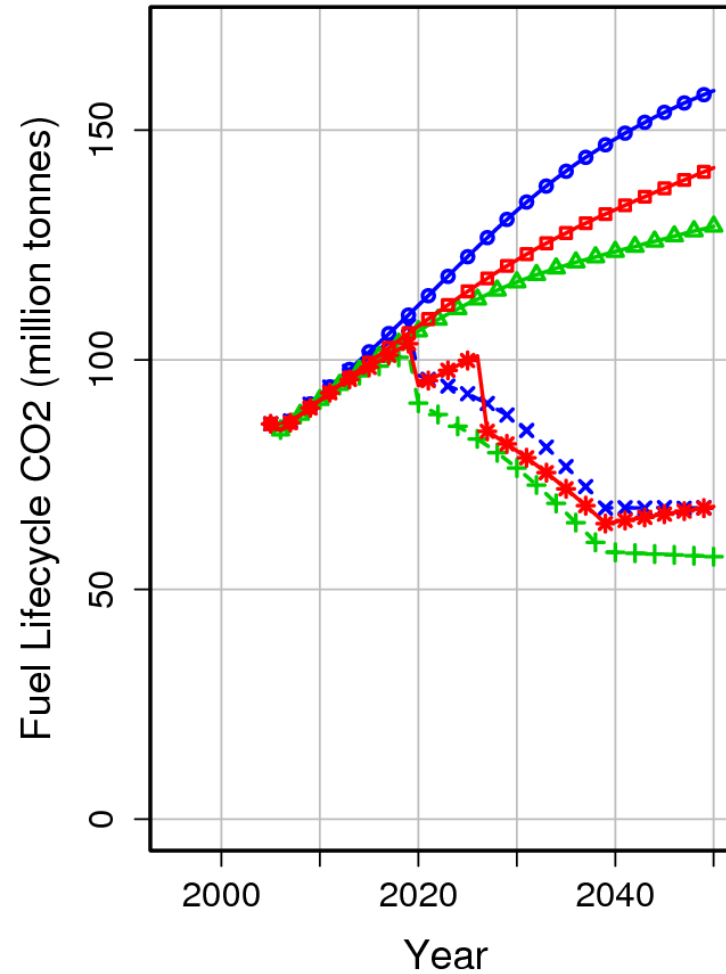
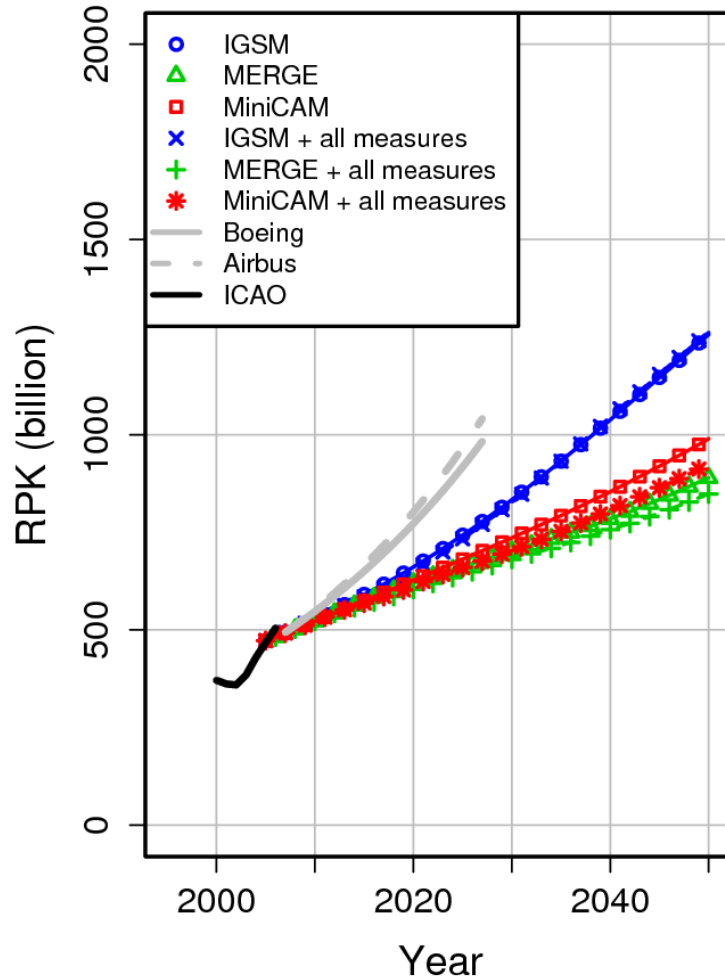


# Policy case vs. unconstrained reference case

- IGSM reference case demand requires at least two-fold capacity at LHR, CDG by 2050.
- CO<sub>2</sub> emission reductions result from adoption of mitigation technologies and reduced demand

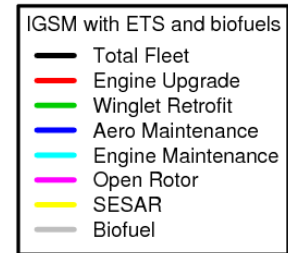
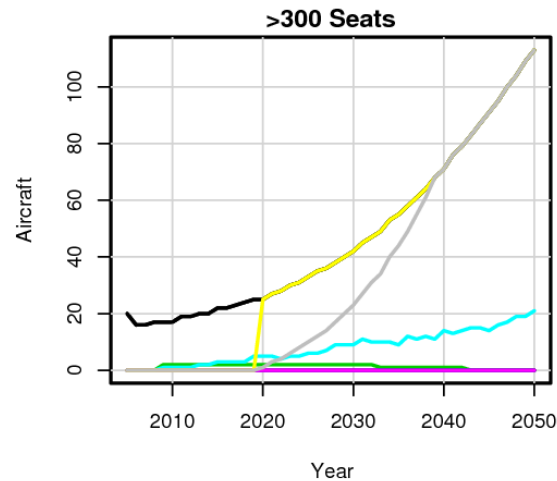
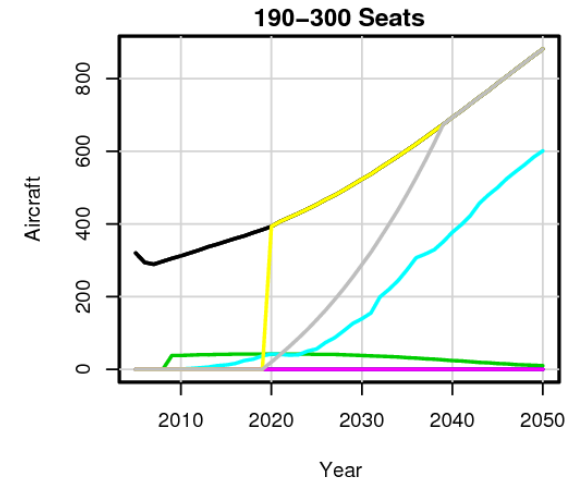
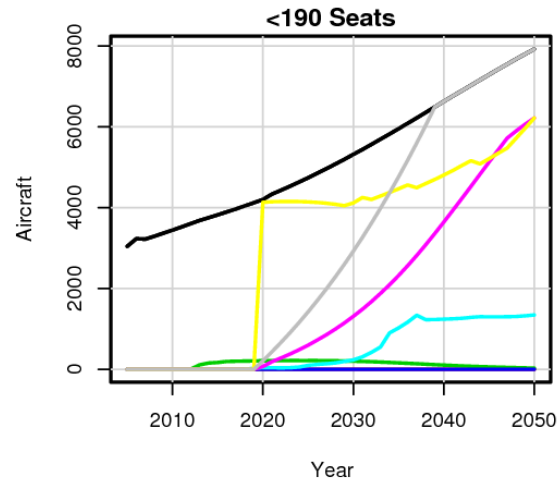


# Policy case



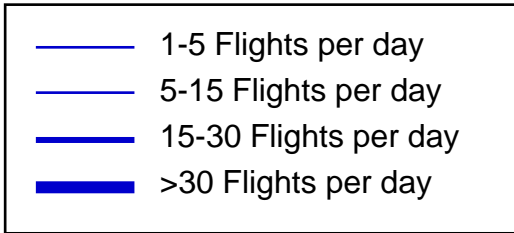
# Technology adoption

- ❑ Complex interactions - uptake of one mitigation measure can lower future uptake of other measures
- ❑ Largest effects on lifecycle emissions from SESAR and 50/50 BTL/jet fuel blends
- ❑ BTL land-use implications significant
- ❑ Open rotors enter in high-cost scenarios only
- ❑ Retrofit/maintenance measures experience limited adoption



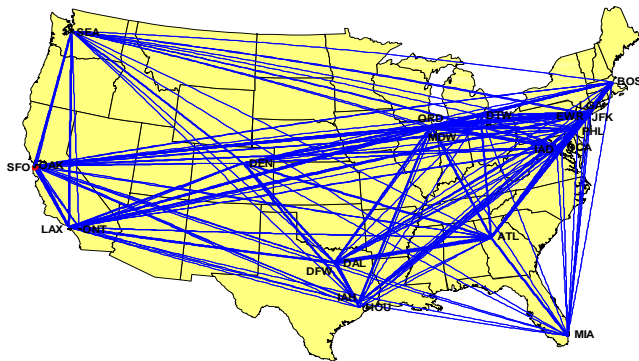
IGSM Scenario

# Airline competition and flight frequency

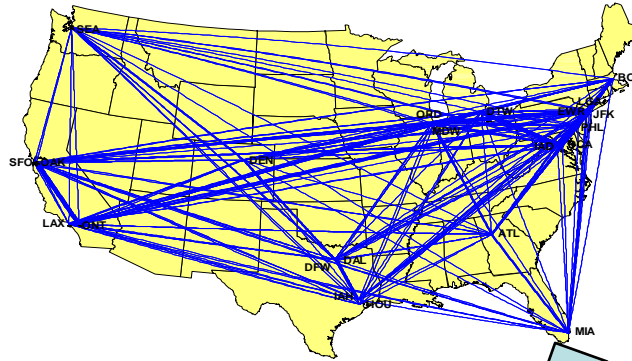


## Ph.D. work by Antony Evans:

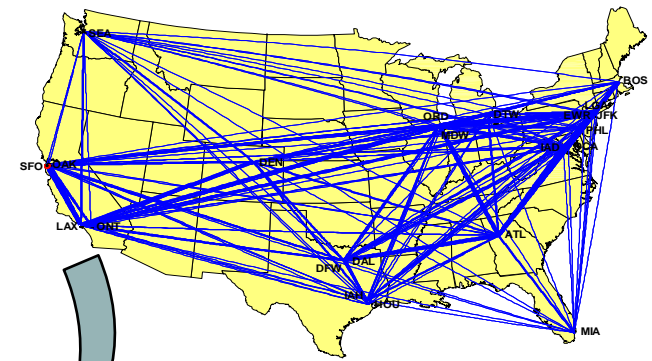
- Model 5 airlines in 14 cities / 22 airports / 11 hubs in the domestic US in 2005
- Maximise profit function (system-wide vs. airline-specific), given OD demand, fares



Actual Network Operated, 2005



System Optimal Network



Airline Game Theoretical Equilibrium Network

*Tripling of 2005 fuel cost*

System Optimal Network

Airline Optimal Network

O-D Seats		O-D Flt Freq.		Segment Flt Freq.	
% diff. System	R <sup>2</sup>	% diff. System	R <sup>2</sup>	% diff. System	R <sup>2</sup>
9% low	0.703	26% low	0.618	29% low	-
24% high	0.804	13% high	0.925	11% high	0.674

# Summary

---

- Demand for transportation likely to continue to grow strongly, and for aviation in particular (→ fixed budgets of money and time expenditures)
- Rising potential for reducing aviation-related CO<sub>2</sub>-emissions, mainly offered through SESAR and 2<sup>nd</sup> generation biofuels
- Inefficiencies result in higher than system-optimum flight frequencies → implications for market consolidation