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Air quality impacts of UK airport capacity expansion

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This report summarises the results of peer-reviewed papers published or forthcoming in the UK-based scientific journal *Atmospheric Environment* on the topic of emissions from UK airports, their impacts on public health today and in the future, and viable near-term mitigation approaches. Particular attention is paid to the potential for either expanding Heathrow or building a new hub airport in the Thames Estuary.

The work was conducted using EPSRC funds in the UK and the study leader's discretionary research funds in the US. From 2010-2012 the work was primarily undertaken at the Laboratory for Aviation and the Environment, which is a unit of the Department of Aeronautics and Astronautics at the Massachusetts Institute of Technology (MIT). Additionally work was undertaken at the University of Cambridge as part of its Energy Efficient Cities Initiative, where the project started in 2009 before the study leader moved to MIT in 2010.

The authors have no conflicts of interest in this work.

The work was conducted by:

- Dr Steven Barrett, study leader, an Assistant Professor at the Massachusetts Institute of Technology and Director of the Laboratory for Aviation and the Environment; his research and teaching focuses on the environmental impacts of aviation and other modes of transport;
- Dr Steve Yim, a Research Scientist at the MIT Laboratory for Aviation and the Environment; he is an expert in air pollution modelling;
- Marc Stettler, a PhD candidate in Engineering at the University of Cambridge and former visiting PhD student at MIT; his research focuses on aircraft emissions; and
- Sebastian Eastham, an MIT PhD candidate in Aerospace Engineering, who contributed to early stages of the work on aircraft emissions estimation.

1. Introduction

The environmental impacts of aviation are of significant public concern in the UK today. With airport capacity expansion being considered, there is a need for an independent assessment of the air quality and human health impacts of UK airports. This document summarises the results of a three-year study that comprehensively examined emissions from UK airports and calculated their health impacts on the British population. The full reports are available in the UK-based scientific journal *Atmospheric Environment*.

The study addressed four questions in particular:

- What are the air quality and human health impacts of UK airports today?
- What will these impacts be in the future?
- How will the impacts change if airport capacity is expanded (either by addition of a third runway at Heathrow or by replacing Heathrow with a new hub airport in the Thames Estuary)?
- How can the impacts of UK airports on public health be reduced?

2. Methods

Pollution emissions at the top 20 UK airports (by passenger numbers) were computed using an approach based on aircraft engine certification measurements with corrections to account for operational factors. Flights and airports accounting for 95% of UK air passengers were used in the study. Non-scheduled flights were not included. In addition to aircraft engine emissions, emissions associated with ground support equipment and aircraft auxiliary power units were considered.

A base year of 2005 was used, with a future year of 2030 where forecast flights were from the UK Department for Transport aircraft and passenger forecasts. New aircraft entering the fleet were considered, including anticipated changes in environmental performance for newer aircraft.

Three future scenarios were considered:

- No airport capacity expansion (constrained growth). Airport utilisation continues to increase resulting in increasing emissions.
- A third runway at London Heathrow (unconstrained growth).
- A new hub airport in the Thames Estuary (unconstrained growth). In this scenario it is assumed that London Heathrow is closed on the basis that there can only be one UK hub airport.

Four near-term mitigation measures were considered:

- Removal of sulphur from jet fuel. This has already been done for road transport.
- Single engine taxiing. This means that twin-engine aircraft would consistently use one engine to taxi out to and back from the runway.
- Electrification of ground support equipment. In this scenario, air-side vehicles would not directly emit pollution, but may do so indirectly due to power stations needed to supply electrical power to recharging stations.
- Avoidance of aircraft auxiliary power unit (APU) usage. The APU is the small gas turbine at the back of aircraft. It is used for air conditioning and electrical power when the engines are not running. Its use can be avoided by consistently using fixed

ground electrical power and preconditioned air supplied by the airport – if the facilities are available – thereby reducing emissions at the airport.

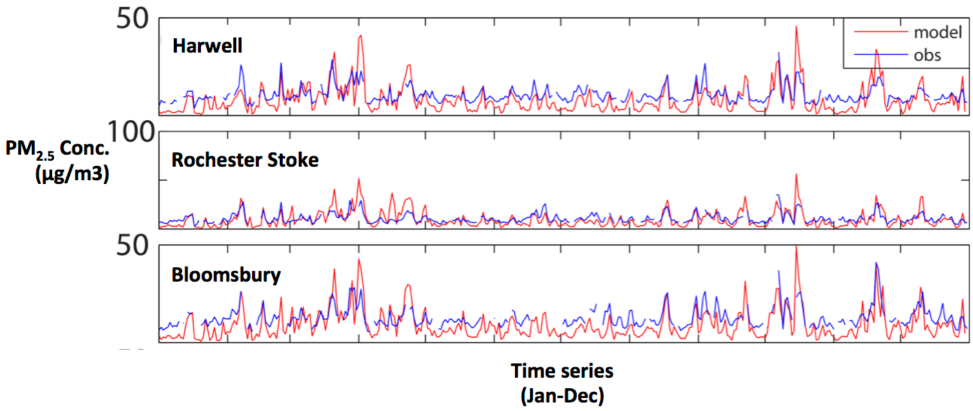

Figure 1. Example comparison between modelled and observed fine particulate matter ($PM_{2.5}$) concentrations at three UK sites in 2005.

The CMAQ air quality model – described by the US Environmental Protection Agency as "state-of-the-science" – was used to map each emissions scenario to air quality impacts. CMAQ has been extensively applied and evaluated, and in this study was further evaluated relative to measured air quality in London and the rest of the UK. A sample of this evaluation is shown in Figure 1, where CMAQ-modelled fine particulate matter concentrations are compared to measured values. Further, near-airport air quality pollution "peaks" were captured using an approach based on a model called AERMOD. This also has been extensively applied and evaluated.

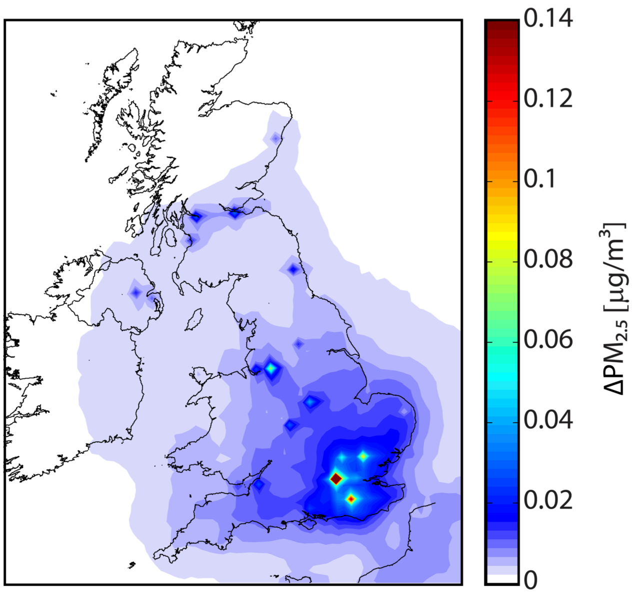

Figure 2. CMAQ-modelled $PM_{2.5}$ concentration due to UK airport emissions in 2005. Near-airport peaks modelled by AERMOD are not included.

Population exposure to airport pollution under each scenario was calculated by overlaying modelled changes in air quality (e.g. Figure 2) under each scenario on population density. In future years, future population projections were used.

Finally, population exposure to airport pollution was related to health impacts. This draws on quantitative epidemiological evidence amassed in extensive cohort studies that has found that exposure to fine particulate matter ($PM_{2.5}$) is the air pollution exposure metric that is most independently and consistently associated with increased risk of early death due to lung cancer and cardiopulmonary diseases. In quantitative terms, long-term exposure to an additional 1 $\mu g/m^3$ of $PM_{2.5}$ increases risk of early death by about 1%. This means that the health impacts of each emissions scenario can be expressed in terms of early deaths in the UK.

A comprehensive uncertainty assessment was conduced to establish confidence intervals for all results. These are given in the journal publications, while central estimates are given in this summary report for clarity.

3. Findings

Approximately 110 people in the UK die early each year due to airport emissions today. Of these deaths, approximately 50 are due to emissions from London Heathrow.

By 2030, without airport capacity expansion, the number of early deaths per year caused by UK airport emissions is projected to increased to 250. Factors contributing to this are: (i) aircraft emissions are increasing due to increasing utilisation of existing airports; (ii) the population is growing so pollution emissions result in greater exposed population; (iii) the population is aging so becomes more susceptible to air quality-related diseases; and finally (iv) the atmosphere is projected to be cleaner in the future in the UK so the incremental impact of aircraft emissions is projected to be greater. (Simplifying – emitting one tonne of pollution into a clean atmosphere causes a greater impact than emitting it into an already polluted atmosphere.) Of the 250 early deaths per year in 2030, about 110 are due to Heathrow emissions.

If a third-runway is built at London Heathrow, early deaths due to emissions from Heathrow increases from 110 to 150. This is compensated for by reductions at other London airports as air traffic moves to Heathrow so that nationwide there are about 10 additional early deaths per year.

If instead of a third-runway at Heathrow, the UK hub airport is moved to the Thames Estuary and Heathrow (the current hub airport) is closed, we find that the hub impacts decrease by 60-70% to about 50 early deaths per year. On a nationwide basis, early deaths due to UK airport emissions decrease by a quarter relative to an unexpanded Heathrow. In other words, airport capacity would be expanded and health impacts reduced under the Thames Hub scenario.

The reason that the Thames Estuary option reduces health impacts of the UK hub by 60-70% is that prevailing winds in the region are southwesterly (towards the northeast). Heathrow is embedded in the major population centre of Greater London, and upwind of a significant portion of it. In contrast, the Thames Hub would be downwind of London, such that much of the pollution from a Thames Hub would blow into the North Sea and English Channel. This means that a Thames Hub option would result in lower population exposure to $PM_{2.5}$ than the same emissions at Heathrow.

In terms of near-term mitigation measures:

- Removal of sulphur from jet fuel would avert 20 early deaths per year. (Alternatively, use of biomass-derived alternative fuels could avert up to 50 early deaths per year.)
- Single engine taxiing would avert up to 10 early deaths per year.
- Electrification of ground support equipment would avert up to 30 early deaths per year.
- Avoidance of aircraft APU usage would avert up to 10 early deaths per year.

We note that: (i) these measures are not entirely additive, and that the overall potential reduction may be less than sum of each individual measure; (ii) for single engine taxiing and APU avoidance, these measures are already implemented to an unknown extent at the discretion of pilots and depending on facility availability, so the above figures represent an upper bound on possible reductions; (iii) electrification of ground support equipment may increase power station emissions that would offset some of the benefits of the measure; (iv) the health benefits of desulfurising jet fuel or use of biofuels are likely higher as emissions throughout all phases of flight – not just at the airports – would be reduced.

Under a 2030 expanded-Heathrow scenario, up to 120 of the nationwide 250 early deaths per year could be averted by implementing all of the aforementioned mitigation measures. If the UK hub was moved to the Thames Estuary, 140 early deaths could be averted.

Finally, in addition to early deaths, UK airport emissions cause morbidity outcomes. Based on airport emissions today on an annual basis, these morbidity outcomes include upper and lower respiratory symptoms in asthmatic children (4400 cases) and asthma exacerbation in asthmatic children (2300), as well as lost work days (16,000) and minor restricted activity days (89,000). Mortality estimates in this study account for UK-specific factors, while the morbidity outcomes are based on a simple scaling from a congressionally mandated study of health impacts of US airports done at MIT.

4. Conclusions

UK airport emissions cause about 110 early deaths per year today, rising by 170% in 2030. Employing near-term mitigation measures could avert half of these impacts. Moving the UK hub airport (currently London Heathrow) to the Thames Estuary would reduce health impacts of UK airports by a quarter, and the health impacts of the UK hub specifically by 60-70%.

5. Further Information

This report summarises the contents of two peer-reviewed papers:

- M. E. J. Stettler, S. Eastham and S. R. H. Barrett, 2011. Air quality and public health impacts of UK airports. Part I: Emissions. *Atmospheric Environment* 45 (31), pp. 5415-5424. DOI: 10.1016/j.atmosenv.2011.07.012.
- Steve H.L. Yim, Marc E.J. Stettler, Steven R.H. Barrett. Air Quality and Public Health Impacts of UK Airports Part II: Impacts and Policy Assessment, 2012. To appear in *Atmospheric Environment*.

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