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The environmental effects of peak hour air traffic congestion: The case of London Heathrow Airport

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ABSTRACT

The commercial air transport sector currently faces the serious and seemingly incompatible challenge of meeting growing consumer demand for flight whilst reducing its environmental impact and meeting increasingly stringent international emissions targets. Growing demand for air travel combined with improvements in environmental performance in other industrial sectors means that commercial aviation has become a key focus for tackling climate change. The aim of this paper is to quantify the impacts of capacity-induced airport congestion using the case of London Heathrow Airport. The paper quantifies the environmental effect of airborne delays to inbound aircraft at the heavily constrained London Heathrow Airport on emissions and local air quality. The findings reveal that the additional CO_2 and NO_x emissions resulting from airborne delays are significant and will increase if capacity constraints on the ground are not addressed. The results are analysed in the context of Heathrow's climate change targets and current debates surrounding expansion and the challenge of reconciling environmental sustainability with aviation growth.

1. Introduction

Concern about the negative effects of commercial aircraft emissions on local air quality and the global climate remain high on public and political agendas. The air transport industry is committed to reducing its environmental externality effects by developing new more fuel-efficient technologies, exploring alternative fuel sources and by adopting more environmentally efficient operating procedures. However, incremental improvements in environmental performance are being offset by rising global consumer demand for flight and the concomitant increase in air traffic movements. The mismatch between growing demand for flights and a limited supply of runway slots is particularly acute in major world cities which have long been the epicentres of global aeronautical activity. The capacity constraints and the economic disbenefits that accrue from current levels of congestion are driving the development of new terminals, runways and airports but this process is highly controversial with the anticipated socio-economic benefits of airport growth juxtaposed against the negative socio-economic and environmental externalities of expansion.

Estimations of aviation's contribution to climate change are complicated by factors such as cloud enhancement and amplification by altitude, which are much less understood than other more general aspects of climate change. Lee et al. (2009) estimate that the contribution of aviation to the global problem of climate change is between 2% and 14% (including aviation-induced clouds). There are a number of different ways in which aviation impacts climate change, however the largest, most understood and most measurable is CO_2, and this will be the focus of this paper in terms of climate change.

In the European Union, aviation-derived CO_2 emissions alone have risen 110% between 1990 and 2008 to account for one fifth of the global total of aviation-derived CO_2 (Anger-Kraavi and Kohler, 2013). In an effort to limit and mitigate the effects of this pollution a range of international, national and local emissions targets have been introduced. The International Air Transport Association (IATA) has set a target of reducing global aviation CO_2 by 50% by 2050 (IATA, 2015) while the European Commission (EC, 2011) aims to reduce European aviation's CO_2 emissions by 75% and NO_x (nitrous oxide) emissions by 90% relative to the 2000 figure. In the UK, the Government's Committee on Climate Change established a target of stabilising CO_2 emissions at 2005 levels by 2050 in order to meet a national target of an 80% reduction in CO_2 relative to 1990

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(CCC, 2011). In addition, individual airports, such as London Stansted and East Midlands, have set challenging targets for reducing the carbon intensity of their operation. However, CO_2 is just one of a number of pollution species that contribute to anthropogenic climate change and concern is also being articulated about aviation's non-CO_2 effects and climate change impact of NO_x, carbon monoxide (CO), water vapour and contrails, methane, unburnt hydrocarbons (HCs or particulates) and non-methane volatile organic compounds.

Unsurprisingly, concentrations of these emissions are often high around the world's major airports. In order to minimise emissions it is imperative that aircraft are handled in the most environmentally efficient manner possible, but a lack of runway capacity means that many aircraft arriving at the world's most capacity constrained airports are required to fly racetrack-shaped holding patterns for several minutes before landing which significantly increases the fuel burnt and concentrates low altitude emissions over urban areas. A study by Reynolds et al. in 2009 revealed that holding and vectoring inbound aircraft was responsible for 25% of all airborne flight inefficiency in European airspace and that this practice accounted for an average track extension of 14 nautical miles on every intra-European service. Given the adverse environmental implications of airborne delays and the relative paucity of academic research into their effects, this paper studies arrivals during one peak hour period in January 2015 at London Heathrow and calculates the CO_2, HC, CO and NO_x emissions that are generated by aircraft in the hold.

The paper is structured into four sections. Following this introduction, section two reviews the salient literature on aviation, climate change and sustainability and identifies a need to better understand the environmental effects of peak hour air traffic congestion. In order to generate the dataset, an innovative data collection and analysis method was developed and deployed and this is detailed in section three. The results of the research are then presented and discussed in section four in the context of continued concern about air transport and urban climate change.

2. Literature review

The literature addressing commercial aviation's contribution to anthropogenic climate change has a long historical pedigree and the contemporary corpus of work is multidisciplinary, wide ranging and challenging. The crux of the issue is that when jet fuel is burnt in an aircraft's engines a range of gaseous and solid emissions, including carbon dioxide, carbon monoxide, water vapour, nitrous and sulphurous oxides, methane and particulate matter is emitted (Budd and Ryley, 2012). Depending on the altitude and latitude at which they are released, these pollution species can perturb the global climate and degrade local air quality (Popp, Bishop, & Stedman, 1999; Zhu, Fanning, Yu, Zhang, & Froines, 2011). Historically, CO_2 has been the focus of much of the research as its production is easy to quantify and its environmental effects are relatively easy to determine. However, despite attempts to limit aviation-derived CO_2 emissions through a raft of political instruments and industry targets, the difficulties inherent in attempting to attribute responsibility for aircraft emissions in international airspace has meant that aviation has not been included in the Kyoto Protocol and the decision to incorporate aviation within the EU's Emissions Training System has proved highly controversial.

As a consequence, the regulations governing emissions from international aviation remain highly fragmented and challenging to enforce. The UK, in common with many countries, has not been able to resolve the issue of which flights (or portion of flights) it is responsible for, as individual flights may originate and/or terminate overseas, be transporting passengers from multiple countries, be transiting the airspace of several nations for differing lengths of time en-route to its destination, and be operated by an airline based in another country. As such, only domestic aviation is included in the UK's carbon budget (DECC, 2012).

Although scientific uncertainty remains as to likely future CO_2 emissions from aviation, a comprehensive review of likely scenarios by Gudmundsson and Anger (2012) found a mean value of 2332 million tonnes of CO_2 for the year of 2050. This represents a 143% increase on the same figure for 2015. At a time when most industries are seeking to reduce their CO_2 emissions by as much as 75% and the Copenhagen accord aims to limit global increases in surface temperatures to no more than 2 °C, the impact of continued growth in aviation emissions will be significant (Bows-Larkin and Anderson, 2013).

In addition to research that examines the global climate impacts of CO_2 emissions, studies into the effects of aircraft emissions on local air quality have typically focused on the near-field effects on the population who live adjacent to an airport or under its final approach paths (Garnier, Baudoin, Woods, & Louisnard, 1997; Zhu et al., 2011). Of critical importance in understanding the impacts of these emissions is identifying the possibilities for reducing them and the relative merits of the different options that are available. The European Commission (2011) anticipated that the introduction of new technology would be the main mechanism for reducing aircraft emissions in the future while the Sustainable Aviation Group, a consortium of UK airlines, airports, airframe manufacturers and regulators, identified improvements in aircraft technology, more efficient operations, the use of alternative fuels and carbon trading as being four ways in which CO_2 emissions from aviation can be effectively reduced to around half of 2005 levels by 2050 even with an anticipated 150% growth (Sustainable Aviation, 2012).

Aircraft technologies have received considerable attention as a means of reducing aviation's CO_2 emissions. New aircraft, including the Boeing 787, feature lighter carbon composite materials and engines with higher bypass ratios. These lighter-weight airframes offer lower fuel consumption and a reduced environmental impact compared to older models. The 787 burns 13% less fuel than a 767 and 26% less than a 777 (EASA, 2015). However the delay in uptake of new technology associated with a 20–25 year airframe lifecycle and the high volume of emissions from the manufacturing process mean a full life-cycle analysis would need to be undertaken to truly quantify the net benefit from new equipment. According to Bows-Larkin and Anderson (2013), tackling aviation's climate challenge now will be critical in reducing the severity of improvements required in the future.

Looking instead at the possibilities for operational improvements, Nikoleris, Gupta, and Kistler (2011) studied the impacts of capacity constraints on taxi time and associated emissions. They concluded that taxiway congestion meant an increase in ground-based fuel burn of 35%. In terms of airspace, some progress has been made by air traffic service providers such as NATS (the air traffic service provider for the UK) to improve the flow of aircraft in their airspace. NATS estimate that their plans to introduce time based separation at Heathrow (in which aircraft are separated by time rather than distance) in early 2015 will cut delays by around 20 s per arrival while their 'free flight' trial proved that optimising the en-route track of flights conferred significant environmental benefits (NATS, 2014).

Emissions created by aircraft during holding patterns may have an impact on both the surrounding air quality and the global climate. However while emissions from aircraft at ground level are very well understood for their effects on air quality there remains a degree of uncertainty over the impacts associated with aircraft that

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