Cranfield UNIVERSITY

GARS, DLR, Cologne

The potential for European aviation CO_2 emissions reduction through the replacement of small regional jets

Dr Peter Morrell
p.s.morrell@cranfield.ac.uk

29 November 2007

Potential for European aviation CO_2 emissions reduction through the replacement of small regional jets

Background

Fuel efficiency versus aircraft size

Past trends in aircraft capacity

Replacement of small regional jets: LH case study

Replacement potential

Conclusions

Climate change: the aviation background

- Need to halt or slow climate change
- Carbon dioxide has largest impact (NOx also important, especially for aviation)
- Aviation growth well above achievable emissions reductions scenarios
- Emissions trading most cost-effective way of reducing emissions without taxes or restricting output
- Kyoto Protocol (December 1999) included only domestic aviation: international aviation agreed to be discussed in ICAO:

→

Voluntary schemes and targets

- IATA: 26% improvement in fuel efficiency between 1990 and 2012
- British Airways: 30% improvement in fuel efficiency between 1990 and 2010 (20% already achieved by 2000)
- ATAG and others: average annual reduction of 1.9% between 2002 and 2008 (vs past trend of just over 1%)
- ICAO: 8% reduction in fuel efficiency from ATC and other operational improvements
- ACARE: 50% reduction in CO_2 emissions per tonne-km for an aircraft entering service in 2020 versus 2000 equivalent
- Green et al: laminar flying wing estimated to give 70% reduction in fuel burn per tonne-km vs existing aircraft

Future trends in aircraft fuel efficiency

- Traffic capacity forecast to grow at 4-5% a year
- Fuel efficiency to improve at ?% a year
- Increasing aviation CO_2 emissions in absolute terms and as % world total
- Fuel efficiency improvement, 2000 to 2040

  IPCC: used for most scenarios: 1.4% a year

  Lee et al (2001): between 1.2% and 2.2% improvement

- **Look at past trends** (Peeters et al, 2005)

Past trends in fuel efficiency

- IPCC 1960 to 2000: MJ per ASK down by 75%
- IPCC 1960 to 1980: MJ per ASK down by 67%
- IPCC 1980 to 2000: MJ per ASK down by 26%

- IPCC 2000 to 2040: MJ per ASK down by 43%

Problems:

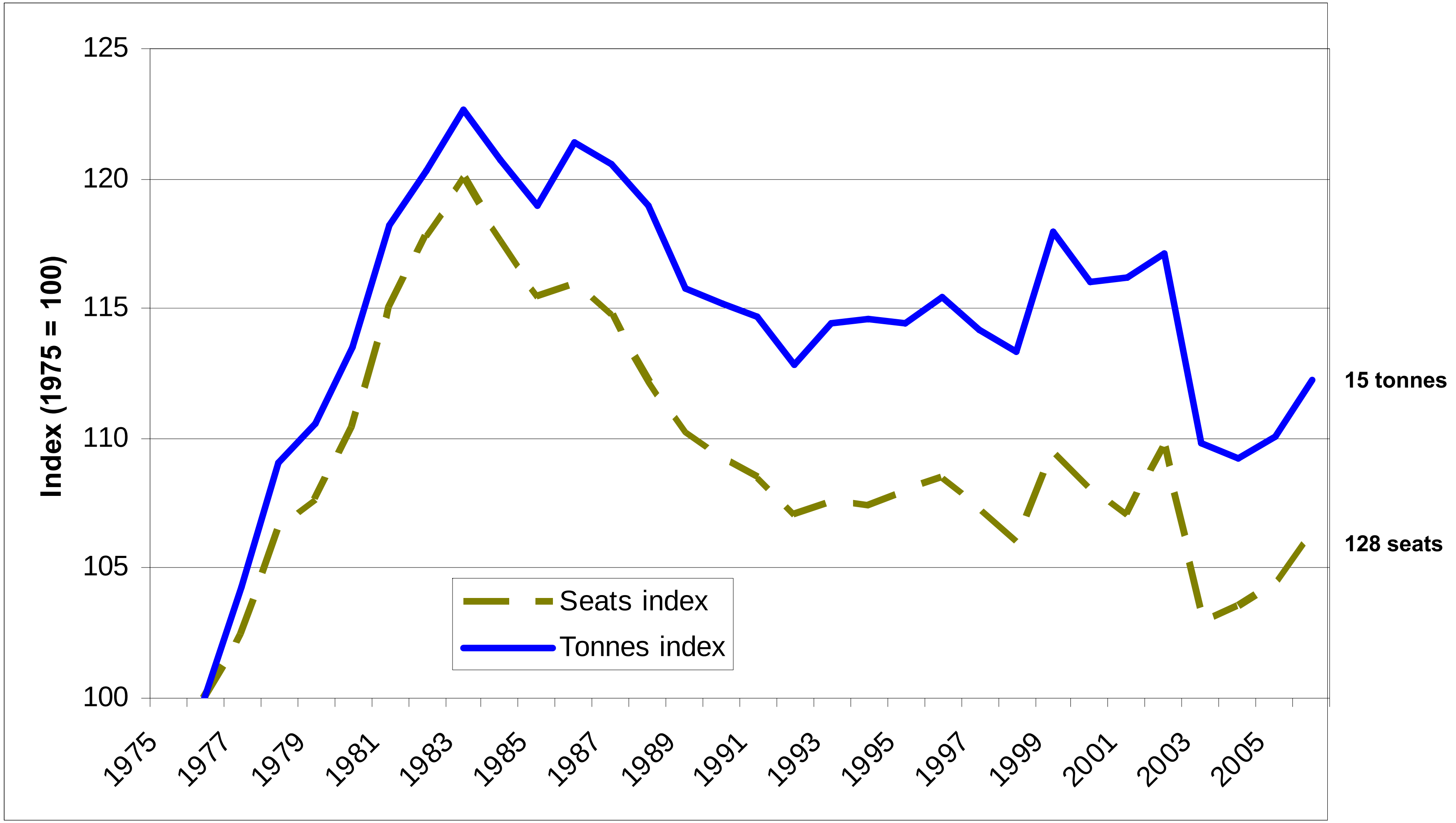
Only jet aircraft in past trends

Almost all long-haul aircraft

Enough weight given to more recent past?

- Aircraft size increase gave boost from 1960-80
- How will aircraft size change in the future?

Capacity per flight: AEA member airlines: Intra-European routes



Recent average aircraft size forecasts

- Boeing: hardly any increase over next 20 years
- Airbus: +20% over next 20 years
- Rolls-Royce: +0.6% pa over next 20 years (about 13% up overall)
- Frankfurt/Main Airport: +1.2% pa from 2005 to 2020
- London Heathrow between 2000/01 and 2012/13

  Domestic: +1.0% pa

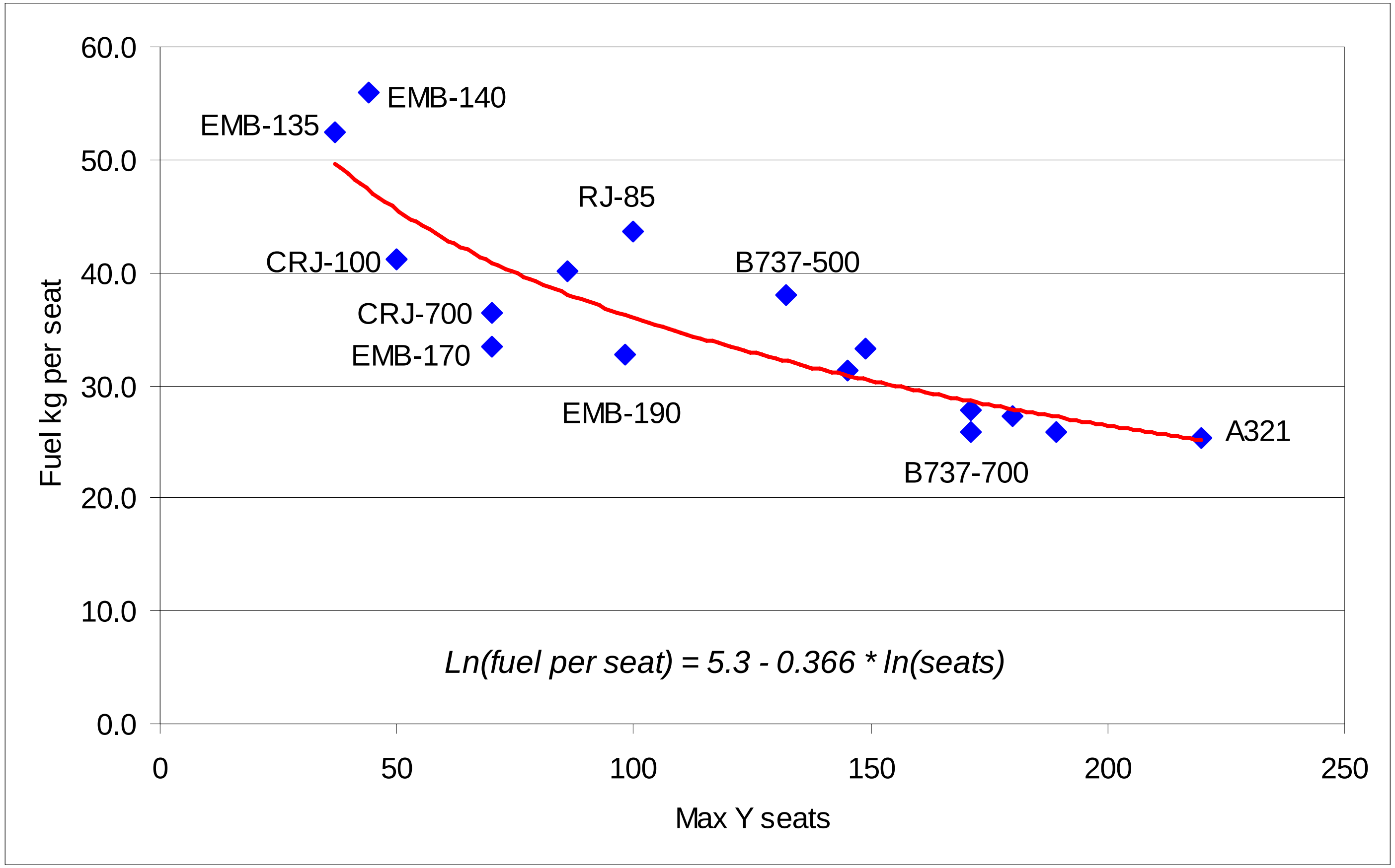
  Short-haul: +1.3% pa

  Long-haul: +1.7% pa
- ACI Europe (pax per flight) + 2% pa 2005 to 2025

Fuel efficiency vs size calculation

- Actual airline data or estimates?
- Use similar range: 90 minutes for short/medium-haul
- Where possible, used ICAO database for LTO cycle fuel burn (by engine type)
- Where possible, used Eurocontrol database for cruise fuel consumption by aircraft type
- Cross-check where possible against US data (Form 41)
- Use fuel per seat since cargo space in lower deck limited, especially on smaller aircraft

Fuel efficiency versus aircraft size by aircraft type



Single-aisle short/medium haul jet aircraft

- **Strong correlation between fuel efficiency and aircraft size in terms of number of seats in one-class configuration:**

*ln(fuel consumption per seat) = 5.24 - 0.366 * ln(no. seats)*
(+18.7) (-6.2)

- Similar seat pitch in one class configuration
- 10% increase in aircraft size gives 3.7% reduction in fuel per seat
- Moving from 50 seater to 70 seater would give a 14% improvement in fuel efficiency (to 90 seats would give a 29% improvement)

Replace 50 seat jet with turbo-prop

- 15-40% reduction in fuel per seat possible with no impact on frequency
- Other cost savings: maintenance, landing fees

but:

- Passengers prefer jets:

  Lower cabin noise

  Less turbulence

  Extra speed?

- Need extra airside capacity at congested airports

How do Lufthansa use their smallest regional jets?

- Use CityLine, Eurowings and Air Dolomiti as operators
- CRJ200s used on 107 routes in Summer 2007:

  18 sole airline and aircraft type routes, 23 only LH but other aircraft types, the remainder (66) in competition

  On the 23 with other LH aircraft, CRJ200s have 33% of weekly frequencies

  20 domestic and 87 international

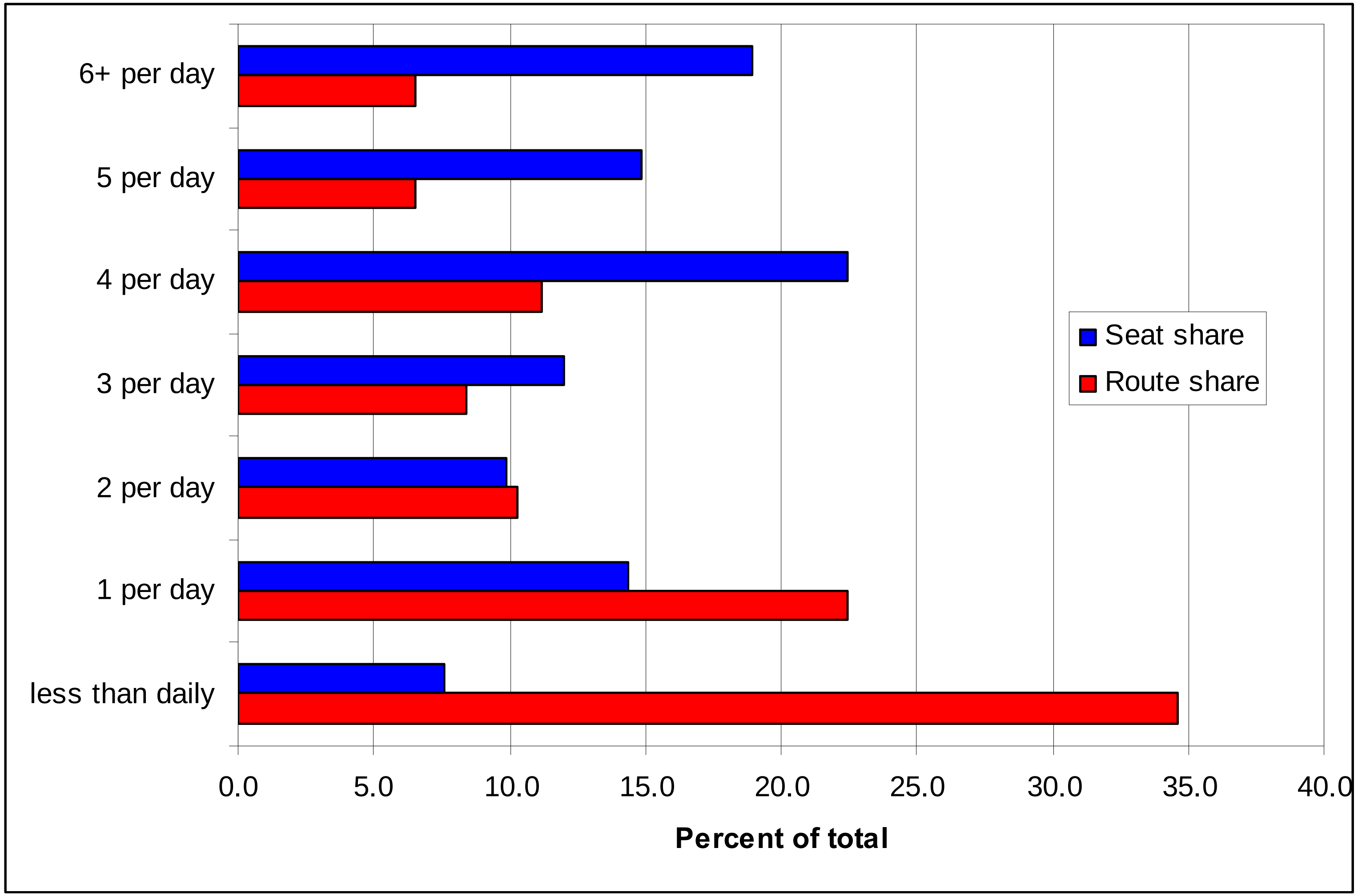
  13 involve Frankfurt and 24 involve Munich (major LH hub connectors)

  Average sector length on all 107 routes: 633 kms or

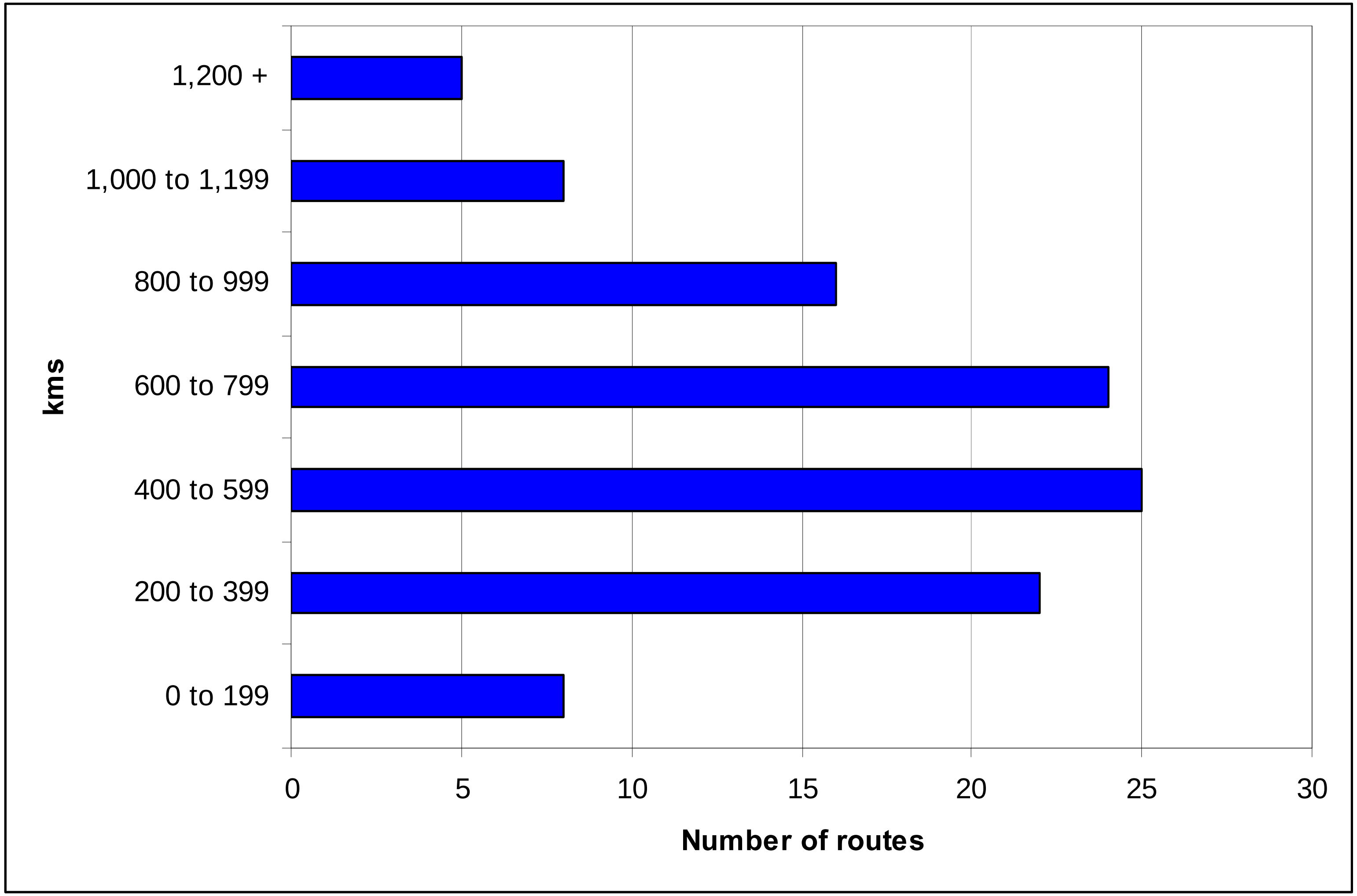
  Average sector on single aircraft routes: 612 kms

  On all except the 18 routes, Lufthansa use a mix of two or three aircraft types

Lufthansa CRJ200 frequencies (Summer 2007)



Lufthansa 50 seat jet routes by sector distance



Potential for greater use of turbo-props

- High fuel prices should provide large enough inventive?
- Regional jets depreciated over around 20 years
- Sector lengths could be handled by turbo-props?
- Do regional jets reach efficient cruise altitude?
- Mixed fleet problems: all or none
- No reduction in frequency
- Small reduction in product quality
- Little loss of passenger time
- Runway capacity issues
- Public relations benefits of lower fuel/emissions

Conclusions

- Past trends of fuel efficiency may not be helpful in forecasting, especially with high fuel prices and/or fuel or emissions tax
- Past trends helped by move to larger aircraft which give scale economies in fuel consumption
- Various forecasts of future aircraft size, but generally implying less than 1% pa improvements in fuel efficiency from this source
- Small regional jets provide frequency and greater comfort, but at expense of fuel efficiency
- Considerable fuel efficiency benefit available by trading up to larger jet, but this might affect competitive position of operators such as Lufthansa
- On many routes, turbo-prop could offer same seat number and frequency but at much better fuel efficiency
- Sector length of these routes not long enough to result in much longer flight times or increased turbulence
- BA abandons regional jet bases at Birmingham and Manchester, so emissions charging probably not necessary