Implications of Climate Change on Air Transport

~ A UK Case Study ~

International Air Safety & Climate Change Conference

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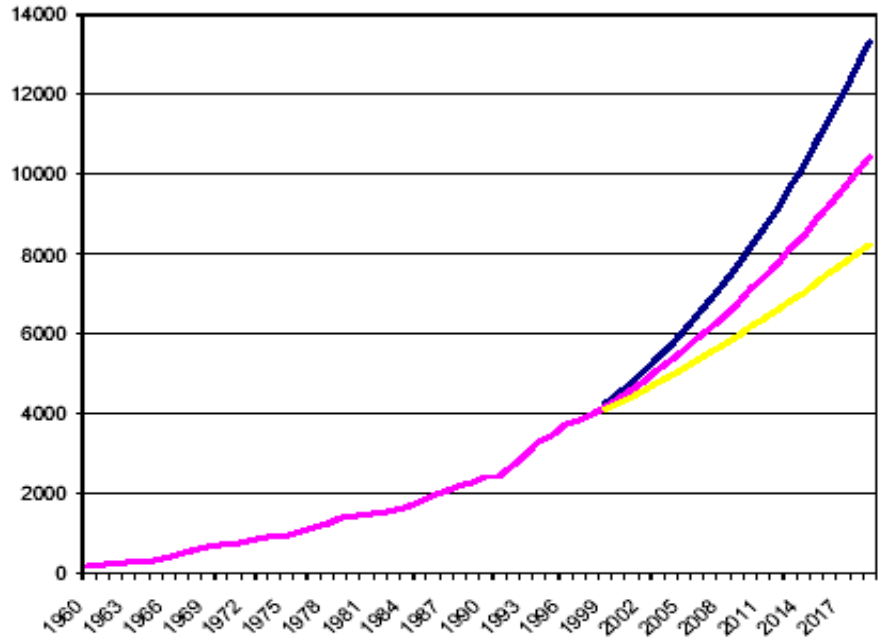
Outline

- Intro
- Implications of climate change
- Research focus
- Example
- Conclusions/Findings

Introduction

- Air transport growth → climate impacts increase
- Impact of aviation on climate change – well researched topic
- Impact of climate change on aviation – limited research
- Impact:
  - Operational
  - Economical



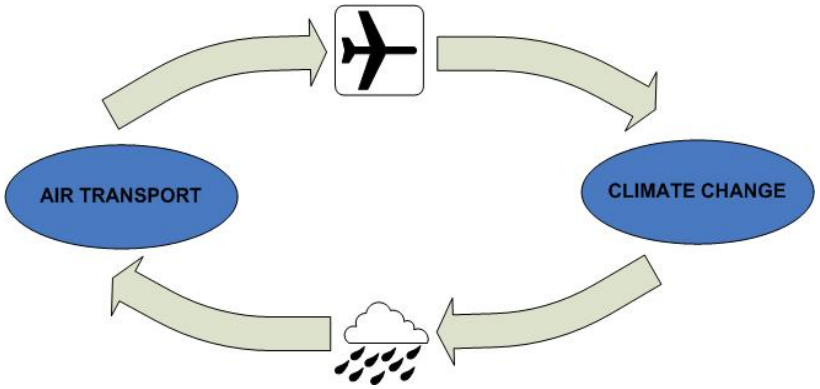
Forecasts of worldwide passenger aviation demand in terms of billion seat kilometers offered (source: DTI)

Implication of climate change

- Changes in localized weather
- Possibly more severe weather patterns:
  - More intense rainfall
  - More frequent thunderstorms
  - Changes in wind patterns
- Outcome:
  - Reduced safety margins and efficiency
  - Decreased runway capacity
  - Possible airspace and airport closures

Research focus

- 3 year research at Imperial College London into possible **impacts of climate change on air transport sector** in the UK
  - Changes in wind patterns
    - Impact on fuel use and CO_2 emissions
  - Weather-related delays
    - Identification of the key weather parameters
    - Modelling and forecasts
  - **Severe weather events**
- Feedback mechanism



Example - Heathrow closure

- Simulated short closure of Heathrow airport
- Focus on both operational and environmental costs (emissions - CO_2)
- System disruptions included:
  - Delays (air and ground)
  - Flight rerouting to alternate airports
  - Flight cancellations
  - Repositioning

Analysed costs

- **Economic consequences**:
  - Delays
  - Increased fuel burn
  - Flight detour or alternates
  - Flight cancellations
- **Environmental costs**:
  - Increased emissions of CO_2 / fuel burn
    - due to increased travel time, flight diversions and flight repositioning

Not analysed

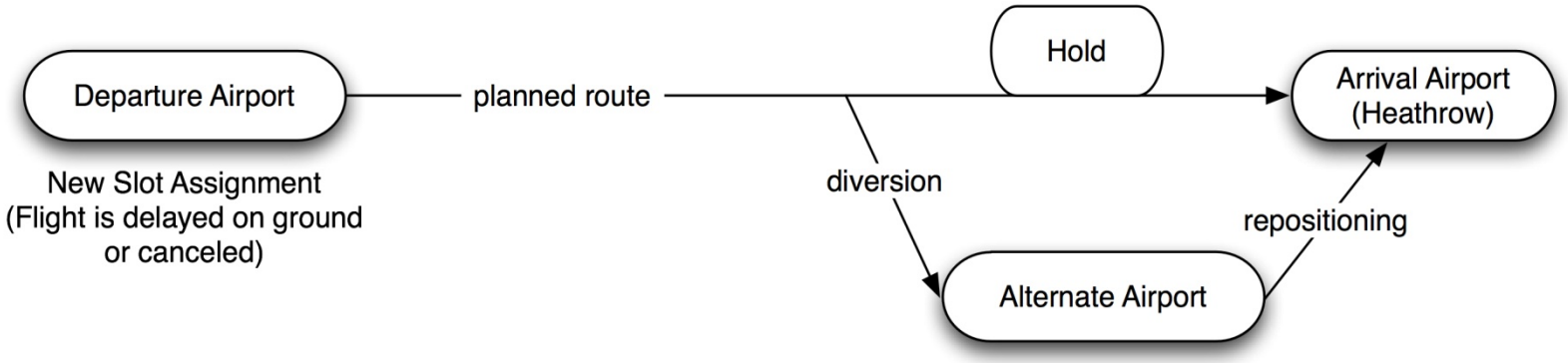
- Additional costs related to:
  - The airport (*i.e.* airport charges)
  - Airlines (*i.e.* maintenance and crew costs)
  - Passengers (*i.e.* passenger satisfaction and compensation)
- The impact of ground delays
  - Aircraft ground hold practices (*i.e.* APU, GPU, or engines running)
- The other environmental aspects
  - Noise, degraded air quality, soil or water pollution, and non-carbon global impacts such as NOx

Assumptions

Cause of closure	• Unexpected severe weather event • Unknown duration of severe weather conditions
Closure time/duration	Airport closed during peak hour (“worst case” scenario): •Busiest hour for departures •Period: 6-7 PM •Duration: 1 hour
Heathrow closure traffic details	Scheduled traffic: •48 departures •43 arrivals
Modelling constraints	• Heathrow is open until 11:30 PM • Maximum number of departures at Heathrow (*i.e.* maximum declared capacity for departures) is set to 48 • Maximum flight delay is set to 4 hours (after that flight is cancelled)

Analysis of arrivals

- Extra Fuel Burn
- Delays (travel time changes)
- Simple rules: alternate or hold
- 2 scenarios
  - Diverting all arriving traffic to alternate airports
  - Delays imposed on some flights (either through an airborne hold or ground hold)

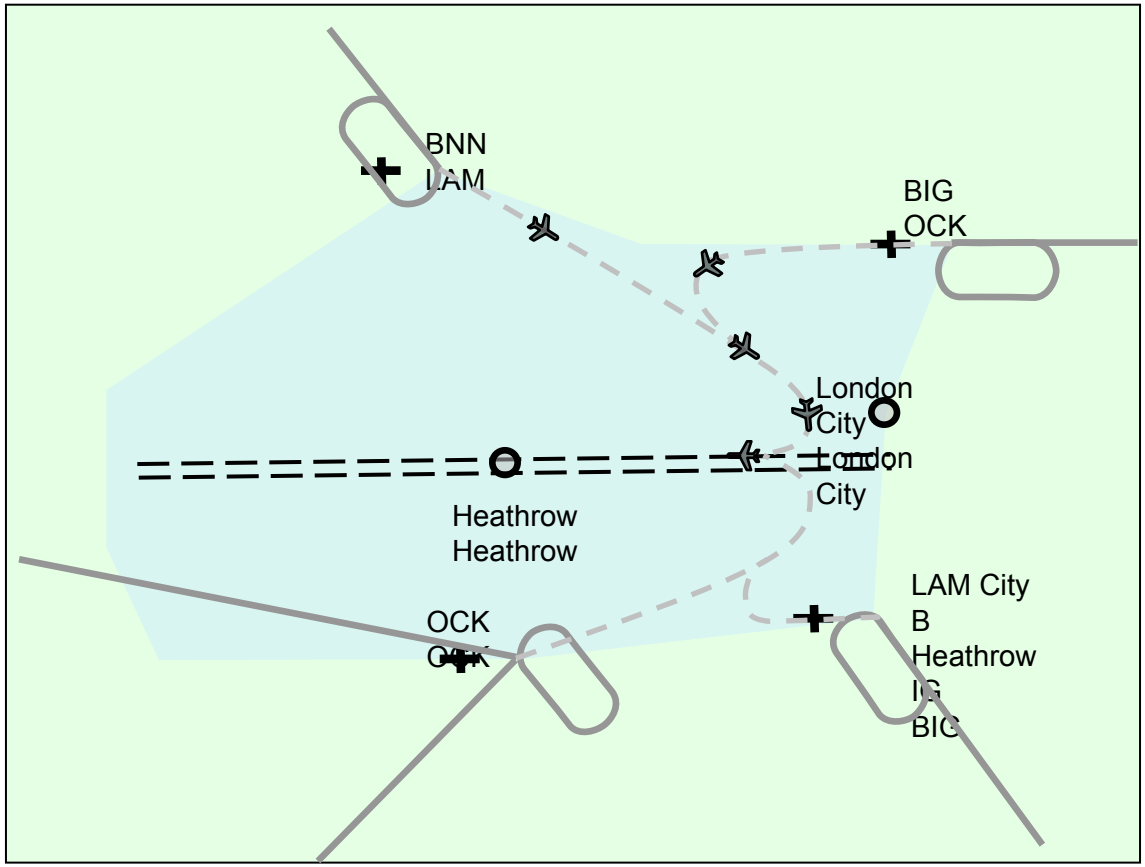


Analysis of arrivals – Scenario 1

- All diverted
- Repositioning

Analysis of arrivals – Scenario 2

- Diversions
- Ground delays
- Airborne delays
- Repositioning



Arrivals summary

- Added fuel consumption
- Ground delays
- 410t (CO_2) ~ 1% of daily arrivals

	Ground Delays (min)	Extra CO_2 Alternate (t)	Extra CO_2 Airborne Hold (t)	Extra CO_2 Repositioning (t)	Total CO_2 (t)	Daily Heathrow CO_2 for arrivals (%)
Scenario 1	N/A	102.98	N/A	308.2	411.18	0.95
Scenario 2	120	70.27	39.43 - 49.57	171.5	281.20 - 291.34	0.65 – 0.67

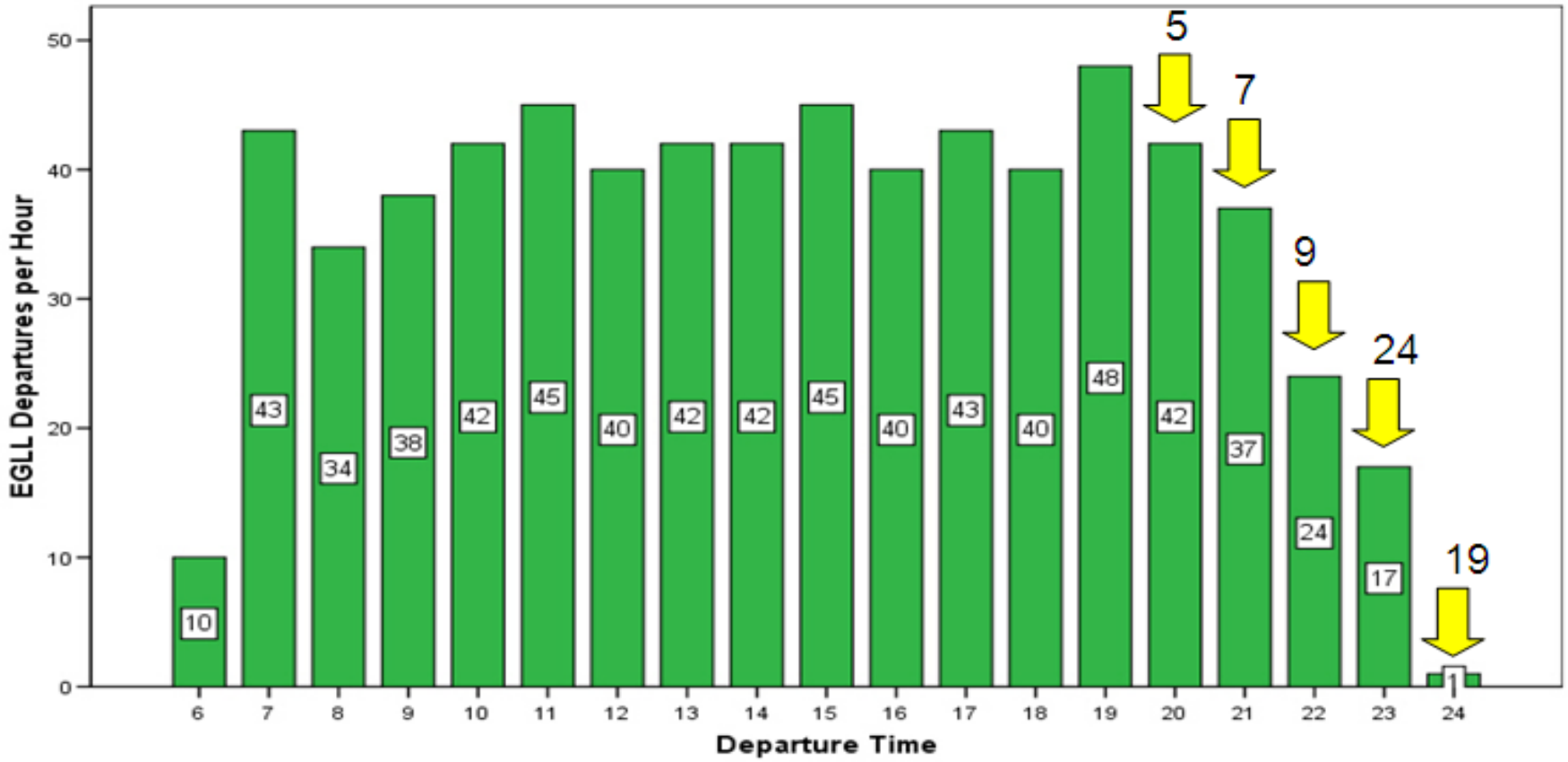
Analysis of departures

- Extra travel time based on induced delays
- Cancellations (due to excessive delay > 4h)
- Simple rules
- 2 scenarios depending on operational practices
  - Rescheduling only delayed flights
  - All new slots based on the least average delay
- Night noise restrictions taken into account

Analysis of departures – Scenario 1

- Traffic is rescheduled based on the following rules and assumptions:
  - Departures that are scheduled to depart after 7PM do not change their originally scheduled departure time
  - Delayed flights (24) are rescheduled to available slots after 7PM considering that:
    - Minimum separation time between flights is set to 1.25 min
  - Rescheduled flights depart in the same order as in the original sequence (with the exception that intercontinental flights have priority over short haul and domestic)
  - Destination airports are open to accept departing traffic regardless of their time of landing

Analysis of departures – Scenario 1



Analysis of departures – Scenario 2

- Traffic is rescheduled based on the following rules and assumptions:
  - All flights (48), originally scheduled to depart after 6PM, were allocated new slots based on the least average delay
    - If the new slot is earlier than the scheduled one the flight will use the scheduled one
  - Minimum separation time between flights is set to 1.25 min
  - All flights depart in the same order as in the original sequence
  - There are no constraints on routes and destination airports

Departures summary

- This assumed short airport closure resulted in cancellation of over 16 % of the remaining departures
- The implications of a longer airport closure or cancellation of airport operations earlier during the day would be much larger

	Total Delay (min)	Average Delay (min)	No of cancelled flights
Scenario 1	4027	28	24
Scenario 2	10103	60	0

Operational costs

- Costs of air traffic delays, flight cancellations and flights diverting to alternate airports

Arrivals (€)

	Ground Delay	Cancellation (Simple)	Cancellation (Case Specific)	Cost Total (Simple)	Cost Total (Case Specific)
Scenario 1	314,074.8	160,320	635,000	474,394.8	949,074.8
Scenario 2	788,026.2	N/A	N/A	788,026.2	

Departures (€)

	Ground Hold	Airborne Hold	Diversion (Simple)	Diversion (Case Specific)	Cost Total (Simple)	Cost Total (Case Specific)
Scenario 1	N/A	N/A	204,680	239,000	204,680	239,000
Scenario 2	9,360	48,360	123,760	142,000	181,480	199,720

[1] *The Stern report does not have a firm recommendation for a carbon price, it gives a range from 120-140$ per tonne of carbon.*

[2] *ETS carbon price – market price from December 7th, 2007.*

Environmental costs (only arriving traffic)

Cost (1000 €)	€/CO_2 tonne	Alternate	Hold (average)	Repositioning	Total
Scenario 1					
Low	11	42	N/A	125	167
Base	33	126	N/A	376	502
High	55	210	N/A	627	837
Stern	82 - 95	312	N/A	935	1,248
		362		1,083	1,445
ETS	22.3	85	N/A	254	339
Scenario 2					
Low	11	29	18	70	117
Base	33	86	54	209	350
High	55	143	91	349	583
Stern	82 - 95	213	135	520	869
		247	156	603	1,006
ETS	22	58	37	142	236

Cost summary

- One-hour airport closure:
  - Estimates between €700,000 to €1,250,000
- Carbon costs:
  - €230,000 to €340,000 based on ETS costs to airlines
  - Worst case: If carbon costs are considered the total costs of an airport closure could double
- External cost:
  - Estimates up to €1,400,000

Conclusions/Findings

- The traffic disruptions have been measured through delays, additional fuel consumption, flight rerouting to alternate airports, and flight cancellations
- **Hidden threat - Flight repositioning**: represent ~ 3.7 and 2 % of daily emissions of all UK domestic flights
  - This clearly emphasises the importance of future disruptions to national UK emissions estimate

Conclusions/Findings (Cont'd)

- **Ground delays principle**: The CFMU principle concerning allocation of the new flight departure slots might not be always correct one!
  - The total cost for arrival scenarios are much less than costs related to departing traffic disruptions (~ 1/5)
  - This suggest that in severe weather events of this magnitude, the common belief that it is cheaper to delay flights on the ground than in the air may be untrue in broader terms
- May impact airlines policies re which flights to delay and when

Conclusions/Findings (Cont'd)

- **Implications on the overall network:** are expected to be much larger
  - *i.e.* loss of connecting flights, impact on operations of other airports, airspace congestion, etc.
- **Adding additional costs** would increase the overall cost
  - operational (eg airports, airlines, pax) and
  - environmental costs (eg NOx)

Thank you for your attention

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