# AVIATION POLLUTION

DISSERTATION REPORT SUBMITTED FOR THE PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR

EXECUTIVE BBA (AVIATION OPERATIONS)

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Further, I certify that the work is based on the investigation made, data collected and Analyzed by him and it has not been submitted in any other University or Institution for Award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation
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## Executive Summary / Abstract:

Airport operations are an important factor in our economy, for tourism, imports, exports and business. However, these benefits must be weighed against the impact air travel is having on the quality of life of increasing numbers of people and on the local and global environment. Noise and air pollution – both from aircraft and from airport ground operations – are a problem for those who live, work and study around airports.

The most immediate impact of aircraft is noise whether it is the regular rumble of international jets or the buzz of microlights and light aircraft on sunny afternoons. The noise from airborne aircraft is related to air speed. Any fast-moving components, such as propellers and compressor blades, generate noise, as do the exhaust gases of jets. Aircraft are also responsible for an increasing proportion of air pollutant emissions, both at local and global level.

Aviation is a critical part of our national economy, providing for the movement of people and goods throughout the world, enabling our economic growth. In the last 35 years there has been a six-fold increase in the mobility provided by the U.S. air transportation system. At the same time there has been a 60% improvement in aircraft fuel efficiency and a 95% reduction in the number of people impacted by aircraft noise.

Immediate, focused action is required to address the interdependent challenges of aviation noise, local air quality and climate impacts. Not acting, as stated above, will not only affect millions of Americans living near airports but will adversely impact the vitality and security of our nation. A national vision and strategic plan of action are required.

The Commission is due to publish its interim report, assessing the most credible options for providing any new airport capacity, by the end of 2013. Criteria that the Commission is using to identify options include strategic, economic, surface access and environment. Environment criteria include air quality and noise. The Commission's final recommendations are expected by summer 2015.

Measures introduced to reduce noise include Noise Preferential Routes and restrictions on night flying. Maximum noise limits for departing aircraft are set and monitored and noise insulation schemes are in operation. Noise from aircraft on the ground is the responsibility of the airport operator. To comply with the EU Environmental Noise Directive, operators of airports with over 50,000 movements a year have been required to draw up Noise Action Plans (under criteria set for this 15 airports are designated in England, three in Scotland and one in N Ireland).

This document reports the results of a study mandated by the United States Congress in December
Public Law 108-176). Section 321 of the legislation mandates that the Secretary of Transportation,

in consultation with the Administrator of the National Aeronautics and Space Administration, shall conduct a study of ways to reduce aircraft noise and emissions and to increase aircraft fuel efficiency.

# CHAPTER 1

# INTRODUCTION

Airports and aircraft cause many types of air pollution at many different elevations and at considerable distances.

Of foremost concern to those living and working even as far as many miles from an airport or under aircraft flight tracks are these: hazardous and toxic air emissions.

Aircraft fly over head emitting these toxic compounds in massive amounts and these emissions are spread generally over an area 12 miles long, 12 miles wide on take-off, 12 - 6 miles on landing, (per runway and/or flight track).

The area heavily contaminated by a light to medium traffic two runway airport is approximately 12 miles around the field and 20 miles or more downwind. A single runway equipped airport with light to medium traffic contaminates an area about 6 miles around the field and 20 downwind. O'Hare Airport has seven runways; to date, an airport thoroughgoing study has never been undertaken.

Newer aircraft, even though emissions go relatively unseen, could be at least as bad at polluting as older aircraft for many reasons including production of smaller particulate matter, with different combustion processes, different formulations in fuel, etc.

Thus, the number of people exposed to aviation pollutants and who are affected in an airport's vicinity can be immense. In Chicago, for instance, a medical doctor who teaches clinical medicine at the University of Illinois-Chicago, School of Public Medicine, estimated that as many as 5-million people's health could be affected as a result of just one airport, O'Hare. There are four major airports located in the Chicago area. Similar conditions exist in other communities, nationally.

The United Nations has released a report stating that aviation is responsible for over half of the pollution caused by transportation. In comparison to ground transportation with its millions upon millions of vehicles, there are surprisingly few aircraft (34,444 US-civil, 5,778 US-commercial). Thus, one can only imagine the massive amounts of pollution they emit. A loaded jumbo 747, for instance, uses tens of thousands of pounds of fuel on merely take-off.

## 1.1 Some Facts About Fuel

One aircraft take-off can burn thousands of pounds of fuel.

Air pollution levels from one 747 takeoff is similar to setting the local gas station on fire and then flying it over your head!

The pollution from just one, two-minute 747 takeoff is equal to operating 2.4 million lawnmowers simultaneously. That's four states worth!

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**1.2 The Problem with Plane Deicing**

The chemicals used to deice aircraft are ethylene glycol and propylene glycol, both deadly substances in small quantities. Ethylene glycol causes central nervous depression and kidney and liver damage; propylene glycol, when used by the airports with anticorrosion chemicals, is just as toxic!

The lethal dose in adults is 1.4 ml or 3.3 fl. No studies have been done on its effects on humans. However, each winter large amounts of fish and wildlife are poisoned to death by aircraft deicing chemicals.

Additional pollutants, including fuels and other toxic substances, are also washed off the planes during deicing procedures. Currently, O'Hare has no method of recycling deicing fluids. Instead, these pollutants are released into the surrounding environment.

The number of aircraft operations (defined as one aircraft takeoff *or* landing) in the U.S. has grown substantially, from around 15 million in 1976 to almost 30 million in 2000, a cumulativegrowth of about 105 percent.

## 1.3 Environmental impact of aviation

The **environmental impact of aviation** occurs because aircraft engines emit heat, noise, particulates and gases which contribute to climate change and global dimming.[3] Despite emission reductions from automobiles and more fuel-efficient and less polluting turbofan and turboprop engines, the rapid growth of air travel in recent years contributes to an increase in total pollution attributable to aviation. In the European Union, greenhouse gas emissions from aviation increased by 87% between 1990 and 2006.

There is an ongoing debate about possible taxation of air travel and the inclusion of aviation in an emissions trading scheme, with a view to ensuring that the total external costs of aviation are taken into account.[5]

### Climate change

Like all human activities involving combustion, most forms of aviation release carbon dioxide ($CO_2$) and other greenhouse gases into the Earth's atmosphere, contributing to the acceleration of global warming and (in the case of $CO_2$) ocean acidification. These concerns are highlighted by the present volume of commercial aviation and its rate of growth. Globally, about 8.3 million people fly daily (3 billion occupied seats per year), twice the total in 1999.U.S. airlines alone burned about 16.2 billion gallons of fuel during the twelve months between October 2013 and September 2014.

In addition to the $CO_2$ released by most aircraft in flight through the burning of fuels such as Jet-A (turbine aircraft) or Avgas (piston aircraft), the aviation industry also contributes greenhouse gas emissions from ground airport vehicles and those used by passengers and staff to access airports, as well as through emissions generated by the production of energy used in airport buildings, the manufacture of aircraft and the construction of airport infrastructure.

While the principal greenhouse gas emission from powered aircraft in flight is $CO_2$, other emissions may include nitric oxide and nitrogen dioxide (together termed oxides of nitrogen or $NO_x$), water vapour and particulates (soot and sulfate particles), sulfur oxides, carbon monoxide (which bonds with oxygen to become $CO_2$ immediately upon release), incompletely burned hydrocarbons, tetra ethyllead (piston aircraft only), and radicals such as hydroxyl, depending on the type of aircraft in use. Emissions weighting factor (EWFs) i.e., the factor by which aviation $CO_2$ emissions should be multiplied to get the $CO_2$-equivalent emissions for annual fleet average conditions is in the range 1.3–2.9.

## 1.4 Mechanisms and Cumulative Effects of aviation on Climate

The contribution of civil aircraft-in-flight to global $CO_2$ emissions has been estimated at around 2%. However, in the case of high-altitude airliners which frequently fly near or in the stratosphere, non-$CO_2$ altitude-sensitive effects may increase the total impact on anthropogenic (human-made) climate change significantly. A 2007 report from Environmental Change Institute / Oxford University posits a range closer to 4 percent cumulative effect. Subsonic aircraft-in-flight contribute to climate change in four ways:

### Carbon dioxide ($CO_2$)

$CO_2$ emissions from aircraft-in-flight are the most significant and best understood element of aviation's total contribution to climate change. The level and effects of $CO_2$emissions are currently believed to be broadly the same regardless of altitude (i.e. they have the same atmospheric effects as ground based emissions). In 1992, emissions of $CO_2$ from aircraft were estimated at around 2% of all such anthropogenic emissions, and that year the atmospheric concentration of $CO_2$ attributable to aviation was around 1% of the total anthropogenic increase since the industrial revolution, having accumulated primarily over just the last 50 years.

### Oxides of nitrogen ($NO_x$)

At the high altitudes flown by large jet airliners around the tropopause, emissions of $NO_x$ are particularly effective in forming ozone ($O_3$) in the upper troposphere. High altitude (8-13km) $NO_x$ emissions result in greater concentrations of $O_3$ than surface $NO_x$ emissions, and these in turn have a greater global warming effect. The effect of $O_3$concentrations are regional and local (as opposed to $CO_2$ emissions, which are global)

$NO_x$ emissions also reduce ambient levels of methane, another greenhouse gas, resulting in a climate cooling effect. But this effect does not offset the $O_3$ forming effect of $NO_x$ emissions. It is now believed that aircraft sulfur and water emissions in the stratosphere tend to deplete $O_3$, partially offsetting the $NO_x$-induced $O_3$ increases. These effects have not been quantified. This problem does not apply to aircraft that fly lower in the troposphere, such as light aircraft or many commuter aircraft.

One of the products of burning hydrocarbons in oxygen is water vapour, a greenhouse gas. Water vapour produced by aircraft engines at high altitude, under certain atmospheric conditions, condenses into droplets to form Condensation trails, or contrails. Contrails are visible line clouds that form in cold, humid atmospheres and are thought to have a global warming effect (though one less significant than either $CO_2$ emissions or $NO_x$ induced effects).[1] Contrails are extremely rare from lower-altitude aircraft, or from propeller-driven aircraft or rotorcraft.

Cirrus clouds have been observed to develop after the persistent formation of contrails and have been found to have a global warming effect over-and-above that of contrail formation alone. There is a degree of scientific uncertainty about the contribution of contrail and cirrus cloud formation to global warming and attempts to estimate aviation's overall climate change contribution do not tend to include its effects on cirrus cloud enhancement.

## 1.5 Greenhouse gas emissions per passenger kilometre

Emissions of passenger aircraft per passenger kilometre vary extensively because of differing factors such as the size and type aircraft, the altitude and the percentage of passenger or freight capacity of a particular flight, and the distance of the journey and number of stops en route. Also, the effect of a given amount of emissions on climate (radiative forcing) is greater at higher altitudes: see below.

Some representative figures for $CO_2$ emissions are provided by LIPASTO's survey of average direct emissions (not accounting for high-altitude radiative effects) of airliners expressed as $CO_2$ and $CO_2$ equivalent per passenger kilometre

- Domestic, short distance, less than 463 km (288 mi): 257 g/km $CO_2$ or 259 g/km (14.7 oz/mile) $CO_2e$
- Domestic, long distance, greater than 463 km (288 mi): 177 g/km $CO_2$ or 178 g/km (10.1 oz/mile) $CO_2e$
- Long distance flights: 113 g/km $CO_2$ or 114 g/km (6.5 oz/mile) $CO_2e$

These emissions are similar to a four-seat car with one person on board;[19] however, flying trips often cover longer distances than would be undertaken by car, so the total emissions are much higher. For perspective, per passenger a typical economy-class New York to Los Angeles round trip produces about 715 kg (1574 lb) of $CO_2$ (but is equivalent to 1,917 kg (4,230 lb) of $CO_2$ when the high altitude "climatic forcing" effect is taken into account).

Within the categories of flights above, emissions from scheduled jet flights are substantially higher than turboprop or chartered jet flights. About 60% of aviation emissions arise from international flights, and these flights are not covered by the Kyoto Protocol and its emissions reduction targets.

## 1.6 Emissions by passenger class, and effects of seating configuration

In 2013 the World Bank published a study of the effect on $CO_2$ emissions of its staff's travel in business class or first class, versus using economy class. Among the factors considered was that these premium classes displace proportionately more economy seats for the same total aircraft space capacity, and the associated differing load factors and weight factors. This was not accounted for in prior standard carbon accounting methods.

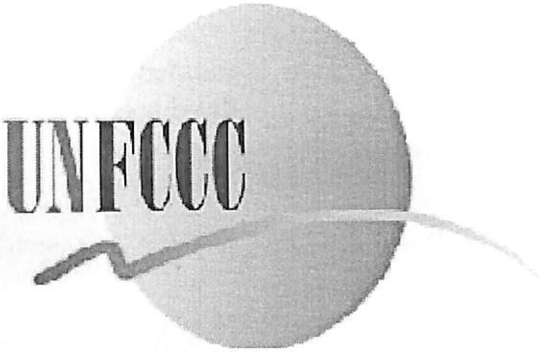
The study concluded that when considering respective average load factors (percent of occupied seats) in each of the seating classes, the carbon footprints of business class and first class are three-times and nine-times higher than economy class. A related article by the

International Council on Clean Transport notes further regarding the effect of seating configurations on carbon emission.

**Total climate effect**

- **United Nation Framework Convention on Climate Change (UNFCCC) 1992**
  - General commitment to reduce certain greenhouse gas emissions

- **Kyoto Protocol 1997 (2005)**



  - Specific targets for reductions
  - Developing countries exempt (for now)
  - Coverage of domestic aviation up to each country
  - International aviation subject to ICAO plan (per Article 2.2)
- **ICAO Decision in 2004**
  - Limit or reduce the impact from aviation greenhouse gas emissions on climate change

In attempting to aggregate and quantify the total climate impact of aircraft emissions the Intergovernmental Panel on Climate Change (IPCC) has estimated that aviation's total climate impact is some 2-4 times that of its direct $CO_2$ emissions alone (excluding the potential impact of cirrus cloud enhancement).This is measured as radiative forcing.

While there is uncertainty about the exact level of impact of $NO_x$ and water vapour, governments have accepted the broad scientific view that they do have an effect. Globally in 2005, aviation contributed "possibly as much as 4.9% of radiative forcing. UK government policy statements have stressed the need for aviation to address its total climate change impacts and not simply the impact of $CO_2$.

The IPCC has estimated that aviation is responsible for around 3.5% of anthropogenic climate change, a figure which includes both $CO_2$ and non-$CO_2$ induced effects. The IPCC has produced scenarios estimating what this figure could be in 2050. The central case estimate is that aviation's contribution could grow to 5% of the total contribution by 2050 if action is not taken to tackle these emissions, though the highest scenario is 15%. Moreover, if other industries achieve significant cuts in their own greenhouse gas emissions, aviation's share as a proportion of the remaining emissions could also rise.

### 1.7 Future emission levels

Even though there have been significant improvements in fuel efficiency through aircraft technology and operational management as described here, these improvements are being continually eclipsed by the increase in air traffic volume.

***Continual increases in travel & freight***

From 1992 to 2005, passenger kilometers increased 5.2% per year, even with the disruptions of 9/11 and two significant wars. Since the onset of the current recession:

"During the first three quarters of 2010, air travel markets expanded at an annualized rate approaching 10%. This is similar to the rate seen in the rapid expansion prior to the recession. November's results mean the annualized rate of growth so far in Q4 drops back to around 6%. But this is still in line with long run rates of traffic growth seen historically. The level of international air travel is now 4% above the pre-recession peak of early 2008 and the current expansion looks to have further to run.

"Air freight reached a new high point in May (2010) but, following the end of inventory restocking activity, volumes have slipped back to settle at a similar level seen just before the onset of recession. Even so, that means an expansion of air freight during 2010 of 5-6% on an annualized basis – close to historical trend. With the stimulus of inventory restocking activity removed, further growth in air freight demand will be driven by end consumer demand for goods which utilize the air transport supply chain. ... The end of the inventory cycle does not mean the end of volume expansion but markets are entering a slower growth phase.

... as is the environmental footprint...

**Preliminary Emissions for NextGen 2X Growth Scenario**

| | |
|---|---|
| *HC* | *+ 75%* |
| *CO* | *+ 70%* |
| *NOx* | *+ 90%* |
| *SOx* | *+ 85%* |

In a 2008 presentation and paper Professor Kevin Anderson of the Tyndall Centre for Climate Change Research showed how continued aviation growth in the UK threatens the ability of that nation to meet $CO_2$ emission reduction goals necessary to contain the century-end temperature increase to even 4 or 6C°.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 HISTORY

In 2011, approximately 200 million passengers passed through mainland UK airports. This was a return to growth, following a recent period of decline in passenger numbers and air transport movements between 2007 and 2010. Government forecasts predict that this will rise to 255 million in 2020 and 313 million in 2030.

Airport operations are an important factor in our economy, for tourism, imports, exports and business. However, these benefits must be weighed against the impact air travel is having on the quality of life of increasing numbers of people and on the local and global environment. Noise and air pollution – both from aircraft and from airport ground operations – are a problem for those who live, work and study around airports.

The most immediate impact of aircraft is noise - whether it is the regular rumble of international jets or the buzz of microlights and light aircraft on sunny afternoons. The noise from airborne aircraft is related to air speed. Any fast-moving components, such as propellers and compressor blades, generate noise, as do the exhaust gases of jets. Aircraft are also responsible for an increasing proportion of air pollutant emissions, both at local and global level.

The Government has set up the Airports Commission, chaired by Sir Howard Davies, to look at long-term airport capacity issues in the UK. The Commission is examining the scale and timing of any requirement for additional capacity, focusing in particular on aviation hub issues, and identifying how any need for additional capacity should be met in the short, medium and long term.

The Commission is due to publish its interim report, assessing the most credible options for providing any new airport capacity, by the end of 2013. Criteria that the Commission is using to identify options include strategic, economic, surface access and environment. Environment criteria include air quality and noise. The Commission's final recommendations are expected by summer 2015.

Despite this progress, and despite aviation's relatively small environmental impact in the United States, there is a compelling and urgent need to address the environmental effects of air transportation. Because of strong growth in demand, emissions of some pollutants from aviation are increasing against a background of emissions reductions from many other sources. In addition, progress on noise reduction has slowed.Millions of people are adverselyaffected by these side effects of aviation.

As a resultof these factors and the rising value being placed on e nvironmentalquality, there are increasing constraints on the mobility,economic vitality and security of the nation. Airport expansionplans have been delayed or canceled due to concerns overlocal air quality, water quality and community noise impacts.Military readiness is challenged by restrictions on operations. These effects are anticipated to grow as the economy and demandfor air transportation grow. If not addressed, environmental impacts may well be the fundamental constraint on airtransportation growth in the 21st century.The concerns extend well beyond American shores. For example, within the EuropeanUnion (EU) the climate impacts of aviation are identified as the most significant adverseimpact of aviation, in contrast to the United States and many other nations where air qualityand noise are the current focus of attention.

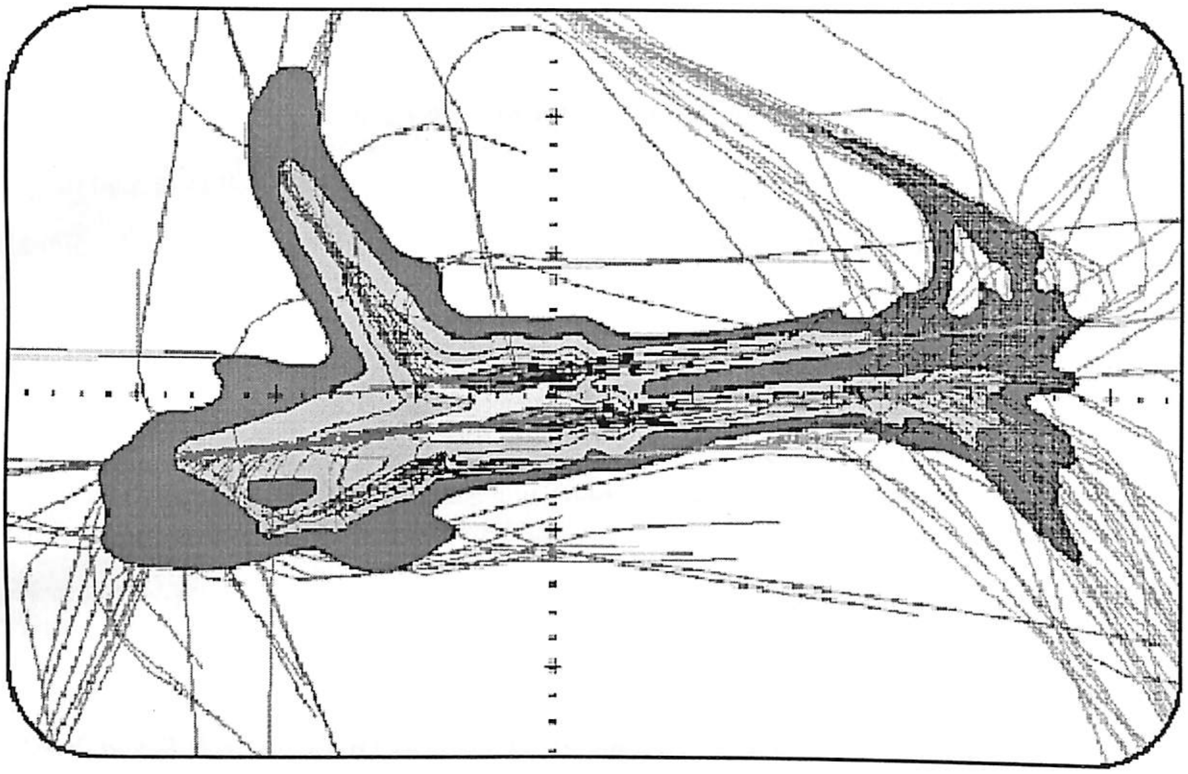
The International Civil Aviation Organisation (ICAO) is responsible for drawing up aviation noise standards with the European Civil Aviation Conference, and UK standards are set in accordance with these.

Currently the Government only has direct responsibility for aircraft noise management at Heathrow, Gatwick and Stansted. Measures introduced to reduce noise include Noise Preferential Routes and restrictions on night flying. Maximum noise limits for departing aircraft are set and monitored and noise insulation schemes are in operation. Noise from aircraft on the ground is the responsibility of the airport operator.

To comply with the EU Environmental Noise Directive, operators of airports with over 50,000 movements a year have been required to draw up Noise Action Plans (under criteria set for this 15 airports are designated in England, three in Scotland and one in N Ireland).

Noise limits have been introduced at the designated airports to cover the period 0700h – 2300h. Airport companies are responsible for monitoring compliance and breaches are subject to a financial penalty. Night flights are restricted between 2300h – 0600h and airports are given quotas of the number of night movements of noisier aircraft allowed to land during these periods.

Environmental Protection UK believes that any developments or alterations to the UK aviation infrastructure, air operations or flight scheduling, should not result in an increase to the night-time or day-time noise exposure of either the general population or of individual communities. Where an increase in exposure is unavoidable, a full package of mitigation measures should be offered to those affected, and the costs of such measure should be met by the aviation industry.



The FAA Integrated Noise Model (INM) is the principal tool used around the world for assessing the noise of aircraft around airports. Shown here are contours of day-night noise level (blue = 55dB-65dB, green = 65dB-75dB) and departure and arrival flight tracks (blue and red respectively) for a major international airport

## 2.2 Addressing aviation pollution

Environmental Protection UK is concerned at the potential impact of the apparent 'predict and provide' approach that is being taken to air travel in the UK and we would like to see the environmental impacts caused by any expansion reduced or avoided. We will be following the recommendations of the Airports Commission with interest.

We would like to see aviation policies developed in a way which is consistent with the approach used for other transport sectors, and aviation should be fully bedded into an integrated transport policy, rather than being treated as a separate issue.

The Government should also seek to reduce the environmental and social harm arising from aviation through a balanced programme of progressive introduction of improved technology, better operational practice and demand management. Where new infrastructure is required, or where existing capacity is expanded, the mitigation of further environmental and social harm should be seen as a key priority.

Action to reduce the environmental and social harm caused by aviation will require international cooperation. The Government should adopt a leading and active role in international debate, particularly within the European Union, and should encourage the development of radical and innovative solutions.

Environmental Protection UK has been lobbying the Government on aviation pollution, and responded to the consultation on the Draft Aviation Policy Framework.

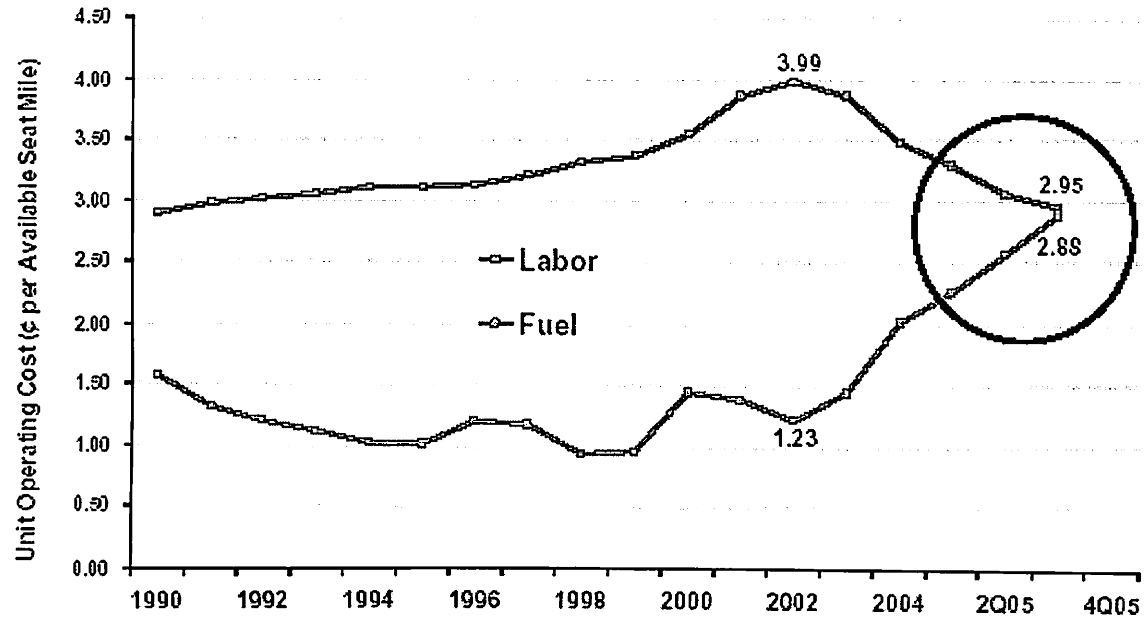
### 1.3 Surface access

Planning development to meet the projected increased demand in passenger air traffic is also a cause for concern. While emissions from road vehicles are expected to decrease, this will be offset by growth in surface access movements around airport. Increasing capacity in more rural areas will lead to the erosion of tranquillity, loss of habitats for wildlife and increased surface traffic.

The environmental impact of aviation must include the impact of surface access to airports, and given that passengers, employees and goods often travel considerable distances to reach certain airports, this must be considered across the widest possible geographical context.

Where any airport infrastructure development occurs, either as new build or extension to existing infrastructure, surface access infrastructure must be planned, funded and delivered as an integral and wholly necessary part of the project. It should therefore be a condition of any new airport infrastructure development that the necessary surface access infrastructure be in place in its entirety before the airport facility comes into use.

## Cost and taxation



Under international law, aviation fuel for international flights is exempt from taxation, which means air travel is relatively cheap. This also reduces the incentive for airlines to invest in more efficient aircraft. Aircraft operators are included within the European Union Emissions Trading Scheme. They could be further incentivised via fuel tax (which could be levied for domestic flights). This could:

- ensure airlines pay for the pollution they cause, like other transport operators
- encourage the development of more fuel-efficient aircraft
- help reduce the demand for air travel as other options become more competitive
- be consistent with UK pledges to reduce greenhouse gas emissions from airport operations

Policy should progressively seek an equitable cost/taxation basis across all modes of transport. In particular, all possible attempts should be made to ensure that the costs of aviation fully include the environmental and social costs, in accordance with the "polluter pays" principle.

The Government should also acknowledge the fact that the tax free status of aviation fuel effectively acts as a subsidy for the aviation industry, and should therefore fully factor this into its economic analysis of the costs and impacts of the industry.

## 2.4 Operational Options

In addition, airlines have worked collaboratively with the FAA to implement many measures to reduce fuel burn and emissions. These measures include reduced auxiliary power unit usage, single engine taxiing, coordination with air traffic control centers to select more fuel-efficient routes and speeds, reduced levels of excess fuel carried, and more regular maintenance and cleaning of engines and airframes to correctminor deterioration, among other measures.

There are also significant opportunities forreduced fuel burn, noise and emissions, both local and enroute, from major infrastructurechanges such as the National Airspace Redesign and modernization of the air trafficmanagement system.Operational procedures will provide the greatest near term benefits for both noise andemissions.

A significant new program should be established to accelerate the assessment,development, and implementation of operational strategies for reducing noise and emissions.The program should be built upon existing NASA and FAA efforts in this area. Theprogram should address community noise impacts, local air quality impacts and climateimpacts of aviation and thus should focus on both airport-area operations and enrouteoperations.

## Land-use and other policy options

New policies and programs will be required to provide incentives and funding opportunitiesto enable the adoption of best practices for reducing the environmental impacts of aviation.

One recent example of such a program is the Voluntary Airport Low Emissions (VALE) program, a national program designed to reduce airport ground emissions at commercialservice airports located in air quality nonattainment and maintenance areas. This programwas mandated by the United States Congress in the *Vision 100 — Century of Aviation ReauthorizationAct* (P.L. 108-176).

This statute directed the FAA to establish a national program to provide airport sponsors with financial and regulatory incentives to take early action to reduce airport emissions using proven low emission technologies. The VALE program allows airport sponsors to use the Airport Improvement Program (AIP) and PassengerFacility Charges to finance the airport air quality improvements.

Funding for the program is being made available under the new Noise Abatement/ Air Quality “Set-Aside” within the AIP. Eligible vehicles include ground service equipment, airport service and security vehicles, and parking lot shuttles and buses.

Under the new legislative guidelines, the FAA, in consultation with the EPA, is required to issue guidance that will ensure airport sponsors receive appropriate airport emission reduction credits forVALE projects. Although there are likely to be many opportunities for innovative policies, one of the most pressing needs is in the area of land-use planning around airports.

Community noise is the most significant environmental impediment to expanding airports to satisfy mobility needs. There is also sample evidence that local land-use decisions around airports contribute to the problem. Therefore, we recommend that a new program be developed to address the disconnect between federal aviation policy andlocal land-use decision-making. This program should be built upon the Land-Use Planning Initiative (LUPI) that the FAA initiated in 1999 to develop processes by which the agency can better influence land-use planning and zoning around airports.

One of the products of this initiative was the formation of an Airport Compatibility Planning Committee. This committee provides an opportunity for interaction among federal government agencies, planning organizations, airports, state and local governments, and public interest groups involved with airport compatibility planning issues.

# CHAPTER 3

## RESEARCH DESIGN, METHODOLOGY AND PLAN

From 1992 to 2005, passenger kilometers increased 5.2% per year, even with the disruptions of 9/11 and two significant wars. Since the onset of the current recession:

"During the first three quarters of 2010, air travel markets expanded at an annualized rate approaching 10%. This is similar to the rate seen in the rapid expansion prior to the recession. November's results mean the annualized rate of growth so far in Q4 drops back to around 6%. But this is still in line with long run rates of traffic growth seen historically. The level of international air travel is now 4% above the pre-recession peak of early 2008 and the current expansion looks to have further to run.
"Air freight reached a new high point in May (2010) but, following the end of inventory restocking activity, volumes have slipped back to settle at a similar level seen just before the onset of recession. Even so, that means an expansion of air freight during 2010 of 5-6% on an annualized basis – close to historical trend. With the stimulus of inventory restocking activity removed, further growth in air freight demand will be driven by end consumer demand for goods which utilize the air transport supply chain. ... The end of the inventory cycle does not mean the end of volume expansion but markets are entering a slower growth phase.

In a 2008 presentation and paper Professor Kevin Anderson of the Tyndall Centre for Climate Change Research showed how continued aviation growth in the UK threatens the ability of that nation to meet $CO_2$ emission reduction goals necessary to contain the century-end temperature increase to even 4 or 6C°. (See also: the 4 Degrees and Beyond International Climate Conference (2009)and its proceedings.) His charts show the projected domestic aviation carbon emission increase for the UK as growing from 11 MT in 2006 to 17 MT in 2012, at the UK's historic annual emission growth rate of 7%. Beyond 2012 if the growth rate were reduced to 3% yearly, carbon emissions in 2030 would be 28 MT, which is 70% of the

UK's entire carbon emissions budget that year for all sectors of society. This work also suggests the foreseeable future which confronts many other nations that have high dependency on aviation. "Hypermobile Travelers, an academic study by Stefan Gössling et al. (2009) in the book "Climate Change and Aviation,also points to the dilemma caused by the increasing hypermobility of air travelers both in particular nations and global .

## 3.1The scope for improving efficiency, to reduce emissions

While it is true that late model jet aircraft are significantly more fuel efficient (and thus emit less $CO_2$ in particular) than the earliest jet airliners, new airliner models in the first decade of the 21st Century were barely more efficient on a seat-mile basis than the latest piston-powered airliners of the late 1950s .Claims for a high gain in efficiency for airliners over recent decades (while true in part) has been biased high in most studies, by using the early inefficient models of jet airliners as a baseline. Those aircraft were optimized for increased revenue, including increased speed and cruising altitude, and were quite fuel inefficient in comparison to their piston-powered forerunners.

Today, turboprop aircraft - probably in part because of their lower cruising speeds and altitudes (similar to the earlier piston-powered airliners) compared to jet airliners - play an obvious role in the overall fuel efficiency of major airlines that have regional carrier subsidiaries. For example, although Alaska Airlines scored at the top of a 2011-2012 fuel efficiency ranking, if its large regional carrier - turbo-prop equipped Horizon Air - were dropped from the lumped-in consideration, the airline's ranking would be somewhat lower, as noted in the ranking study.

Aircraft manufacturers are striving for reductions in both $CO_2$ and NOx emissions with each new generation of design of aircraft and engine.While the introduction of more modern aircraft represents an opportunity to reduce emissions per passenger kilometre flown, aircraft are major investments that endure for many decades, and replacement of the international fleet is therefore a long-term proposition which will greatly delay realizing the climate benefits of many kinds of improvements. Engines can be changed at some point, but nevertheless airframes have a long life. Moreover, rather than being linear from one year to the next the improvements to efficiency tend to diminish over time, as reflected in the histories of both piston and jet powered aircraft.

### *3.2 Operations efficiency*

Adding an electric drive to the airplane's nose wheel may improve fuel efficiency during ground handling. This addition would allow taxiing without use of the main engines.

Other opportunities arise from the optimisation of airline timetables, route networks and flight frequencies to increase load factors (minimise the number of empty seats flown),together with the optimisation of airspace. However, these are each one-time gains, and as these opportunities are successively fulfilled, diminishing returns can be expected from the remaining opportunities.

Another possible reduction of the climate-change impact is the limitation of cruise altitude of aircraft. This would lead to a significant reduction in high-altitude contrails for a marginal trade-off of increased flight time and an estimated 4% increase in $CO_2$ emissions. Drawbacks of this solution include very limited airspace capacity to do this, especially in Europe and North America and increased fuel burn because jet aircraft are less efficient at lower cruise altitudes.

While they are not suitable for long-haul or transoceanic flights, turboprop aircraft used for commuter flights bring two significant benefits: they often burn considerably less fuel per passenger mile, and they typically fly at lower altitudes, well inside the tropopause, where there are no concerns about ozone or contrail production.

### ***Life-cycle assessment of emissions by airliners made of composites***

A life-cycle assessment of the cradle-to-grave energy consumption of airliners made of carbon-fiber-reinforced polymer (CFRP) has shown that by 2050 such aircraft could result in a 14-15% reduction in $CO_2$ emissions by the airline industry, compared to conventional airliners. The study considers the $CO_2$ emissions of the construction, operation and eventual disposal of aircraft like the Boeing 787. While the emissions reduction for an individual aircraft is estimated to be 20%, the study arrived at the 14-15% fleet-wide estimate "because of the limited fleet penetration by 2050 and the increased demand for air travel due to lower operating costs."

In addition, there are also several tests done combining regular petrofuels with a biofuel. For example, as part of this test Virgin Atlantic Airways flew a Boeing 747 from LondonHeathrow Airport to Amsterdam Schiphol Airport on 24 February 2008, with one engine burning a combination of coconut oil and babassu oil. Green peace's chief scientistDoug Parr said that the flight was "high-altitude  green wash" and that producing organic oils to make bio fuel could lead to deforestation and a large increase in greenhouse gas emissions.Also, the majority of the world's aircraft are not large jetliners but smaller piston aircraft, and with major modifications many are capable of using ethanol as a fuel. Another consideration is the vast amount of land that would be necessary to provide the biomass feedstock needed to support the needs of aviation, both civil and military.

In December 2008, an Air New Zealand jet completed the world's first commercial aviation test flight partially using jatro pha-based fuel. Jatropha, used for biodiesel, can thrive on marginal agricultural land where many trees and crops won't grow, or would produce only slow growth yields. Air New Zealand set several general sustainability criteria for its Jatropha, saying that such biofuels must not compete with food resources, that they must be as good as traditional jet fuels, and that they should be cost competitive with existing fuels.

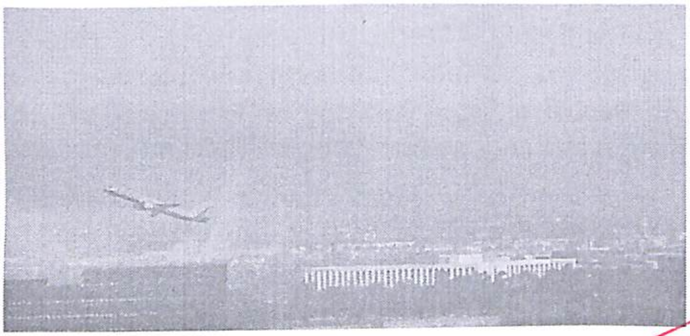
In January 2009, Continental Airlines used a sustainable biofuel to power a commercial aircraft for the first time in North America. This marks the first sustainable biofuel demonstration flight by a commercial carrier using a twin-engined aircraft, a Boeing 737-800, powered by CFM International CFM56-7B engines. The biofuel blend included components derived from algae and jatropha plants.

One fuel biofuel alternative to avgas that is under development is Swift Fuel. Swift fuel was approved as a test fuel by ASTM International in December 2009, allowing the company to continue their research and to pursue certification testing. Mary Rusek, president and co-owner of Swift Enterprises predicted at that time that "100SF will be comparably priced, environmentally friendlier and more fuel-efficient than other general aviation fuels on the market".

As of June 2011, revised international aviation fuel standards officially allow commercial airlines to blend conventional jet fuel with up to 50 percent biofuels. The renewable fuels "can be blended with conventional commercial and military jet fuel through requirements in the newly issued edition of ASTM D7566, Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons.

In December 2011, the FAA announced it is awarding $7.7 million to eight companies to advance the development of drop-in commercial aviation biofuels, with a special focus on ATJ (alcohol to jet) fuel. As part of its CAAFI (Commercial Aviation Alternative Fuel Initiative) and CLEEN (Continuous Lower Emissions, Energy and Noise) programs, the FAA plans to assist in the development of a sustainable fuel (from alcohols, sugars, biomass, and organic matter such as pyrolysis oils) that can be "dropped in" to aircraft without changing current infrastructure. The grant will also be used to research how the fuels affect engine durability and quality control standards.

### 3.3 Reducing air travel



"Aviation has been growing faster than any other source of greenhouse gases. Between 1990 and 2004, the number of people using airports in the UK rose by 120%, and the energy the planes consumed increased by 79%. Their carbon dioxide emissions almost doubled in that period - from 20.1 to 39.5 megatonnes, or 5.5% of all the emissions this country produces. Unless something is done to stop this growth, flying will soon overwhelm all the cuts we manage to make elsewhere. But the measures the government proposes are useless.

Thought on how to grapple with this unsustainable growth, and even to reduce air travel from its present level in order to avoid dangerous climate change, seems to be most prominent in the UK. Although the specifics differ globally, this work in the UK is likely to be widely applicable.

## 3.4 Policy Strategies for Reducing Airport Emissions

Chapter III describes technological and operational measures for reducing emissions from aircraft, ground service equipment, and ground access vehicles at airports. This chapter discusses policy strategies that could be used to compel or encourage the implementation of the technologica land operational options to reduce emissions that were discussed in the previous chapter.

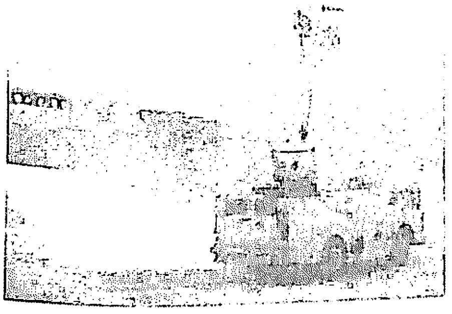
This chapteris divided into two sub-sections. The first subsection discusses the general regulatory approaches that states and potentially localities could utilize, and the second subsection consists of case studies of programs that have been proposed or implemented at airports. Due to statutory or legal constraints -- or in some cases for political reasons-- some of the approaches described in the firstportion of the chapter may not be available to environmental regulators, especially at the state andlocal levels.

Notwithstanding, there are a variety of strategies that could be pursued. The innovativeapproaches described in the second portion of the chapter highlight how a number of the approaches mentioned in the first portion of the chapter have been applied in practice, some using a combination of policies. In most cases, these efforts encompass a range of emissions reducing measures.

### Policy Options

This sub-section covers a number of the more promising regulatory opportunities for state and local policymakers to reduce airport-related emissions. Specifically, this portion of the chapterdiscusses: (1) standards and activity restrictions; (2) more innovative regulatory approaches likeemissions-based fees, cap-and-trade, and " bubble" programs; (3) initiatives targeted at GSE and commercial GAV fleets; and (4) efforts to increase high-speed rail and reduce passenger GAV tripsto the airport. For each policy, a general overview of the approach is discussed, along with severalof the key design considerations and advantages of the option. While some of the potential legalbarriers are highlighted, Chapter V provides greater detail on applicable legal considerations and preemption issues.

## 3.5 Emissions Standard



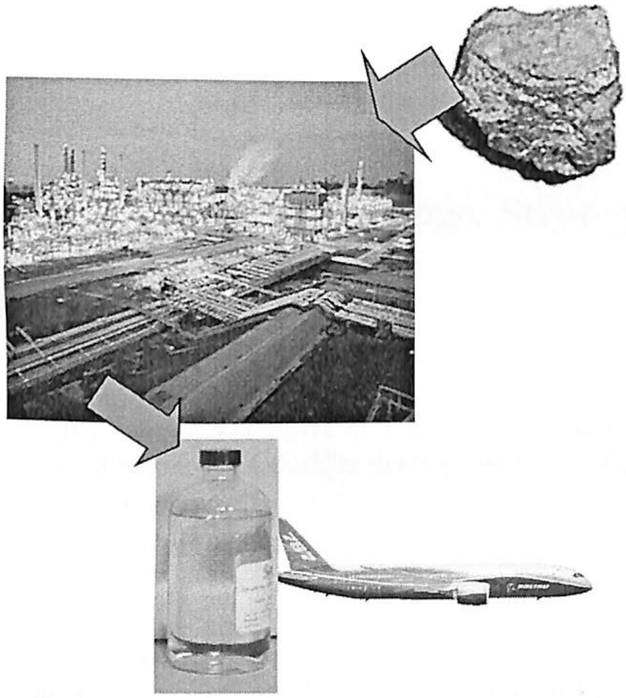
Emissions standards represent a viable mechanism for promoting the introduction of cleaner aircraft and equipment at airports. This command-and-control approach played an important role inpast regulatory efforts to improve air quality in the U.S. and has dramatically reduced emissions from pollution sources as diverse as automobiles, waste incinerators and architectural coatings.

As a regulatory option, emissions standards have a number of important advantages. Chief among these is that they can provide certain, lasting, and substantial air quality benefits within a defined timeframe. Applied across a broad source category such as automobiles or aircraft, the cost of achieving standards on a per unit basis tends to be low and widely distributed among manufacturers and consumers.

Moreover, standards can have an important technology forcing effecton driving future innovations in emissions control. Implementing this regulatory approach poses its own political, technical, and procedural challenges.

Typically, a legislative mandate is followed by a rulemaking process where the feasibility and cost-effectiveness of achieving different emissions limits is evaluated. It often involves extensive coordination among different federal agencies, public notice and comment, and, in some cases, legal action by one or more stakeholders. The following section discusses how emissions standards could be applied to aircraft, GSE and GAV.

### *Aircraft Standards*



Substantial reductions in aircraft emissions appear to be technically feasible through a combination of improved engine designs, structural innovations, and materials advances.105 While aircraft manufacturers will have some incentive to incorporate these changes even without regulatory intervention -- for reasons such as increasing aircraft capacity or reducing fuel consumption --emissions standards could greatly accelerate the rate at which pollution-reducing technology innovations penetrate the commercial aircraft fleet.

As discussed more fully in the next chapter, federal law currently provides the EPA with sole standard setting authority over aircraft engines. The U.S. has elected to conform its aircraft engine emissions standards to those developed by ICAO.106 ICAO standards for aircraft engine emissions have been in place since 1981, when ICAO established its first SARP for aircraft. This first SARP covered emissions of NOX, CO, and HC. These standards were amended in 1993 (commonly referred to as the "CAEP/2 standards" ) to establish a more stringent standard for NOX, which was equivalent to a 20 percent reduction over the 1981 ICAO NOX emissions standards.

The CAEP/2 standards took effect in 1996 for all newly certified engines and in 2000 for all newly manufactured engines.107 The standards were adopted by EPA in 1997, and are the current standards for aircraftengine emissions.108 In April 1998, during the fourth CAEP meeting, a NOX standard 16 percent more stringent than the CAEP/2 NOx standard was recommended. These CAEP/4 standards take effect in 2004. Since these new standards have been included in Annex 16, contracting states are xpected to adopt them;

EPA also plans to adopt them in the near future. While the new standards will affect engines certified after 2004, they will not require manufacturers to cease production of engines designed under the previous standard (Figure IV-1). A new NOx standard and production cut-off for the CAEP/4 standard is being considered at the next CAEP meeting (CAEP/6) in early 2004. Given that some engine and aircraft designs remain in circulation for many years – the average age of the U.S. fleet is about 11 years -- large decreases in emissions may not materialize for several years.

In the context of noise emissions from aircraft, ICAO has resolved this lag in technology uptake by recommending the phase-out of older aircraft.110 A similar approach, or one involving incentives for early retirement of older aircraft, could prove useful in spurring greater uptake of newer aircraft in airline fleets.

## 3.6 Innovative Regulatory Strategies for Reducing GSE and GAV Fleet Emissions

In addition to the regulatory approaches discussed previously in this chapter for limiting emissions from airports as a whole, or from aircraft as a particular source category, regulatory options may be available for limiting GSE and GAV fleet emissions. This section discusses howairport operators might craft control programs for either GSE or GAV fleets by: (1) promoting orrequiring the purchase of cleaner alternatives when fleet vehicles or equipment are replaced or added; (2) developing a declining fleet emissions target; and (3) adopting a combined approach that utilizes both of these strategies.

The federal Urban Bus Program[139] provides a useful model; though it targets only particulate emissions, it could readily be adapted for other pollutants. [140] An approach modeled after the Urban Bus Program would incorporate a performance-based requirement and a fleet-averaging mechanism. Affected vehicles would be required to meet a specific emissions standard at the time the engine is rebuilt or replaced.

The requirement would be automatically waived if no engines certified to meet the standard are available for less than a specified cost.[141] The program would contain " fallback" requirements specifying that "waived" engine families must be retrofitted to achieve a minimum percent reduction in emissions, relative to levels emitted with the original engine configuration. For airport-related vehicles, similar performance standards could be established for airport buses, shuttles and taxis, as well as for ground service equipment.

Maximum stringency in the case of GAV might be CNG or electric technology; for GSE, electric machines would likely represent the cleanest commercially available technology. Rather than being subjected to performance standards on an engine-by-engine basis, fleet operators would have the option of meeting a declining annual average emissions target across their entire fleets.

The target level for each fleet (TLF) would be calculated for each year of the program. For any given year, the average emissions rate from all of the operator' s vehicles with a model year that is earlier than the beginning date of the program (e.g., 1994) must be at or below the TLF established for that calendar year.

The requirement would apply until all pre-1994 vehicles have been retired from the operator' s fleet. Under the Urban Bus Program, TLFs are based on EPA' s determination of the projected emission level for each engine model year in the operator' s pre-1994 model year urban bus fleet.

## 3.7 Impacts of Airplane Pollution on Climate Change and Health

In reality, airplanes accomplish the miraculous feat of hurling hundreds of thousands of pounds of people, baggage, and aluminum thousands of miles at high speeds by consuming huge amounts of fossil fuels. In the process, airlines dump massive amounts of dangerous pollutants over our homes and into our atmosphere every day. This great but largely invisible harm will continue to grow at an accelerating rate in the years to come.

Airplanes have three major problems: they are inefficient, they are big, and they run on toxic fuels. A fully laden A380, according to its' engine maker Rolls Royce, uses as much energy as 3,500 family cars, equivalent to six cars for each passenger. Long haul flights produce on average twice as much emissions per mile traveled per passenger than cars and short haul flights produce three times as much.

Unlike cars, however, people do not use airplanes for a few minutes each day to travel just around the corner for groceries or into the office. People fly hundreds or thousands of miles on each flight and airplanes spend many hours each day aloft. A single round trip flight from New York to Europe or San Francisco produces two to three tons of carbon dioxide per person.[2] To put this in perspective, the average American generates 19 tons of carbon dioxide and the average European produces ten over an entire year. A few flights, in other words, can completely overwhelm any attempts to reduce your personal contribution to global warming.

Airplanes achieve such extraordinary levels of energy consumption and carbon emissions by burning large quantities of toxic jet fuel. This fuel produces, in addition to carbon dioxide, NOx, sulphates, and particulate matter, all of which amplify the impact of aviation on global warming. Airplanes emit all of these pollutants directly into the atmosphere, compounding the pollutants' warming impact. Even those innocuous-looking contrails trap heat on the Earth's surface. The combined effect of all of these pollutants multiplies the global warming impact of aviation, making aviation currently responsible for an estimated 5% of global climate pollution.

The burning of incredible quantities of toxic fuel has impacts that extend beyond the climate. As soon as airplanes leave the gate, they begin to produce phenomenal amounts of nitrogen oxides (NOx), carbon monoxide, particulate matter, and cancer-causing toxics such as benzene and formaldehyde.[3] This pollution travels miles downwind, contributing to asthma, lung and heart disease, and a large number of cancers.

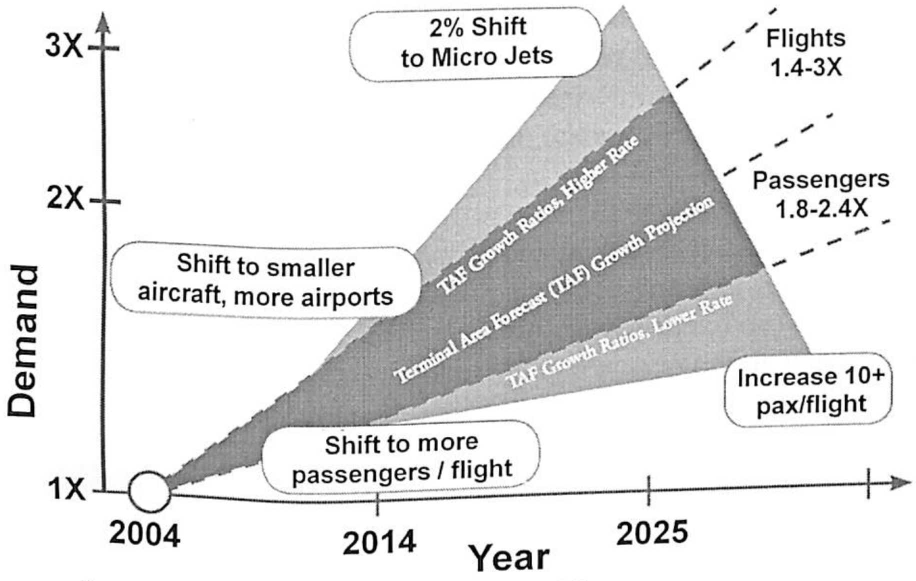
The emissions from taxiing and take-off of aircraft help make airports some of the largest sources of these pollutants and major public health hazards. For example, Los Angeles Airport is the largest source of NOx, a key cause of the region's copious smog, in California and the third largest source of carbon monoxide.

Logan Airport in Boston, MA produces twice as much benzene as the next largest source in Massachusetts. [5] Scientists have found that even small increases in taxi time at airports in Southern California contribute to significant increases in asthma, respiratory ailments, and heart disease in surrounding communities. [6] Scientists also believe that particulate matter emissions from airplanes, along with ships and trains, contribute to 1,800 early deaths per year in the United Kingdom alone. These health impacts also translate into large economic costs for society.

All of these climate, health, and economic impacts will escalate enormously in the future as more and more people around the world fly. Analysts expect the global aviation industry to grow by 5% per year for the next two decades. [8] At this rate, the size of the industry will double in 15 years and triple in 23. Scientists expect aviation carbon dioxide emissions to double by 2030, bringing with them more toxic pollution. [9] Airplanes have become more efficient and less polluting over time. But these small gains have and will continue to be overwhelmed by the gross inefficiency of the activity and the rapid growth of the industry.

Despite their shiny chrome exterior, an airplane, just like a power plant or an oil refinery, is dirty. Worse still, it is an industry on the move, growing in size and pollution in leaps and bounds. The governments of the world have the opportunity to dramatically cut airplane pollution, and help the climate. But until United Airlines and other airlines clean up their operations and support common sense, low-cost emissions reduction policies, aviation pollution will just keep growing, hurting local communities and the global climate.

## 3.8 National Vision For Aviation and the Environment



**Source: NextGen Integrated Plan, 2004**

The consensus of the stakeholders who participated in this study is that immediate, focused action is required within the United States to jointly address the interdependent challenges of aviation noise, local air quality and climate impacts. For this, a national vision and strategic plan of action are required.

The stakeholders who participated come from 38 organizations that span the aerospace industry, NASA, FAA, EPA, DOC, DoD, academia, local government and community activists. When they were asked to define a vision for success, some diverging views were expressed, but there were many more elements in common among the stakeholders. This enabled them to identify a national vision that they all support and recommend for action

Reducing significant aviation environmental impacts in absolute terms is a challenging goal, especially when considered in light of the projected growth in aviation traffic. While in some areas absolute reductions are already being achieved (e.g., a reduction in the number of people exposed to significant levels of aircraft noise), these reductions will be difficult to sustain as traffic grows.

Further, there are areas (such as NOx emissions) where technology and operational measures combined have not been sufficient to offset the increase in emissionsassociated with traffic growth. Accordingly, the vision statement is aspirational. To achieve the vision, immediate and sustained public and private commitment to investment, experimentation, communication, feedback and learning at local, regional, national and international levels is required.

Immediate action will provide both near-term and long-term benefits. Throughout the process of realizing this vision, there must be careful attention to fostering distributed leadership, responsibility and burdens among all stakeholders.

In drafting this vision, specific attention was given to separating issues for which the impacts are sufficiently well understood such that action is appropriate, from those for which uncertainty is high and research must be done to reduce uncertainty before it is appropriate to define specific actions. Community noise and local air quality impacts due to NOx, CO, and UHC were considered to be actionable now. Impacts of aviation PM, HAPS and aviation climate effects require further research to understand the effects and the relationship to aviation technology and operations.

However, in light of growing national and sinternationalrequirements to assess and mitigate these impacts, expeditious action is urgently required.Further, our use of “significant” in the first paragraph of the vision statement is meant to signal a specific regulatory threshold for consideration. It is beyond the scope of this report to define these levels of significance, but we look to the relevant agencies to define and amendthese thresholds as necessary.

For example, the U.S. EPA defines thresholds for attainment of national ambient air quality standards and thresholds of significance for health effects ofhazardous air pollutants. These should be taken into account in considering whether action should be taken to mitigate these effects of aviation.

## 3.9 Greenhouse gases

Aircraft burn hydrocarbon fuel. The principle emissions from this are carbon dioxide and water. There is also some nitrogen oxide. The SAS airlines have developed a nice spreadsheet of airplanes vs. GHG emissions for travellers who want to reduce their global warming footprint.

Greenhouse gas emissions from fuel consumption in international aviation, in contrast to those from domestic aviation and from energy use by airports, are excluded from the scope of the first period (2008-2012) of the Kyoto Protocol, as are the non-$CO_2$ climate effects. Instead, governments agreed to work through the International Civil Aviation Organization (ICAO) to limit or reduce emissions and to find a solution to the allocation of emissions from international aviation in time for the second period of the Kyoto Protocol starting from 2009; however, the Copenhagen climate conference failed reach an agreement.

Recent research points to this failure as a substantial obstacle to global policy including a $CO_2$ emissions reduction pathway that would avoid dangerous climate change by keeping the increase in the average global temperature below a 2 °C rise.

### 3.10 Particulate emissions

Aircraft fuels contain some sulfur compounds. These are emitted as particulates. These particulates act as nuclei for cloud formation which may impact the ratio of light reaching the Earth from the sun. This may be seen as a "good thing" as it might reduce global warming, but putting all your potential impacts in a pot and stirring them is not good science.

### Noise

The familiar roar of aircraft can reduce the enjoyment of living under an approach route to a busy airport. Some sites have curfews (designated quiet hours) or alternate approach routes for use at night.

As part of that process the ICAO has endorsed the adoption of an open emissions trading system to meet $CO_2$ emissions reduction objectives. Guidelines for the adoption and implementation of a global scheme are currently being developed, and will be presented to the ICAO Assembly in 2007, although the prospects of a comprehensive inter-governmental agreement on the adoption of such a scheme are uncertain.

Within the European Union, however, the European Commission has resolved to incorporate aviation in the European Union Emissions Trading Scheme (ETS). A new directive was adopted by the European Parliament in July 2008 and approved by the Council in October 2008. It became effective on 1 January 2012.

Researchers at the Overseas Development Institute investigated the possible effects on Small Island Developing States (SIDS) of the European Union's decision to limit the supply of Certified Emission Reductions (CERs) to its ETS market to Least Developed Countries (LDCs) from 2013.Most SIDS are highly vulnerable to the effects of climate change and rely heavily on tourism as a basis for their economies, so this decision could place them at some disadvantage. The researchers therefore highlight the need to ensure that any regulatory frameworks put in place to tackle climate change take into account the development needs of the most vulnerable countries affected.

A report published by researchers at the Centre for Aviation, Transport and Environment at Manchester Metropolitan University found that the only way to have a significant impact on emissions was to put a price on carbon and to use a market-based measure (MBM), such as the EU Emissions Trading Scheme (ETS).

During fueling and reving up and taxiing (when engines' exhaust composition changes) there can be an increase in hydrocarbon emissions. Hydrocarbons and NOx, both components of air traffic, can contribute to photochemical smog.
During emergencies, aircraft often dump fuel into the air to reduce fire hazards. While this is necessary for passenger safety it still contributes to hydrocarbon levels.

# CHAPTER 4

# ANALYSIS:

The nation must pursue a research program to assess the unique impacts of aviation on climate, weather and local air quality. A focused research program similar to the Atmospheric Effects of Aviation Program (AEAP) that was supported by NASA as an element of the high-speed civil transport and subsonic aviation programs should be developed.

This new program should integrate atmospheric observations with local, regional and global modelling to reduce the uncertainty in the understanding of aviation's climate, weather and local air quality impacts, and to reduce the uncertainty in the relationship between these impact sand technological and operational options for mitigation. An improved understanding of aviation climate, weather and local air quality effects is necessary to ensure investments in aircraft technology and operations are effective.

Information has been collected regarding airport-related hazardous air pollutants (HAPs) via a literature review and communication with experts in the field. The state of knowledge has been assessed, information gaps have been identified, and research topics to address these gaps have been proposed.

A prioritized list of gas-phase HAPs emitted by airport emission sources has been constructed based on the product of the compounds' toxicities and emission rates. This list consists of acrolein (propenal), formaldehyde, 1,3-butadiene, naphthalene, benzene, acetaldehyde, ethylbenzene, and propanal (propionaldehyde). Glyoxal, methylglyoxal, and crotonaldehyde (butenal), although not officially hazardous air pollutants, may be comparable in importance to the compounds listed above.

Within the airport perimeter, aircraft engines during idle/taxi are the largest emission source for most of these compounds, although gasoline engines (used in ground access vehicles and some ground service equipment) can in some cases emit comparable amounts of benzene and 1,3-butadiene.

The sources that contribute the most to human *exposure*
depend heavily on the particular exposure group and airport and cannot be easily generalized. For example, nearby residents' exposure may be most affected by the aircraft or ground access vehicles depending on meteorology and the relative location of busy roadways, airport runways, and residential areas.

Future studies such as health risk assessments, however, should not limit themselves to the above compounds and should consider all types of particulate matter (refer to *ACRP*

parameters such as the relative location of emission sources and the relevant exposure groups.
It is recommended that ACRP fund the following research topics. Research on these topics

would enable airport operators to develop more accurate HAP emission inventories and/or to reduce emissions most cost effectively.

4.1. **Quantify the dependence of HAP emissions from aircraft as a function of ambient conditions (temperature, pressure, humidity) and engine technology.** Gas-phase HAP emissions increase greatly with decreasing temperatures; however, they have never been measured at sub-freezing temperatures. This can result in over a factor of two uncertainty in emission inventories.

2. **Quantify the actual thrust levels used by aircraft during the idle/taxi phase of a landing and/or take-off cycle.** The current uncertainty in the actual thrust levels used during taxi/idle results in up to a factor of two uncertainty in HAP emission inventories.

3. **Quantify HAP emissions from general aviation aircraft.** With the exception of lead, aircraft emissions from piston engine aircraft, which are unregulated, remain unquantified.

4. **Identify the emission sources most important to on-airport and off-airport exposure.** Exposure (and therefore human health risk) depends on several factors such as meteorology and the relative location of emission sources and exposure groups. Such a project will help airport operators to identify the "low-hanging fruit" with regards to minimizing the health risk presented by the various emission sources present at an airport.

In addition to the information gaps identified in the research statements above, there are Information gaps related to the current state of knowledge regarding the toxicity of the following two classes of compounds: alkenes and certain aldehydes (including glyoxal, methylglyoxal, and crotonaldehyde).

Of these compounds, addressing information gaps for glyoxal, methyl glyoxal, and croton aldehyde is most critical, as they may be emitted in sizeable quantities, and limited toxicological information for these compounds indicates their toxicity could be comparable to that of formaldehyde, acetaldehyde, and acrolein. The toxicity of gly oxal, methyl glyoxal, and crotonaldehyde is highly uncertain.

The issue of airport pollution is of great concern to the international aviation community. Today we stand at a decision point critical to this issue. The direction we take could have a major effect on engine designs and costs. The decision is not an easy one. Data collected through extensive airport pollution measurement programs have not clearly demonstrated the influence of airports on the environment. Although air pollution dispersion modeling studies have not been fully accepte das predictors of airport air quality, many have indicate da small impact for most pollutants. Reviews of both measurement and modeling studies have been published. In March of this year, the United States Environmental Protection Agency published a comprehensive review of past work to assess the air quality impact of commercial aircraft.[1] The1975 Federal Aviation Administration review of modelin gassessment techniques presents a comprehensive look at all but the most recent developments in airport air qualitymodeling.[2] These studies have outlined strengths and short comings of both measurement and modeling. The following discussion will briefly address some of the issues identifieding these reports and review several Air Force programs which are dedicated to resolving the outstanding problems.

## 4.2 Measurement Programs

Major airport air quality measurement programs have been conducted at several sites since passage of the 1970 Air Pollution Control Act. These measurement programs have generally been conducted in conjunction with computer modelling studies in an attempt to verify modeling techniques. These studies have all suffered from the inability to separate clearly the airport and background urban pollution components. For this reason the U.S. Navy, Environmental Protection Agency and Air Force joined together to measure and model pollution.

Emission Factors and Fuel Flow Rate: Fuel flow rate and emission factors for NOx and HC were obtained from the ICAO Emissions Databank. ICAO requires engine manufacturers to submit emissions data as part of the engine certification process. These emission factors are the same as those recommended by EPA and used in the EDMS model. The emission factors and fuel flow rates are measured for each of the four LTO cycles, and are reported in pounds of pollutant emitted per thousand pounds of fuel burned.

The emission factors were gathered from newly manufactured engines and do not account for deterioration.[33] Aircraft/Engine Combinations: Since several models of aircraft engines can power the same aircraft body, the assignment of engines, and therefore emission factors, to specific aircraft bodies must be determined. Data on the type and number of engines used on aircraft in service around the world are available from Jet Information Services' World Aircraft Inventory.

This inventory alsoincludes the number and types of planes owned by commercial carriers and governments worldwide, and specifies the engines used on those planes. In the NESCAUM inventory, engines were assignedas listed in the World Aircraft Inventory, and a weighted average of engine types for each aircraft body in an airline' s fleet was developed. For example, weighted averages were taken for Continental' s Boeing 727-200s (four engine models on nine planes), Continental' s Boeing 737-300s(two engine models on 65 planes), and FedEx' s Airbus 310-200s (four engine models on 40 planes),etc.

The aircraft/engine combinations for the projection year were created using Boeing and Airbus forecasts and current orders to adjust the current fleet mix.Time in Mode: For each operation mode in the LTO cycle, ICAO has determined a defaulttime, as shown in Table II-2. NESCAUM modified these times when more accurate data wasavailable.

The default taxi/idle time was replaced with monthly, airport-specific taxi times from DOT' s Bureau of Transportation Statistics.[34] These substitutions reduced taxi/idle time forManchester and Bradley airports, and in most cases increased taxi/idle time at Logan. The defaulttimes for approach and climbout were adjusted with meteorological data from mixing height stationsnear the airports of study. Mixing height data from US EPA' s Support Center for Regulatory AirModels (SCRAM) were used to calculate monthly average times-in-mode for approach andclimbout. Flight profile data from FAA' s Integrated Noise Model (INM) were incorporated. Thesenew data, indicating that takeoff power is sustained to 1000 feet of altitude, not the 500 feet ofaltitude assumed in the ICAO default times, were used to increase the modeled takeoff time.

Reverse thrust time was not affected. The impact of using these data is explained later in this chapter.Changes to these revised times-in-mode were minimal for the forecast year. Because meteorology is not expected to change significantly, no changes were made to the times for approachor climbout. Similarly, no changes in takeoff operations are expected, so takeoff times were notchanged. By contrast, as airports experience growth that leads to congestion, taxi/idle times are expected to change. Taxi/idle times were adjusted based on information from airport planning.

NOx emissions for the three airports are presented in Table II-4. NOx is primarily produced during high-power engine use, mainly during the takeoff and climbout phases of the LTO cycle.
NOx emissions from air carriers dominate the inventory at each airport, even though air carrier LTOs make up less than half of total LTOs at Manchester and Bradley airports. General aviation aircraft at Manchester make a larger proportional contribution to total emissions than at any other airport. As expected, air carriers dominated the NOx inventory for several reasons.

First, air carriers had a significant number of LTOs at each of the three airports (53%, 41%, and 31% of total LTOs at Logan, Bradley, and Manchester, respectively). Second, on an engine-per-engine basis, air carriers produce more pollutants per minute and burn more fuel per minute than the smaller aircraft.

Third, many of the air carrier aircraft have three or four engines, whereas air taxi and general aviation aircraft have only one or two. These factors result in air carriers contributing approximately 67 to 90 percent of the total aircraft NOx inventory for these three airports. The results of the inventory calculation indicate that controlling air carrier NOx emissions is an important strategy in reducing overall airport-related NOx emissions.

As noted previously, aircraft typically account for the great majority (45-85%61) of total airport emissions. A variety of aircraft types operate at commercial airports, including large commercial jets, smaller commuter aircraft powered by turboprop engines, piston–engined general aviation aircraft, and other miscellaneous aircraft. In addition, military aircraft also operate at some commercial airports.

This chapter primarily focuses on measures relating to large commercial jets, since their emissions typically represent 80 percent of the total emissions inventory for all types of aircraft (i.e., air carriers, commuter, cargo and general aircraft). Sources of aircraft emissions include airplane engines and auxiliary power units used to provide electricity, ventilation, and air conditioning to the airplane at the gate. Control options for APUs will be discussed in the section on GSE since measures to reduce APU usage also reduce use of ground power units.

# CHAPTER 5

## INTERPRETATION OF RESULTS:

The GSE emission modelling results for NOx, VOC and total PM are reported in this section.
As reports the population and activity inputs at each of the airports studied for both thebase and projected years. The subsequent tables (Tables II-19b–d) contain the emission

modelingresults for the primary pollutants of interest. Emissions were also calculated for CO, $CO_2$, and $SO_2$;however, as these pollutants are not of primary interest, these results can be found . Emissions are reported using the US EPA and CARB methodologies. These emissionswere calculated using t activity rates and load factors, with population figures from the paper and visual surveys. Also included for comparative purposes are the SIP inventories for NOx, VOC, and CO supplied by Massachusetts and Connecticut.

**Basic Airport Modeling Input Values for Population and Activity**
**Airport Equipment Population Total Activity**
**(Hours/Year)**
**Modeled Year: 1999**
Logan International Airport 1,173 1,617,439
Bradley International Airport 366 358,726
Manchester Airport 141 68,904

**Modeled Year: 2010**
Logan International Airport GSE 1,276 1,769,508
Bradley International Airport GSE 480 473,263
Manchester Airport GSE 206 101,437

**GSE NOx Emission Results and SIP Inventories (1999 and 2010)55**
**Airport EPA Exhaust NOx ARB Exhaust NOx SIP estimates Exhaust NOx**

**Modeled Year: 1999** (Tons/Year) (Tons/Year) (Tons/Year)
Logan International Airport 293 235 132
Bradley International Airport 96 78 Not Available
Manchester Airport 33 27 Not Available

**Modeled Year: 2010**
Logan International Airport 291 235 Not Available
Bradley International Airport 110 90 Not Available
Manchester Airport GSE 35 29 Not Available

**GSE THC Emission Results and SIP inventories (1999 and 2010)**
**Airport EPA**
**Exhaust +Evaporative THCARB Exhaust + Evaporative THC SIP Exhaust VOC**
**Modeled Year: 1999** (Tons/ Year) (Tons/ Year) (Tons/ Year)
Logan International Airport GSE 1999 Actual 233 120 58
Bradley International Airport GSE 1999 Actual 50 30 221
Manchester Airport GSE 1999 Actual 10 6 Not Available

**Modeled Year: 2010**
Logan International Airport GSE 2010 Projection 253 130 Not Available
Bradley International Airport GSE 2010 Projection 63 39 Not Available
Manchester Airport GSE 2010 Projection 11 7 Not Available

**GSE PM Emission Results (1999 and 2010)**
**Airport EPA Exhaust Total PM ARB Exhaust Total PM**

**Modeled Year: 1999** (Tons/ Year) (Tons/ Year)
Logan International Airport GSE 1999 Actual 30 12
Bradley International Airport GSE 1999 Actual 11 4
Manchester Airport GSE 1999 Actual 4 1

**Modeled Year: 2010**
Logan International Airport GSE 2010 Projection 30 13
Bradley International Airport GSE 2010 Projection 13 5
Manchester Airport GSE 2010 Projection 41

Generally, CARB' s *OFFROAD* method produces lower emissions estimates than US EPA' s *NONROAD* model. The primary reasons for differences in emission estimates are variations in the emission factors upon which these calculations are based and differences in assumed engine deterioration rates. As stated previously, US EPA combines all GSE into a single category that contains only a single emission factor; CARB has separate emission factors for 22 categories ofGSE.

Differences between state and NESCAUM estimates were the result of a variety of factors. First, Massachusetts and Connecticut used different methods in developing GSE emission inventories. Massachusetts used the EDMS model to calculate SIP inventories while Connecticutused a 1990 inventory supplied by US EPA and applied a growth factor to project future year emissions.

Second, EDMS assumes a higher percentage of gasoline powered GSE than the survey results. Gasoline engines emit less NOx than diesels; therefore, EDMS is expected to predict lower NOx emissions than the EPA and CARB methods. EDMS, a traditiona ltool for GSE inventory development, associates a fixed GSE activity with each LTO.

To reiterate, this study took an alternate approach, combining actual counts of airport GSE populations with activity from surveys of the equipment operators. Third, EDMS does not account for airport maintenance GSE; as a result EDMS may underestimate total GSE use and emissions.

At the airports studied, GSE emissions of NOx and VOC range from seven to seventeen percent of aircraft emissions. In general terms, GSE can be expected to account for ten percent ofairport emissions, as GSE activity tends to be proportional to aircraft activity.

As it is not possible to determine the exact number of GSE operating at each airport using the survey techniques employed for this report, percent data capture was estimated by using a combination of GSE data gathered at each airport and LTOs of individual airlines at each airport t.One major issue confounds the ability to calculate GSE data capture rates: many airlines contract GSE services to FBOs .collected GSE data from the majority of FBOs operating at each of the airports studied; however, limited information was collected regarding the extent to which these FBOs service individual airlines.

At Bradley International Airport, approximately 80 percent of the GSE fleet was accounted for by based on the various survey methods employed (four paper and eleven visual surveys). At Logan International Airport, anywhere from 69 to 82 percent of the GSE fleet was accounted for, using the survey methods described. Of the 86 airlines that operated at Logan in 1999, GSE that service twenty-one air carriers were identified.

This inventory is based on ten paper surveys, two in-person interviews and one telephone interview. Approximately 99 percent of the GSE population at Manchester Airport was accounted for with six paper and 11 visual surveys. Of the 21 airlines identified as operating out of Manchester Airport, all major-air-carrier GSE and two of four national-air-carrier GSE populations were accounted for; the remaining air carriers represent less than one percent of total aircraft activity at Manchester Airport. Appendix, Section C provides detailed information on survey reporting statistics.

Over 130 airlines have "frequent flyer programs" based at least in part on miles, kilometers, points or segments for flights taken. Globally, such programs included about 163 million people as reported in 2006. These programs benefit airlines by habituating people to air travel and, through the mechanics of partnerships with credit card companies and other businesses, in which high profit margin revenue streams can amount to selling free seats for a high price.[59] The only part of United Airlines business that was making money when the company filed for bankruptcy in 2002 was its frequent flyer program.

Concerning business travel, "The ease of international air travel and the fact that, for most of us, the costs are met by our employers, means that ... globe trotting conference travel is often regarded as a perk of the job. However, the perk usually is not only the business trip itself, but also the frequent flyer points which the individual accrues by taking the trip, and which can be redeemed later for personal air travel.

Thus a conflict of interest is established, whereby bottom-up pressure may be created within a firm or government agency for travel that is really not necessary. Even when such conflict is not a motivation, the perk of frequent flyer miles can be expected to lead in many cases to personal trips that would not be taken if a ticket had to be paid for with personal funds.

By just using an airline-sponsored credit card to pay one's household expenses, personal or business bills, or even expense bills charged to an employer, frequent flyer points can be racked up quickly.Thus, free travel—for which the individual has to pay nothing extra—becomes a reality. Across society, this too can be expected to lead to much air travel—and greenhouse gas emissions—that otherwise would not occur.

Several studies have contemplated the elimination of frequent flyer programmes (FFPs), on the grounds of anti-competitiveness, ethics, conflict with society's overall well-being, or climate effects. There is a record of governments disallowing or banning FFPs and of industry players requesting bans.

Denmark did not allow the programs until 1992, then changing its policy because its airlines were disadvantaged. In 2002, Norway banned domestic FFPs in order to promote competition among its airlines. In the U.S. in 1989, a vice president of Braniff "said the government should consider ordering an end to frequent-flyer programs, which he said allow unfair competition.

A Canadian study said that because of competition no airline could unilaterally end its FFP, but that a national government could use its regulatory power to end the programs broadly, which in Canada's case would also require North America-wide cooperation. In further analysis, a Scandinavian study which recommended an end to frequent flyer plans said, "the only possible way of prohibiting FFPs successfully now that they have spread from the US to Europe to the Far East would be to do so on a global basis.

The basis exists: it could be done by the World Trade Organization. A recent study which surveyed frequent flyers in the U.K. and Norway, looked into behavioral addition to frequent flying and the "flyer's dilemma" of the conflict between "the social and personal benefits of flying and air travel's impact on climate change. It concluded that:

"Continued growth in both frequent flying practices and concern over air travel's climate impacts are in a dynamic relationship and the question of whether one or the other will reach a tipping point cannot yet be determined. Self-regulation, external regulation, social norms, technology and physical resources will continue to co-constitute the balance. An increasing stigmatisation of 'excessive' air travel may (re)frame flying as more open to collective external mitigation," meaning government action.

## 1999 APU NOx and HC Emissions at the Airports Studied

| | Logan | Bradley | Manchester |
|---|---|---|---|
| Tota l NOx (tons/year) | 144. | 9 29.7 | 7.9 |
| Total HC (tons/year) | 12 | .4 3.6 | 0.9 |

shows NOx and HC emissions from APUs for 1999. As expected, emissions correspond to airport size, with Logan having the highest and Manchester the lowest emissions.NOx is primarily produced during high-power engine operation, while HC are mainly producedduring low-power operation.

Calculated NOx emissions are about 10 times larger than HCemissions, showing that APUs function under significant load during operation. APUs are foundonly on air carrier aircraft, and add an emissions burden to this category of about 5.5 percent forNOx. The ratio of HC emissions to aircraft emissions is about three percent at Logan and sixpercent at Bradley and Manchester. Longer taxi times at Logan create more HC at that airport per LTO.

## CHAPTER 6

## CONCLUSION AND SCOPE FOR FUTURE WORK:

From 1992 to 2005, passenger kilometers increased 5.2% per year, even with the disruptions of 9/11 and two significant wars. Since the onset of the current recession:

"During the first three quarters of 2010, air travel markets expanded at an annualized rate approaching 10%. This is similar to the rate seen in the rapid expansion prior to the recession. November's results mean the annualized rate of growth so far in Q4 drops back to around 6%. But this is still in line with long run rates of traffic growth seen historically. The level of international air travel is now 4% above the pre-recession peak of early 2008 and the current expansion looks to have further to run.

Even though there have been significant improvements in fuel efficiency through aircraft technology and operational management as described here, these improvements are being continually eclipsed by the increase in air traffic volume.

### 6.1 Continual increases in travel & freight

"Air freight reached a new high point in May (2010) but, following the end of inventory restocking activity, volumes have slipped back to settle at a similar level seen just before the onset of recession. Even so, that means an expansion of air freight during 2010 of 5-6% on an annualized basis – close to historical trend. With the stimulus of inventory restocking activity removed, further growth in air freight demand will be driven by end consumer demand for goods which utilize the air transport supply chain. ... The end of the inventory cycle does not mean the end of volume expansion but markets are entering a slower growth phase.

In a 2008 presentation and paper Professor Kevin Anderson of the Tyndall Centre for Climate Change Research showed how continued aviation growth in the UK threatens the ability of that nation to meet $CO_2$ emission reduction goals necessary to contain the century-end temperature increase to even 4 or 6C°.

His charts show the projected domestic aviation carbon emission increase for the UK as growing from 11 MT in 2006 to 17 MT in 2012, at the UK's historic annual emission growth rate of 7%. Beyond 2012 if the growth rate were reduced to 3% yearly, carbon emissions in 2030 would be 28 MT, which is 70% of the UK's entire carbon emissions budget that year for all sectors of society.

This work also suggests the foreseeable future which confronts many other nations that have high dependency on aviation. "Hypermobile Travelers, an academic study by Stefan Gössling et al. (2009) in the book "Climate Change and Aviation also points to the dilemma caused by the increasing hypermobility of air travelers both in particular nations and globally.

### 6.2 Aircraft efficiency

While it is true that late model jet aircraft are significantly more fuel efficient (and thus emit less $CO_2$ in particular) than the earliest jet airliners, new airliner models in the first decade of the 21st Century were barely more efficient on a seat-mile basis than the latest piston-powered airliners of the late 1950s (e.g. Constellation L-1649-A and DC-7C).

Claims for a high gain in efficiency for airliners over recent decades (while true in part) has been biased high in most studies, by using the early inefficient models of jet airliners as a baseline. Those aircraft were optimized for increased revenue, including increased speed and cruising altitude, and were quite fuel inefficient in comparison to their piston-powered forerunners.

Today, turboprop aircraft - probably in part because of their lower cruising speeds and altitudes (similar to the earlier piston-powered airliners) compared to jet airliners - play an obvious role in the overall fuel efficiency of major airlines that have regional carrier subsidiaries.[36] For example, although Alaska Airlines scored at the top of a 2011-2012 fuel efficiency ranking, if its large regional carrier - turbo-prop equipped Horizon Air - were dropped from the lumped-in consideration, the airline's ranking would be somewhat lower, as noted in the ranking study.

Aircraft manufacturers are striving for reductions in both $CO_2$ and NOx emissions with each new generation of design of aircraft and engine. While the introduction of more modern aircraft represents an opportunity to reduce emissions per passenger kilometre flown, aircraft are major investments that endure for many decades, and replacement of the international fleet is therefore a long-term proposition which will greatly delay realizing the climate benefits of many kinds of improvements. Engines can be changed at some point, but nevertheless airframes have a long life. Moreover, rather than being linear from one year to the next the improvements to efficiency tend to diminish over time, as reflected in the histories of both piston and jet powered aircraft.

Adding an electric drive to the airplane's nose wheel may improve fuel efficiency during ground handling. This addition would allow taxiing without use of the main engines.

Other opportunities arise from the optimisation of airline timetables, route networks and flight frequencies to increase load factors (minimise the number of empty seats flown),together with the optimisation of airspace. However, these are each one-time gains, and as these opportunities are successively fulfilled, diminishing returns can be expected from the remaining opportunities.

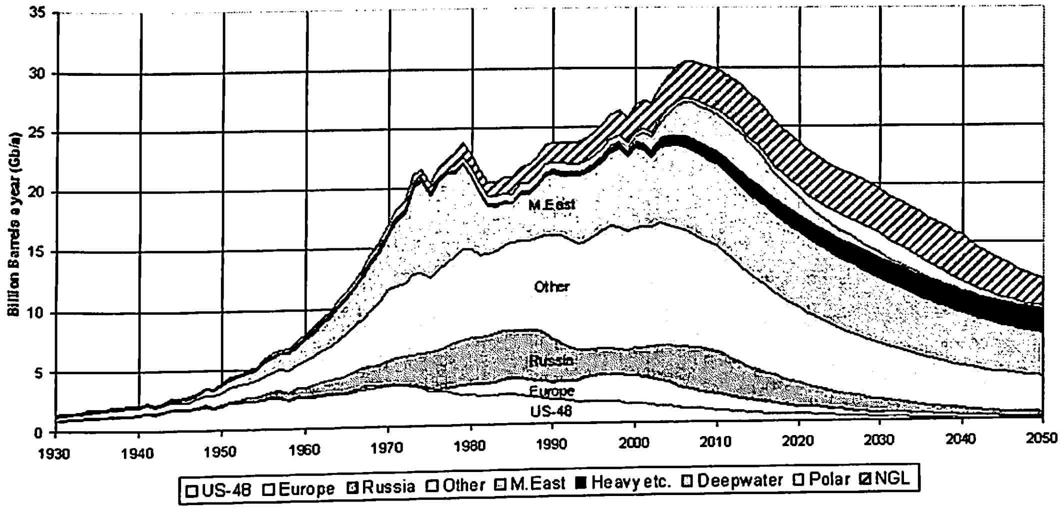
Another possible reduction of the climate-change impact is the limitation of cruise altitude of aircraft. This would lead to a significant reduction in high-altitude contrails for a marginal trade-off of increased flight time and an estimated 4% increase in $CO_2$ emissions. Drawbacks of this solution include very limited airspace capacity to do this, especially in Europe and North America and increased fuel burn because jet aircraft are less efficient at lower cruise altitudes.

While they are not suitable for long-haul or transoceanic flights, turboprop aircraft used for commuter flights bring two significant benefits: they often burn considerably less fuel per passenger mile, and they typically fly at lower altitudes, well inside the tropopause, where there are no concerns about ozone or contrail production.

### *Life-cycle assessment of emissions by airliners made of composites*

A life-cycle assessment of the cradle-to-grave energy consumption of airliners made of carbon-fiber-reinforced polymer (CFRP) has shown that by 2050 such aircraft could result in a 14-15% reduction in $CO_2$ emissions by the airline industry, compared to conventional airliners.[43] The study considers the $CO_2$ emissions of the construction, operation and eventual disposal of aircraft like the Boeing 787. While the emissions reduction for an individual aircraft is estimated to be 20%, the study arrived at the 14-15% fleet-wide estimate "because of the limited fleet penetration by 2050 and the increased demand for air travel due to lower operating costs."

## *6.3* Alternative fuels



Some scientists and companies such as GE Aviation and Virgin Fuels are researching biofuel technology for use in jet aircraft.[1] Some aircraft engines, like the Wilksch WAM120can (being a 2-stroke Diesel engine) run on straight vegetable oil. Also, a number of Lycoming engines run well on ethanol.

In addition, there are also several tests done combining regular petrofuels with a biofuel. For example, as part of this test Virgin Atlantic Airways flew a Boeing 747 from LondonHeathrow Airport to Amsterdam Schiphol Airport on 24 February 2008, with one engine burning a combination of coconut oil and babassu oil.

Greenpeace's chief scientist Doug Parr said that the flight was "high-altitude greenwash" and that producing organic oils to make biofuel could lead to deforestation and a large increase in greenhouse gas emissions. Also, the majority of the world's aircraft are not large jetliners but smaller piston aircraft, and with major modifications many are capable of using ethanol as a fuel. Another consideration is the vast amount of land that would be necessary to provide the biomass feedstock needed to support the needs of aviation, both civil and military.

In December 2008, an Air New Zealand jet completed the world's first commercial aviation test flight partially using jatropha-based fuel. Jatropha, used for biodiesel, can thrive on marginal agricultural land where many trees and crops won't grow, or would produce only slow growth yields. Air New Zealand set several general sustainability criteria for its Jatropha, saying that such biofuels must not compete with food resources, that they must be as good as traditional jet fuels, and that they should be cost competitive with existing fuels.

In January 2009, Continental Airlines used a sustainable biofuel to power a commercial aircraft for the first time in North America. This marks the first sustainable biofuel demonstration flight by a commercial carrier using a twin-engined aircraft, a Boeing 737-800, powered by CFM International CFM56-7B engines. The biofuel blend included components derived from algae and jatropha plants.

One fuel biofuel alternative to avgas that is under development is Swift Fuel. Swift fuel was approved as a test fuel by ASTM International in December 2009, allowing the company to continue their research and to pursue certification testing. Mary Rusek, president and co-owner of Swift Enterprises predicted at that time that "100SF will be comparably priced, environmentally friendlier and more fuel-efficient than other general aviation fuels on the market".

As of June 2011, revised international aviation fuel standards officially allow commercial airlines to blend conventional jet fuel with up to 50 percent biofuels. The renewable fuels "can be blended with conventional commercial and military jet fuel through requirements in the newly issued edition of ASTM D7566, Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons".

In December 2011, the FAA announced it is awarding $7.7 million to eight companies to advance the development of drop-in commercial aviation biofuels, with a special focus on ATJ (alcohol to jet) fuel. As part of its CAAFI (Commercial Aviation Alternative Fuel Initiative) and CLEEN (Continuous Lower Emissions, Energy and Noise) programs, the FAA plans to assist in the development of a sustainable fuel (from alcohols, sugars, biomass, and organic matter such as pyrolysis oils) that can be "dropped in" to aircraft without changing current infrastructure. The grant will also be used to research how the fuels affect engine durability and quality control standards.

The model is not currently equipped to project future year GSE emissions; therefore, NESCAUM grew the GSE inventory in direct proportion to growth in LTOs at each airport. The growth factors employed are listed in , and are based on the expected change in LTOs in the air carrier sector at all three airports. Logan airport is not expected to expand significantly before 2010, therefore only airline GSE fleets were grown (i.e., airport maintenance GSE fleets were not grown). In contrast to Logan, all vehicles in the Bradley and Manchester airport GSE fleets were grown, with the assumption that supporting the increase in air traffic will require each airport to undergo some amount of GSE expansion.

The emissions inventory presented in this chapter focused on aircraft, APU, and GSE emissions. It was the intent of the report organizers to include ground access vehicles and airportrelated stationary sources in the study; however, resource limitations required a focus on the lesserunderstood areas of aircraft and GSE emissions. It is generally accepted that state inventories account for ground access vehicle emissions using traditional mobile source modeling tools (US EPA' s MOBILE model) and for stationary source emissions using AP-42 emission factors. Figures II-7 and II-8, respectively, show the contribution to NOx and HC from the three sources at each airport for 1999.

Aircraft emissions dominate the NOx inventory for the three airports in both 1999 and 2010.

GSE and APU emissions combined represent approximately 15 percent of NOx emissions at each of the studied airports. Among aircraft types, air carriers dominate the inventory because they account for more engines, burn more fuel, and produce more pollutants per minute than air taxi or general aviation aircraft.

Aircraft are also a dominant source of HC emissions compared to APU and GSE. Aircraft account for approximately 80 percent of HC emissions at airports, except at Manchester

Air taxi emissions comprised a larger percentage of total aircraft HC than NOx emissions in 1999 , and an even greater share in 2010. Consequently, reducing both air taxi and air carrier HC emissions is important. This is especially significant for toxic emissions because air taxi HCemissions are high, and the toxic component of air taxi HC emissions is higher than for air carrier emissions.

The results of the inventories prepared for this report differed significantly from state SIP inventories, mainly developed in 1996. NOx emissions estimates in SIPs for aircraft were approximately 50% lower than the NESCAUM estimates (Tables II-4 through II-6). The same istrue for HC with the exception of Manchester Airport, which reported higher HC emissions than this inventory.

The differences in the SIP and NESCAUM inventories are due to the use of 1999 data(more flights than in 1996), different assumptions made regarding takeoff time for aircraft based onupdated FAA data, and more specific data on aircraft/engine combinations. State SIP inventories did not include this updated information.

The primary driver for GSE forecasts is the forecast of LTOs. However, our forecasts for GSE also include assumptions about fleet turnover and the effects of the nonroad diesel rule. Effects from the recently-finalized gasoline nonroad engine rule are not included in our forecast assumptions.

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· ***Appendix:***

Abbreviations

| | |
|---|---|
| AII | Airports Authority of India |
| AERA | Airport Economic Regulatory Authority |
| ATF | Aviation Turbine Fuel |
| CAGR | Cumulative Annual Growth Rate |
| CAT | Category |
| CATC | Civil Aviation Training College |
| CPL | Commercial Pilot Licence |
| DGCA | Directorate General of Civil Aviation |
| DRDO | Department of Defence Research and Development |
| FID | Flight Information Display System |

GDP Gross Domestic Product
GH Ground Handling
HACCP Hazard Analysis and Critical Control Points
HAL Hindustan Aeronautics Limited
IATA International Air Transport Association
IIFCL India Infrastructure Finance Company Limited
ISRO Indian Space Research Organisation
IT Information Technology
LCCs Low Cost Carriers
MIAL Mumbai International Airport Limited
MNC Multinational Companies
MRO Maintenance Repair & Overhaul
NACIL National Aviation Company of India Limited
NAL National Aerospace Laboratories
PAP Project Affected People
PPP Public Private Partnership
RFID Radio Frequency Identification
RMS Risk Management System

ACARE Advisory Council for Aeronautical Research in Europe
AERONET Thematic Network of the European Commission on Aircraft Emissions and Reduction Technologies
AEAP Atmospheric Effects of Aviation Program
AEE FAA Office of Environment and Energy
ANCA Aircraft Noise and Capacity Act
ASP Airspace Systems Program (NASA)
CAEP ICAO Committee on Aviation Environmental Protection
CEQ Council on Environmental Quality
CO Carbon monoxide
CO2 Carbon Dioxide
COE Center of Excellence, Partnership for Air Transportation Noise and Emissions Reduction (PARTNER)
DNL Day-Night Noise Level
DOC Department of Commerce
DoD Department of Defense
DOI Department of the Interior
DOT Department of Transportation
EPA Environmental Protection Agency
EU European Union
FAA Federal Aviation Administration
FICON Federal Interagency Committee on Noise

GAO General Accounting Office
GSE Ground service equipment
HAPS Hazardous air pollutants
ICAO International Civil Aviation Organization
IPT Integrated product team
Appendix B: List of Acronyms
Report to the United States Congress: Aviation and the Environment
JPDO Joint Planning and Development Office
NASA National Aeronautics and Space Administration
NGATS Next Generation Air Transportation System
NOAA National Oceanic and Atmospheric Administration
NOx Oxides of Nitrogen
NPS National Park Service
NRC National Research Council
OST Office of the Secretary of Transportation
OSTP Office of Science and Technology Policy
PARTNER Partnership for AiR Transportation Noise
and Emissions Reductions
PM Particulate matter
QAT Quiet Aircraft Technology
REDAC Research, Engineering and Development Advisory Committee
TRL Technology readiness level
UEET Ultra-Efficient Engine Technology Program
UHC Unburned Hydrocarbons