The Plane Truth: Aviation and the Environment

By Professor John Whitelegg
and Nick Williams

Edited by Chris Evans

THE ASHDEN TRUST

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The major part of the report was written by:

Professor John Whitelegg, School of the Built Environment, Liverpool John Moores University

Section 6, 'Is aviation and airport development good for the economy?', was written by:

Nick Williams, environmental and housing consultant

The report was edited by:

Chris Evans

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Foreword

Since its foundation, The Ashden Trust has taken an active interest in transport policy as it relates to environmental issues. When the trustees were approached by Transport 2000 to fund research on the environmental implications of current trends in aviation, they were pleased to do so.

Professor John Whitelegg and Nick Williams were commissioned to draw together existing information about the environmental impact of aviation, and to clarify issues which demand attention.

It is timely that their work is now being published. The UK government has recently released its consultation paper on air transport. Responses to that consultation will provide important material to feed into the government's proposed White Paper on air transport, which is due in 2001.

This study identifies a range of significant issues surrounding existing practice and predicted trends in aviation as these affect the environment. It has assembled data which must provoke serious concerns at the absence of any systematic approach to the subject of aviation and the environment. The Ashden Trust and Transport 2000 hope that it will stimulate debate leading to a significant realignment of the policy approach to the future development of aviation.

Michael Pattison CBE
Director
The Ashden Trust

Part 1: The impact of aviation on the environment

1 Introduction

This report looks at the current level of civil aviation* and considers the remarkable forecasts for the rates of growth within this industry. It looks at the impact that aviation is currently having on the environment and estimates what that impact might be if these widely predicted rates of growth are achieved. The report concludes that the way aviation affects the environment requires serious discussion.

The aviation industry has grown at an extremely rapid rate and it looks as if future growth may be even faster. Aviation has the highest growth rate of all modes of transport. But there has been no significant debate about the environmental impact this growth has had, nor about the impact that it will have. There appears to be widespread acceptance – not least within government – that rising demand for air travel will continue. Aviation growth will have serious implications for the environment in terms of pollution at local and global levels, and also in relation to land use planning (for instance, more terminals and runways).

The United Kingdom is one of the most important aviation markets in Europe. British Airways is the biggest airline in Europe and Heathrow is the largest airport. The aviation industry in the UK is dynamic and fast-developing, with new low-budget airlines and high rates of passenger growth. Within the economy, the aviation industry enjoys a privileged position. It receives major subsidies from the European Union and the UK government. Most strikingly, aviation fuel is exempt from taxation.

The aviation industry has been active in adopting an environmental agenda, producing environmental reports, supporting threatened species, hiring environmental managers and setting up a professorship of 'sustainable aviation'. But the major area of concern that is outlined in this report has received little attention. This report examines how the industry contributes towards greenhouse gases causing climate change, local air pollution and noise pollution, and looks at how that contribution is likely to increase.

Road transport has recently gone through a major debate about traffic growth, which has significantly influenced transport policy. Aviation needs to go through a similar process. This report hopes to stimulate that debate.

* **This report does not take in defence aviation. All references to aviation should be understood as meaning 'civil aviation'.**

2 How fast is the aviation industry growing?

Aviation is growing at a very rapid rate and forecasts predict that the aviation industry will be very much larger in the future than it is today. A much larger aviation industry will have a much greater environmental impact.

2.1 Recent growth

Aviation has the highest growth rates of all modes of transport. Between 1970 and 1995 the number of kilometres flown by passengers worldwide grew by 360% – from 551 billion to 2,537 billion[1].

UK aviation has grown almost as fast over the same period. In 1970 31.6 million passengers passed through UK airports. By 1995 this figure had risen to 129.6 million passengers. This is an increase over 25 years of 310%. Over the same period, the number of flights in and out of UK airports increased by 166%[2].

Freight aviation grew even more rapidly. Between 1960 and 1995 freight aviation increased in global tonne kilometres by 2,200%[3].

2.2 Future growth

This section discusses three areas of future aviation growth: passengers, freight and recreational flying.

a. Passenger aviation

All the forecasts for passenger aviation predict substantial growth, but the forecasts show a wide range of growth rates. Many of these forecasts have been developed in conjunction with the Inter Governmental Panel on Climate Change*, or IPCC, as part of its work on predicting the future impact of aviation on climate change[1].

The IPCC uses one particular forecast – the 'base case' forecast – as the main model for its calculations on climate change. For the 20-year period between 1995 and 2015 the 'base case' forecast predicted growth of 122%. In 1995 the worldwide total of passenger kilometres flown was 2,537 billion. By 2015, according to the forecast, the worldwide total of passenger kilometres would be 5,639 billion. By 2050 that figure would have risen by 450% (compared to 1995). The worldwide total of passenger kilometres would be 13,934 billion (See Appendix 1).

To get the best picture of the likely rates of growth within the aviation industry, it is necessary to look at a full range of forecasts (See Graph 1). These forecasts use different methodologies and work with a range of assumptions about economic and population growth. Naturally, the growth rates vary, but the overall picture is clear.

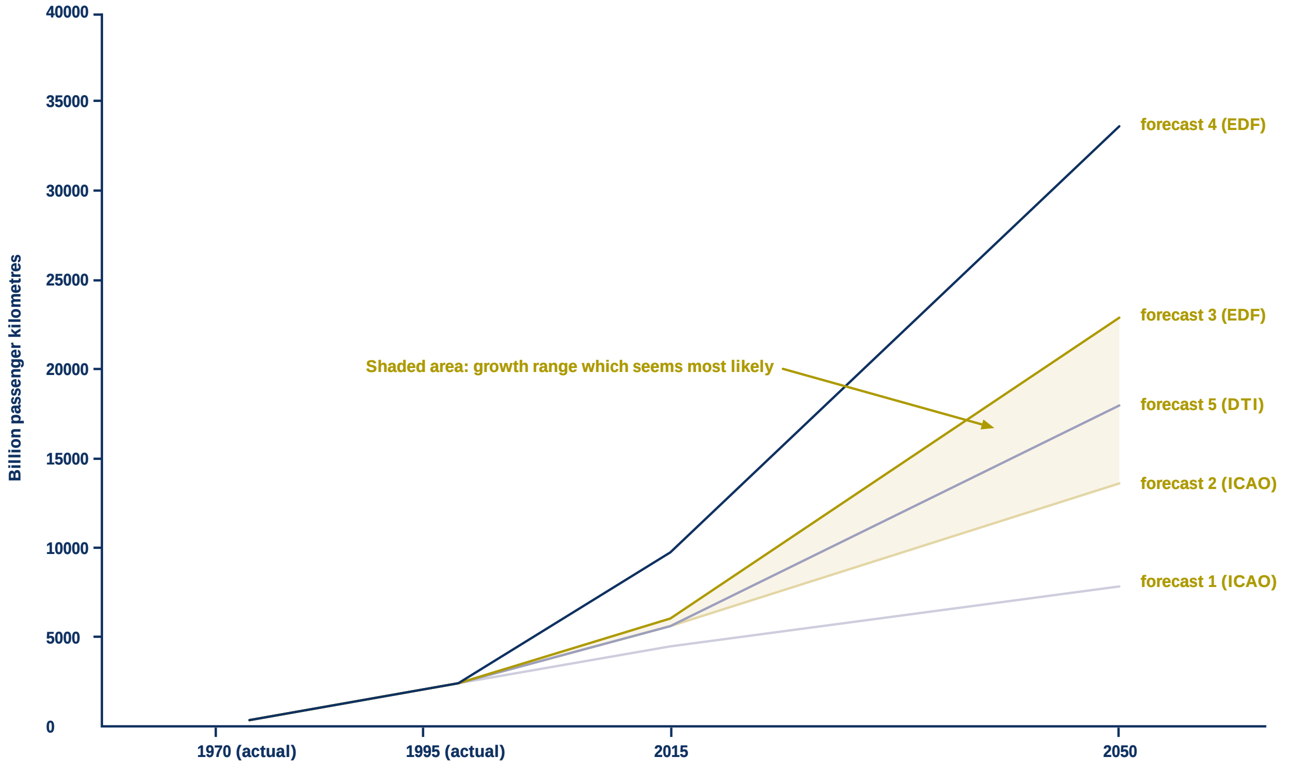
These forecasts show passenger aviation by 2015 growing by somewhere between 81% and 280%. In Graph 1, the lowest forecast estimates 4,596 billion passenger kilometres by 2015 and the highest forecast estimates 9,647 billion passenger kilometres by 2015. The IPCC 'base case' forecast of growth of 122% is at the lower end of this range. It is likely that the 'base case' forecast is an underestimate.

Growth in the range between forecast 2 and forecast 3 seems most likely. This would suggest that the total passenger kilometres by 2050 would be somewhere between 13,934 billion and 23,257 billion. That constitutes growth of between 450% and 820%. A forecast of worldwide aviation growth produced for the UK Department of Trade and Industry also predicts growth within this range (See Graph 1).

Between 1970 and 1995 the highest growth rates in aviation occurred in Asia, where there was an increase of 1,870%[3]. The bulk of future growth will take place in parts of the world experiencing rapid economic expansion: primarily Asia, eastern Europe and, to some extent, Latin America.

***The Inter Governmental Panel on Climate Change was established in 1988 by the World Meteorological Organisation and the United Nations Environment Programme in response to the problem of potential global climate change. The role of the IPCC is to assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change.**

Graph 1: Forecasts of worldwide passenger aviation demand: 2015 and 2050



Sources: *Aviation and the Global Environment* (1999), Special Report, Inter Governmental Panel on Climate Change, Geneva[1]; author's calculations (The figures upon which this graph is based are shown in Appendix 1)

Notes

The figures shown for 1970 and 1995 are actual figures for billions of passenger kilometres flown worldwide. The figures for 2015 and 2050 are forecasts.

Forecasts 1 to 4 were selected by the IPCC for evaluating the environmental impacts of aviation. Forecast 5 was developed independently by the UK Department of Trade and Industry (DTI). Forecasts 1 and 2 were produced by the International Civil Aviation Organisation (ICAO), while forecasts 3 and 4 are the work of the US-based Environmental Defense Fund (EDF). Different scenarios for economic growth and population growth were used to produce the forecasts.

Forecast 1: ICAO – low economic and population growth

Forecast 2: ICAO – medium economic and population growth (the IPCC's 'base case' forecast)

Forecast 3: EDF – medium economic and population growth

Forecast 4: EDF – medium economic and low population growth

Forecast 5: UK Department of Trade and Industry

Nevertheless the UK is one of the most important aviation markets in Europe and future air-passenger growth can be expected to have very significant consequences. The Department of Transport has produced a forecast for the number of passengers passing through UK airports each year by 2015. This forecast predicts a rise from the 1995 figure of 138%[4]. This would increase the number of passengers passing through UK airports each year from 130 million to 310 million. That is another 180 million passengers – about three times the current passenger throughput of Heathrow airport[2].

b. Freight aviation

In the ten years up to 1995 the figure for worldwide tonne kilometres of freight more than doubled to 83.1 billion[3]. In the UK air freight grew even faster. Over the same period it increased by 170% to 4.1 billion tonne kilometres[3]. In 1994 the US Environmental Defense Fund estimated that civil freight accounted for almost 18% of global aviation fuel usage[5].

Air freight is expected to grow rapidly in the future. One reason is that traditional patterns of supply, where local consumption is met by local production, are giving way to global supply lines. Another reason is that two of the world's most populous countries, China and India, are moving into strongly liberalised and deregulated styles of economic activity.

At present most air freight is carried on passenger aircraft. But forecasts predict that by 2050 there could be as many as 19,000 freight aircraft, making up 31% of the total commercial fleet (See Appendix 1).

c. Recreational flying

Recreational flying accounts for 2.8% of global aviation fuel usage[5].

The UK already has a large number of recreational airfields: forty-two alone in the counties of Norfolk, Suffolk, Essex and Cambridgeshire. There is intense pressure to develop small airfields, which has resulted in numerous planning enquiries. Many of these recreational airfields are a source of local concern because of the noise and air pollution they generate.

Recreational flying can be expected to grow rapidly, giving rise to significant environmental impacts. Disposable incomes continue to rise in the advanced industrial economies and leisure pursuits continue to become more specialised, expensive and exotic. In this context recreational flying can be expected to increase dramatically.

This growth will affect the local and the wider environment.

Conclusion

All the forecasts for passenger aviation predict substantial growth, but the forecasts predict a wide range of growth rates. The most probable outcome is that the worldwide total of passenger kilometres will reach between 5,639 billion and 6,115 billion by 2015. This represents growth of between 122% and 141% on 1995 levels of activity. The most likely outcome by 2050 is that passenger aviation will have grown by between 450% and 820%.

Air freight is also expected to continue growing very rapidly. In the ten years up to 1995 worldwide air freight more than doubled in size. Recreational flying is also likely to grow rapidly as disposable incomes continue to rise in the advanced industrial economies.

3 Noise pollution

The impact of aircraft noise on residents near airports and under flight paths has been a source of concern over the last 20 years.

3.1 How does aviation contribute to noise pollution?

Aircraft noise is a serious problem around all airports and under flight paths. Noise levels are measured using the Decibel 'A' Scale, usually expressed as dB(A). A limit of 55dB(A) is regarded as one which should not be exceeded to allow undisturbed sleep, while sound levels above 70dB(A) make normal speech communication impossible[6]. Measuring the levels of noise pollution from aircraft is a controversial area. Local residents and the aviation industry are often unable to agree on which measurement techniques should be used.

For example, the two most commonly used techniques for measuring noise levels are called Leq and Lmax. Leq is often favoured by the aviation industry. It measures the average level of sound intensity over a period of time. Lmax is generally favoured by local residents. It measures the maximum sound pressure level occurring during a certain period of time or during a single noise event. In practice Lmax can identify serious noise problems arising from short-lived single noise events, which are not picked up by Leq.

UK data appears to show that smaller numbers of local residents around airports are affected by aircraft noise than those surveyed in other countries. The UK data says that only 158,000 people are affected by noise above 60 dB(A) around Heathrow and Gatwick airports[6]. However, there are a number of reasons for believing this data is a serious underestimate. Most notably no account is taken of people who live under flight paths, but not in the immediate vicinity of an airport. A more recent study of noise levels around Heathrow airport shows that many more people are disturbed by aircraft noise. This found that 440,000 people around the airport are exposed to noise above 55 dB(A)[7], the level which should not be exceeded for undisturbed sleep.

A survey of noise disturbance in the Netherlands found that 12% of the entire population were ‘considerably annoyed’ by aircraft noise[6]. The size of the aviation industry in the UK and the size of the population within 50 miles of the UK’s three busiest airports (Heathrow, Gatwick and Manchester) would suggest that about one in eight people in the UK may be affected by aircraft noise.

The evidence suggests that, despite the introduction of quieter aircraft engines, the number of people affected by aircraft noise is rising. This is due to the rapid growth in air traffic. Research in Germany shows an increase between 1980 and 1990 of at least 20% in the number of people around airports exposed to serious levels of aircraft noise, where the measurements have exceeded 67dB(A) Leq of outdoor noise[6]. The UK data for numbers of people exposed to noise above 60 dB(A) around Gatwick and Heathrow airports appears to show a different picture. It indicates a decline in numbers of people affected by serious aircraft noise between 1975 and 1989[6]. However, as already discussed the methodology of the UK data is open to question. The German research, which is based on rigorous collection of noise data from individual households, seems more likely to be correct.

3.2 How does aircraft noise affect your health?

In 1993 a World Health Organisation (WHO) report entitled *Community Noise* reviewed the international scientific evidence and found that noise gave rise to a large number of health problems[8]. These ranged from insomnia, stress and mental disorders to heart and blood circulation problems and cardiac diseases (See panel on page 12). Some of these health effects (e.g. increased sensitivity to noise and annoyance) start when people are exposed to noise of around 50dB(A). Other effects, such as hearing pain and hearing impairment, require much higher levels.

High levels of noise can damage human health in the following ways:

- Hearing impairment
- Hearing pain
- Increased sensitivity to noise and annoyance
- Interference with communication and speech perception
- Sleep disturbance
- Psycho-physiological reactions during sleep (including effects on heart rate, finger pulse and respiration)
- Cardiovascular effects (e.g. Ischaemic heart disease)
- Stress
- Dulled startle reflex and orienting response (the person affected is less likely to respond to noise signals that matter e.g. approaching vehicles and dangerous machinery)
- Other effects on physical and psychological health including: nausea, headaches, irritability, argumentativeness, reduction in sexual drive, anxiety, nervousness, insomnia, abnormal somnolence and loss of appetite
- Mental disorders
- Impaired task performance and productivity
- Deficits in reading acquisition in children
- Damaging effects on positive social behaviour (e.g. willingness to help others)

Source: *Community Noise* (1993), World Health Organisation, Copenhagen, Denmark

The WHO report cited evidence from specific studies indicating clear evidence of health damage. The report said that environments with 'heavy noise' (67-75 dB(A)) were characterised by 'cardiac diseases, doctors' calls and purchase of medicine more frequently than in quiet environments'. The report found that noise also affects mental functioning: it reduces task performance and productivity.

The WHO report also found that noise has a detrimental impact on children's education. In noisy environments, infants and pre-school children suffer problems with cognitive development and school children learning to read do so more slowly. In 1995 a study of school children around Munich airport found that children living in areas affected by aircraft noise had poorer long-term memory recall and reading comprehension than those living in a comparable urban environment unaffected by aircraft noise[9]. A study of New York school children in the vicinity of La Guardia and JFK airports concluded that among primary school children – even after allowing for racial, socio-economic and educational factors – the higher the level of environmental noise, the lower the level of reading ability[9].

The extent of these damaging effects has prompted the WHO to propose a range of noise standards that protect human health and recognise the vulnerability to noise of particular sections of the population (e.g. school children, the sick and the elderly). These recommended maximum noise levels are lower than previously accepted levels for 'safe noise' (See Table 1).

Table 1: World Health Organisation recommended maximum noise levels

Context	dB(A)
Bedroom	30 Leq
Balconies, terraces, gardens	55 Leq
Outdoors at night time	45 Leq
Schools and classrooms	35 Leq
Outdoor playgrounds	55 Leq
Inside hospitals	35 Leq
Single noise event in dwelling	45 Lmax

Source: *Community Noise* (1993), World Health Organisation, Copenhagen, Denmark

In the vicinity of airports, and on the flight paths in and out of airports, these ‘safe noise’ levels are regularly exceeded. Around Heathrow airport, for example, 440,000 people are exposed to noise levels above 55 dB(A), the maximum level recommended by the WHO for gardens, terraces and outdoor playgrounds[7]. Exceeding the WHO limits has a harmful impact on local residents and, in particular, groups in schools, hospitals and homes for the elderly. The standards that have been set by the WHO indicate the extent to which people’s health is currently being threatened by aircraft noise. These standards present planners, local authorities, the government and the aviation industry with a very significant challenge.

At present there are no government or industry plans that offer a realistic prospect of reducing aircraft noise to safe levels. If the current forecasts for passenger growth prove to be accurate, the noise pollution outlined in this section will be greatly increased.

Conclusion

Large numbers of people living under flight paths and near to airports are affected by aircraft noise. It seems probable that about one in eight people in the UK are affected by noise from aircraft. Despite the introduction of quieter aircraft, the evidence suggests that the number of people affected by aircraft noise is rising, due to the rapid growth in air traffic.

High levels of noise give rise to a wide range of health problems and have a retarding effect on children’s learning ability. The WHO has proposed a set of recommended maximum noise levels to protect human health. These maximum levels are regularly exceeded in the vicinity of airports. There are no government or industry plans that offer a realistic prospect of reducing aircraft noise to safe levels. As aircraft numbers increase the noise problem will become more serious.

4 Local air pollution

Airports and the aircraft that use them generate large quantities of toxic emissions, giving rise to serious air pollution problems in their vicinity. This air pollution threatens the health of people living and working close to airports.

4.1 How airports contribute to local air pollution

Large airports are heavy generators of air pollution because many aspects of their operations produce toxic emissions. These emissions come not only from the exhaust gases of the aircraft themselves, but also from at least three other major sources. First, there are the extensive supply and maintenance equipment and facilities that provide for the aircraft on the ground. Secondly, the large fuel depots with storage tanks, fuel lines and refuelling facilities from which there is significant evaporation of volatile organic compounds (VOCs). Thirdly, the heavy road traffic generated by airports.

These emissions from airports and their aircraft comprise a wide range of polluting substances that are damaging to human health. The pollutants of greatest concern are nitrogen oxides, VOCs and ground-level ozone. Other toxic pollutants include particulate matter, carbon monoxide and sulphur dioxide.

4.2 How significant is an airport’s impact on its local environment?

In terms of toxic emissions, airports are comparable to large industrial plants. Research in the USA shows that airports rank with chemical factories, oil refineries and power stations among the top four emitters of nitrogen oxides and VOCs[9]. New York's Kennedy airport has been shown to be the largest source of nitrogen oxides in the city, and the second largest source of VOCs[9].

Data from mainland Europe also demonstrates the range of harmful emissions produced by airports and their crucial impact on air pollution levels in the surrounding area. A study of Frankfurt airport, Germany’s largest airport, showed that it was responsible for 74% of unburnt hydrocarbons (these class as VOCs) within the Frankfurt area, and 40-44% of carbon monoxide, sulphur dioxide and nitrogen dioxide[10]. At Zurich airport, research has shown that it is responsible for 28% of nitrogen oxides present in the air within an area around the airport of 9km by 12km[11]. Zurich airport is 40% smaller than Frankfurt airport in terms of numbers of aircraft taking off and landing.

It is not easy to obtain data on the toxic emissions produced by UK airports, as the government’s position is that aviation contributes very little to local air pollution. Official data on airport emissions has therefore not been readily available, and airports are specifically excluded from Integrated Pollution Control, the UK’s pollution control system. But as local authorities implement new legislation on air quality, more data on emissions is now becoming available.

The public inquiry into the building of a fifth terminal at Heathrow airport has made valuable data available on the pollution generated by Heathrow. The British Airports Authority submitted data to the inquiry that shows similarities with the situation at Frankfurt airport. The harmful emissions from Heathrow airport have a crucial impact on air pollution locally. Taking an area around Heathrow of 8km by 6km, the following percentages of pollutants in the atmosphere could be attributed to the airport: 59% of nitrogen oxides; 76% of sulphur dioxide; 48% of VOCs and 45% of carbon monoxide[12].

Another study submitted to the Terminal 5 inquiry looked at the 1991 levels of various emissions, and the forecast levels of emissions with and without construction of Terminal 5 (See Table 2). This study demonstrated how serious the problem is at Heathrow.

Table 2: Forecast emissions from Heathrow airport in 2016, with and without Terminal 5 (tonnes per year)

Year	Nitrogen oxides	Carbon monoxide	VOCs	Sulphur dioxide
1991(actual)	6,200	8,068	2,224	978
2016 – with T5	13,069	9,935	2,052	640
2016 – no T5	8,991	7,709	1,516	457

The table shows airport emissions from all sources including aircraft, road vehicles and boiler house.

Source: *Air Pollutant Emission Inventories for Heathrow Terminal 5: A Reassessment* (1994), Underwood et al, AEA Technology Consultancy Services (SRD)

Firstly, it showed the very high level of VOCs emitted at Heathrow: 2,224 tonnes emitted in 1991. This represents approximately 10% of total VOC emissions in England and Wales, according to Environment Agency figures[13]. The study showed that VOC levels are expected to fall by 2016. This is due to technological improvements. But if Terminal 5 is constructed, the fall in VOC emissions will be less than 10%, down to 2,052 tonnes per annum. This level of VOC emissions is still very high. Heathrow would be generating more VOCs than are currently generated by any other source in England and Wales, apart from the BASF plant on Teesside[13].

The study also showed that growth in air traffic will have a severe impact on other toxic emissions at Heathrow. Although sulphur dioxide pollution levels will fall substantially as a result of technological improvements, nitrogen oxides emissions are predicted to rise dramatically. If Terminal 5 is built, nitrogen oxides emissions are expected to more than double. And even without the construction of Terminal 5 they are predicted to rise by 45%. Carbon monoxide emissions will rise 23% to 9,935 tonnes per year, if Terminal 5 is built.

4.3 The effects on health of airport emissions

The potential damage to human health from toxic emissions from airports is severe. The detailed effects of each type of emission are shown in the panel on pages 16 and 17.

Measurements of pollution levels for aviation emissions around UK airports show that these reach levels that are potentially damaging to human health. Pollution from particulate matter is high and exceeds guidance levels around Gatwick airport. Particulate pollution reaches 85 micrograms per cubic metre at the centre of the airport, and exceeds the 50 micrograms per cubic metre guidance level for many miles around[14].

Nitrogen oxides levels around airports often exceed annual limits[14]. Background levels of nitrogen oxides from road traffic are often high so that nitrogen oxides from the aircraft engines can push levels over the limits.

Nitrogen oxides pollution from road traffic is declining dramatically due to improved technology. However, the planned expansion of airports means that within their vicinity it may be impossible to reduce nitrogen oxides down to new guidance levels. Gatwick airport has proposed a development plan that will see a 40% increase in air traffic. Environmental impact reports for the new development show a dramatic rise in aircraft-derived emissions – particularly nitrogen oxides. These increases will mean that air quality in the neighbouring town of Horley will remain above National Air Quality Strategy levels beyond 2005[14]. This contrasts with the situation for most other local authorities, which predict that they will be able to meet National Air Quality Strategy objectives by 2005.

Specific research into the impact of air pollution around airports on human health is limited. However, in one study the US Environment Protection Agency carried out

Health damage from toxic emissions

Nitrogen oxides

There are three main nitrogen oxide gases: nitrogen dioxide, nitric oxide and nitrous oxide.

Nitrogen oxides affect lung function by impairing respiratory cell function and damaging small blood vessels. They may also harm immune system cells, increasing susceptibility to infection and aggravating asthma. In children, exposure to nitrogen oxides may result in coughs, colds, phlegm, shortness of breath, chronic wheezing, and respiratory diseases including chronic bronchitis.

They also combine with particulate matter in the air to make it even more toxic (See particulate matter, below).

Volatile organic compounds (VOCs)

This category of pollutant includes thousands of different chemicals some of which are recognised as highly damaging to human health: in particular, formaldehyde, benzene and 1,3 butadiene. Benzene and 1,3 butadiene are known carcinogens, and benzene has been clearly linked with an increased risk of adult leukaemia. All three of these compounds can be present in VOCs emitted from airports.

Many of the pollutants classified as VOCs are hydrocarbons. These are believed to cause skin irritation and breathing difficulties, and long-term exposure may impair lung function.

Ground-level ozone

In the presence of sunlight, VOCs and nitrogen oxides at ground level react together to form ozone. Unlike ozone high up in the ozone layer which protects us from the sun's ultra-violet rays, ground-level ozone is highly harmful to human health and leads to increased hospital admissions and mortality rates.

Research demonstrates that exposure to ozone at relatively low levels significantly reduces lung function and induces inflammation inside the lungs during moderate exercise[9]. Chest pain, coughing, nausea and congestion of the lungs often accompany the decrease in lung function. Repeated exposure to ozone for years or even months has been shown to produce permanent structural lung damage with increased loss of lung function.

Asthma sufferers are particularly at risk from ground-level ozone, which exacerbates their condition. Exposure to ozone may also increase susceptibility to infection among the general population.

Particulate matter

Particulate matter (solid and liquid particles in the air) is generated by aircraft and by other airport activities.

Particulate matter (or particulates) is associated with a wide range of respiratory symptoms including coughs, colds, phlegm, sinusitis, shortness of breath, chronic wheezing, chest pain, asthma, bronchitis, emphysema and loss of lung efficiency. In the urban population, as many as 15% of asthma cases and 7% of chronic obstructive pulmonary disease cases may be due to prolonged high-level exposure to particulate matter.

Long-term exposure to particulates has been associated with increased risk of death from heart and lung disease. Particulate matter can also carry carcinogenic materials into the lungs. Particulates are believed to be responsible for 64,000 premature deaths every year in the USA.

The high levels of nitrogen oxides in the air around airports increase the damaging effects of particulate matter. The nitrogen oxides combine with the particulate matter by a process of adsorption, making the particles even more toxic.

Carbon monoxide

At low levels carbon monoxide can impair concentration and nervous system function and may cause exercise-related heart pain in people with coronary heart disease. At high levels, carbon monoxide causes headaches, drowsiness, nausea and slowed reflexes. At very high levels, it kills.

Sulphur dioxide

Sulphur dioxide irritates the lungs and is associated with chronic bronchitis. Asthma sufferers are particularly vulnerable and a few minutes' exposure to sulphur dioxide may trigger an attack. Sulphur dioxide is particularly dangerous if adsorbed by particulate matter. The particulate matter carries the sulphur dioxide deep into the lungs, causing serious health problems.

Except where otherwise indicated, all this material comes from: Transport and Pollution: The Health Costs (1998), British Lung Foundation, London

research on the heightened incidence of cancer in the vicinity of Chicago-Midway airport. The report concluded that the presence of formaldehyde, benzene and 1,3 butadeine from aviation sources was a factor in the elevated rates of cancer. It estimated that emissions from aircraft were responsible for 10.5% of cancers caused by air pollution in the Midway area[15].

No studies of cancer incidence and toxic pollution have been carried out around Heathrow or any other UK airports. Heathrow is substantially larger than Midway: it is used by five times as many passengers and has 50% more landings and take-offs[2]. Gatwick airport is comparable in size to Midway.

Conclusion

Airports and their aircraft produce large quantities of toxic emissions, giving rise to serious local air pollution. The six main pollutants generated by airports are nitrogen oxides, volatile organic compounds (VOCs), ground-level ozone, particulate matter, carbon monoxide and sulphur dioxide. All of these substances are damaging to human health.

In terms of toxic emissions, airports are comparable to large industrial plants. In particular, they produce very large quantities of nitrogen oxides and VOCs. The building of a fifth terminal at Heathrow airport to accommodate ever-increasing air traffic would lead to a doubling of nitrogen oxides emissions. With the construction of Terminal 5, VOC emissions would fall slightly due to technological improvements. However, Heathrow would still be one of the country's main producers of VOCs. Research in the USA has linked VOCs generated by Chicago-Midway airport to elevated rates of cancer in its vicinity.

5 The impact of aviation on global warming and climate change

Aviation's main threat to the wider environment lies in its contribution to global warming and climate change.

5.1 How aircraft emissions cause climate change

A number of aircraft emissions have a warming effect when present in the earth's atmosphere. These emissions prevent heat – in the form of infra-red radiation – from escaping out of the earth's atmosphere. This causes a rise in average global temperatures and also – more significantly – brings about climate change (See panel).

The specific impact of aviation emissions on the atmosphere has been the subject of major research projects, by NASA, the European Commission and the German Ministry of Research. The recent IPCC report compiled the available evidence*.

Emissions from aircraft give rise to a range of different warming effects. There are also some smaller cooling effects. Below is an account of how the most significant of these effects arise from different aircraft emissions.

Carbon dioxide

The carbon dioxide emitted from aircraft has the same impact on the climate as carbon dioxide emitted from other sources. The carbon dioxide accumulates in the atmosphere where it has a direct warming effect.

Aviation today is the source of about 13% of the carbon dioxide emitted by transport and 2% of all carbon dioxide emissions from man-made sources. Transport is responsible for 15% of the global emissions of carbon dioxide.

Climate change and greenhouse gases

Some gases that are naturally present in the atmosphere, such as carbon dioxide and methane, allow radiation from the sun to enter the earth's atmosphere, but prevent infra-red radiation emitted by the earth's surface from escaping. In this way these gases trap heat in the earth's atmosphere, and this effect means that the surface of the earth is on average about 33 degrees centigrade warmer than it would otherwise be. This effect is known as the 'greenhouse effect'. Gases which have this effect are called 'greenhouse gases'.

However, emission of large quantities of man-made greenhouse gases, such as carbon dioxide, ozone and methane, gives rise to extra warming and an increase in the average temperature of the planet. The extra warming seems very likely to increase the frequency and severity of extreme weather, such as hurricanes, flooding and droughts. The extra warming may also alter ocean currents, which could in turn change regional climates. For example, the extra warming could mean that the Gulf Stream is diverted further south, making the climate of the British Isles significantly colder. In addition, the raised average global temperatures caused by man-made greenhouse gases will raise sea levels, causing low-lying islands and coasts to be submerged.

***Most of the material in this section of the report comes from the IPCC Special Report (1999), reference 1.**

Nitrogen oxides

Modern jet engines emit substantial quantities of nitrogen oxides because they operate at very high temperatures and high pressures. These nitrogen oxides have two major impacts in relation to climate change: they create ozone and destroy methane.

Nitrogen oxides emissions from aircraft at cruise altitudes increase ozone concentrations in the upper troposphere and lower stratosphere. Ozone is a particularly potent greenhouse gas. Calculations predict increases during the summer in the principal traffic areas of about 6%.

The nitrogen oxides emissions from aircraft also destroy methane present in the atmosphere. Since methane is a greenhouse gas, this has a cooling effect on global temperatures.

Globally, the cooling effect of the methane destruction and the warming effect of the ozone creation are roughly equal in size and opposite. However the creation of ozone takes place mainly in the northern hemisphere, whereas the destruction of methane is spread more evenly across the globe. This means that at a regional level these two effects do not cancel each other out. Nitrogen oxides emissions from aviation therefore give rise to warming and climate change on a regional basis.

Water vapour contrails

At cruise altitudes the water vapour emitted by jet engines freezes to produce tiny ice particles. These give rise to the familiar contrails that are often visible behind high-flying aircraft. These contrails can be long-lasting – depending on weather conditions – and can spread to a width of tens of kilometres. The contrails have a greenhouse effect, preventing the escape of infra-red radiation out of the earth's atmosphere. In the flight corridors that are most frequently used – such as those over Europe and the North Atlantic – contrails can cover 5% of the sky.

Soot and sulphate

The IPCC report described how particles of soot and sulphate emitted by aircraft into the atmosphere may give rise to the formation of significant extra cirrus clouds (the white, wispy, high-level clouds). These may lead to a very significant greenhouse effect.

5.2 What is the combined result of aviation's warming effects?

The IPCC has developed a measure for calculating the warming effects of different emissions called 'radiative forcing'. It is a measure of the warming capacity of the global atmosphere. This measure calculates the capacity that each emission possesses for trapping infra-red radiation within the atmosphere. This capacity is measured in watts per square metre (W/m^2).

The radiative forcing for aviation is arrived at by calculating the radiative forcing of each of the different warming or cooling effects caused by aircraft emissions, and adding these together. The major warming/cooling effects included in the calculation are those from carbon dioxide, ozone, methane and contrails. Because aviation reduces levels of methane in the atmosphere – a cooling effect – this is a deduction from, rather than an addition to, the total figure for radiative forcing. The formation of cirrus clouds as a result of soot and sulphate emissions is not included, as this effect is not yet well understood.

The use of radiative forcing as a measure is particularly important in relation to aviation. Because most aircraft emissions are released into the atmosphere at a high altitude, they have a greater warming effect, due to factors such as low temperatures, contrails, and the way in which ozone is created and destroyed. It is wrong therefore to judge the impact of aviation on climate change simply by looking at the level of carbon dioxide emissions. The IPCC's calculations suggest that the total net radiative forcing from aviation is 160% higher than the simple radiative forcing effect of aviation's carbon dioxide emissions.

In 1992, total global emissions during the year from all human sources increased radiative forcing by 1.38 W/m^2. Of this, 0.048 W/m^2 was attributable to emissions from all aviation during the year (See Table 3 on page 21). Aviation was therefore responsible for 3.5% of new radiative forcing added to the atmosphere during the year. To some, a figure of 3.5% might seem relatively small. However, this amount of radiative forcing is comparable to the entire impact of Canada's carbon dioxide emissions from all sources. Furthermore, the aviation industry is one of the fastest growing economic sectors.

5.3 What is the projected growth-rate of aviation emissions and aviation-derived warming?

With the rapid growth in aviation, carbon dioxide and nitrogen oxides emissions will increase at a high rate. The work of the IPCC shows that aviation is likely to become one of the most significant causes of man-made warming and climate change.

Forecasts for aviation growth have been developed by the IPCC (See Section 2). Using these forecasts it is possible to calculate future levels of carbon dioxide and nitrogen oxide emissions. The different forecasts, which assume significant reductions in fuel consumption per passenger due to improved technology, predict a range of possible increases.

Carbon dioxide

Carbon dioxide emissions from aviation are expected to more than double by 2015 (compared to the early 1990s) and may grow by 325% (See Appendix 2). Forecasts show that by 2050 carbon dioxide emissions from aviation will have grown by somewhere between 240% and 1,100%. An average figure would suggest a dramatic increase of about 490% (See Appendix 3). These calculations take into account the technological improvements that can be made to the fuel efficiency of planes.

Nitrogen oxides

The same forecasts also show very rapid growth in emissions of nitrogen oxides from aviation. By 2015 nitrogen oxides emissions will rise by a minimum of 96% and could rise by 210%, compared to the early 1990s (See Appendix 2). The 2050 forecasts show nitrogen oxides emissions rising by a minimum of 165%, with a maximum increase of 600%. An average of the forecasts would predict an increase of about 310% in nitrogen oxides from the early 1990s level (See Appendix 3).

In addition to these very large increases in carbon dioxide and nitrogen oxides emissions, vastly increased air traffic will also lead to many more aircraft contrails across the sky. Contrails cover approximately 0.1% of the earth's surface at present, but this could grow to 0.5% by 2050.

The overall effect of this is that the extra warming added to the atmosphere each year by aviation is forecast to rise very steeply. By 2050 the extra radiative forcing caused each year by aviation is predicted to rise by a minimum of 300%, with a maximum possible increase of 1,075% (See Table 3).

A mid-range forecast (Forecast 3) would suggest that aviation's contribution to new man-made radiative forcing will increase by 700% to 0.385 W/m^2 by 2050 (see Table 3 on page 21). This means that aviation will have become one of the most important single sectors contributing to global climate change, contributing 10% of all predicted new man-made radiative forcing. The highest forecast (Forecast 4) has aviation contributing about 15% of predicted total new man-made radiative forcing by 2050.

The scale of these 2050 emissions and their radiative forcing effect can be seen by comparing them with the 1992 figures for total man-made emissions.

Table 3: Forecasts of new radiative forcing added by annual aviation emissions (Watts per square metre)

Forecast	1992 (actual)	2015	2050	Growth 1992 to 2050
1	0.048	n/a	0.193	302 %
2	0.048	n/a	0.192	300 %
3	0.048	0.103	0.385	702 %
4	0.048	0.146	0.564	1075 %
All man-made sources	**1.38 (1990)**	**2.26**	**3.82**	**177 %**

Sources: *Aviation and the Global Environment* (1999), Special Report, Inter Governmental Panel on Climate Change, Geneva[1]; author's calculations

The forecasts for the new radiative forcing that has been specifically caused by aviation are based on passenger growth forecasts selected by the IPCC. These figures were reached by taking the forecasts for growth in passenger aviation and the forecasts for the emissions of carbon dioxide and nitrogen oxides. The radiative forcing effect of these has been combined, along with radiative forcing from contrails and from other smaller warming effects, to arrive at forecasts for the total amount of new radiative forcing that derives from aviation. These figures do not include the warming effect of extra cirrus cloud formation, as these effects are not well understood. In addition the figures for radiative forcing are global figures for the planet as a whole. They do not reflect the extra warming which may occur to some regions because ozone creation in the atmosphere above that region exceeds methane destruction.

Forecasts 1 and 2 were produced by the International Civil Aviation Organisation (ICAO), while forecasts 3 and 4 were produced by the US-based Environmental Defense Fund (EDF). Different scenarios for economic growth and population growth were used to produce the forecasts.

The calculation of carbon dioxide and nitrogen oxides emissions from passenger forecasts involves making assumptions about how improvements in aviation technology will affect emissions of carbon dioxide and nitrogen oxides. In the forecasts, three different technology scenarios are envisaged: A, B and C.

Forecast 1: ICAO – medium economic and population growth, technology scenario A

Forecast 2: ICAO – medium economic and population growth, technology scenario B

Forecast 3: EDF – medium economic and population growth, technology scenario C

Forecast 4: EDF – medium economic and low population growth, technology scenario C

In 1992, total man-made emissions from all sources were generating 1.38 W/m^2 of new radiative forcing each year. This level of emissions was already too large to be sustainable in terms of radiative forcing and climate change. The mid-range forecast (Forecast 3) shows that by 2050 aviation alone may be producing over 25% of the total radiative forcing for 1992.

It should also be noted that these figures do not include the warming effect of extra cirrus cloud formation as a result of aviation-derived soot and sulphates. This effect has not yet been quantified, but it is believed that it could be much bigger than the warming effect of contrails. If this is the case, the figures for aviation's total contribution to warming and climate change have been significantly underestimated.

Conclusion

Aircraft emit a number of different substances into the atmosphere at their cruising altitude. Emissions at this altitude of carbon dioxide, nitrogen oxides and water vapour contrails give rise to a number of warming effects. These warming effects cause global climate change. The overall impact of these combined warming effects can be measured using radiative forcing. The total net radiative forcing from aviation is about 160% greater than the simple radiative forcing effect of aviation's carbon dioxide emissions. In the early 1990s aviation contributed 3.5% of total new man-made warming, measured in terms of radiative forcing.

Aviation's very rapid rate of growth means that it is forecast by 2050 to become one of the single biggest contributors to global climate change. A mid-range forecast suggests that the radiative forcing effect of annual aviation emissions will increase by 700% by 2050. On this basis, 10% of all new man-made radiative forcing would come from aviation by 2050.

6 Is aviation and airport development good for the economy?

Section 2 of this report has shown that aviation is set to grow at a very rapid rate. Sections 3, 4 and 5 have demonstrated that the aviation industry has a substantial impact on the environment in terms of noise pollution, local air pollution and global climate change. These sections also revealed that aviation's very rapid growth means that these impacts will pose a very serious threat to our environment in the near future. It is therefore necessary to consider restricting the growth of the aviation industry. This section considers whether restricting the growth of aviation would be damaging to the wider economy.

6.1 Why aviation is considered good for the economy: the Oxford Economic Forecasting report

The case for unrestricted growth in aviation was put in 1999 in an influential report by Oxford Economic Forecasting[16]. It was produced for a consortium of the UK's major airlines and operators and the Department of the Environment, Transport and the Regions. Its conclusions are widely accepted within the industry and government.

The report argued that aviation growth contributed to economic growth in two ways. First, the growth of the aviation industry itself generated employment, production, exports, value added, investment and contributions to the Exchequer. Secondly, aviation benefited other businesses by helping them expand their markets.

The report estimated that over the last 10 years aviation growth had increased output in the UK economy by £550 million per year. The report compared what would happen if passenger growth were to be restricted to 3.5% per annum rather than the predicted growth rate of 4%. It concluded that Gross Domestic Product would be 2.5% smaller by 2015, as compared to a 'no restriction' scenario. Using 1998 prices, that would be a shortfall of £30 billion.

The report accepted that the environmental impact of air travel had economic consequences, but this area was explicitly excluded from the report's terms of reference.

6.2 Why the argument may be more complicated: the SACTRA report

A recent report from SACTRA, the Standing Advisory Committee on Trunk Road Assessment, is also highly relevant to this discussion. In its 1999 report *Transport and the Economy*, the committee looked not just at roads, but considered all types of transport investment and policy initiatives for all modes of transport[17]. The report examined what evidence there was to say that increased traffic flows give rise to economic growth. The report said that it was quite possible that increased traffic flows are a consequence of growth rather than a cause. It also argued that in a mature economy, which already has a well-developed transport system (such as the UK), any increase in economic growth from improved transport is likely to be modest.

The report said that improvements in transport between different areas do not necessarily bring equal economic benefits to the different areas. There are winners and losers. Competitive areas may gain improved access to weaker areas, which may in turn suffer job losses.

The report also said that when making an assessment of the economic benefits of transport improvements, environmental costs must be included in order to make a full assessment.

6.3 Why aviation expansion may not lead to economic growth

The economic benefits from unrestricted aviation growth appear extremely attractive. But on closer examination, there are a number of reasons why the Oxford Economic Forecasting report is unpersuasive.

1 Since it does not take account of the environmental costs of aviation, its economic analysis is incomplete. When the full extent of the environmental damage is calculated (potentially including storms, flooding, health costs, etc.), the net economic result may not be positive.

2 The economic forecasts in the report are questionable. As the SACTRA report points out, the relationship between traffic growth and economic growth is uncertain. In particular, different locations will gain or lose depending on the strength of each location's economy.

3 The report makes assumptions about the number of jobs that may arise from airport development. There are several ways in which these assumptions are open to doubt.

(a) Airports can vary widely as to how many people they employ (See panel).

(b) It is difficult to estimate the number of airport jobs there will be in the future (See panel).

(c) Estimating the level of induced employment generated by new airport development is particularly difficult (See panel).

Problems in estimating new employment created by airport development

(a) Airports can vary widely as to how many people they employ

Airport employment levels are measured in terms of jobs per 'million passengers per annum' or 'mppa'. Employment levels in Canadian airports in the 1980s varied from less than 1,000 per mppa to over 3,000 per mppa[18]. More recent data for European airports shows Dusseldorf employing 817 per mppa and Amsterdam-Schiphol airport 1,842 per mppa.

(b) It is difficult to estimate the number of airport jobs there will be in the future

Because of the speed of technological, market and organisational change, what has happened in the past is not a good guide to what will happen in the future. For example, increases in 'labour productivity' – the mechanisation of baggage handling, electronic ticketing, etc. – lead to fewer jobs being created per passenger carried. Also the advent of 'no frills' airline services – such as easyJet and Go – reduce levels of employment per passenger carried. Other developments, such as enhanced security arrangements and a rise in the number and quality of services at an airport, lead to increases in employment.

(c) Estimating the level of induced employment created by airport development is particularly difficult

Airports employ people **directly** (employment directly related to aviation services) and also **indirectly** (employment derived from the provision of goods and services procured by the firms involved in aviation). Spending by those employed **directly** and **indirectly** also generates **induced** employment in the vicinity of an airport.

Estimates of the number of **induced** jobs created by new airport development are made in the following way. The total number of **direct** and **indirect** jobs likely to be created is multiplied by a so-called 'multiplier'. The size of the multiplier used can vary from about 0.25 to 0.5, giving a wide range of results. It is frequently suggested that consultants preparing reports to show the job-creating effects of particular airport projects select a multiplier that will show the proposed developments in a more favourable light.

4 The aviation industry will require public and private investment on a massive scale, if it continues to grow at its present very high rate. The construction of Terminal 5, if it goes ahead, will be one of the biggest civil engineering projects ever undertaken in the UK. There has been little public debate as to whether the public money involved could be used in more beneficial ways – for the economy, for the environment and for the community at large.

In particular, investment in aviation infrastructure will give poor returns in terms of job creation. Investment in other industries with lower levels of labour productivity would be more effective in creating new jobs.

5 Much of the growth in air travel has been generated by tourism. Leisure travellers make up 66% of all passengers using UK airports. In 1997, UK air travellers spent £13.4 billion abroad, whereas foreign travellers by air to the UK spent £9.9 billion. That left a net deficit of £3.5 billion.

6 The aviation industry is heavily subsidised. For instance, in the European Union there is no taxation on aviation fuel. That amounts to a subsidy of 17.5 billion euros (£10.7 billion) per annum. Tickets are zero-rated for VAT purposes. That is a subsidy of 6.5 billion euros (£4 billion). In 1994 Air France and Olympic Airways received direct subsidies of 3.4 billion euros (£2.1 billion) and 2.11 billion euros (£1.3 billion) respectively[19]. Other state support for the aviation industry includes: the provision of rights to particular routes to favoured national airlines, the provision of transport infrastructure for airports from state funds and state support for aircraft development and manufacture. (For a fuller discussion of state subsidy and support for the aviation industry, see Section 7.23)

In terms of job creation, these subsidies are not necessarily efficient. There is an argument that more jobs could be created by subsidising industries with a lower level of labour productivity. Some would argue that removing aviation subsidies and investing the resources in more sustainable employment would have environmental as well as economic advantages.

7. It is claimed that excellent air services are a key factor in foreign direct investment decisions. There is no convincing evidence available to show the link between improvements to air services and inward foreign investment.

Conclusion

The consultants Oxford Economic Forecasting have produced an assessment that restricting the growth of aviation would have a significant damaging effect on economic growth. However, there are a number of reasons for questioning this analysis. The most important of these are:

– the analysis did not take into account the environmental costs of aviation

– the calculation of the number of jobs created by airport development is open to question

– the heavy investment required to build new airport capacity could be better deployed in economic sectors which create more jobs.

Given the possibility that further growth in aviation will lead to high environmental costs (particularly in relation to climate change), it could be argued that restricting the growth of the aviation industry may bring net benefits to the wider economy.

Part 2: A new aviation policy

In this part of the report John Whitelegg sets out his personal views on a new aviation policy for the UK. In particular he argues the case for the introduction of transport demand management for aviation, and discusses the ways in which this could be implemented.

7 A new aviation policy based on transport demand management

The aviation industry needs to play its part in delivering strategies for greenhouse gas reduction. Given the high levels of projected growth in the aviation industry, this will require the industry to implement a policy of 'transport demand management'.

7.1 Why we need a new approach to aviation policy

The continuing growth of demand in passenger and freight air transport is not inevitable. Nor can this rapid rate of growth remain exempt from policy discussion. In 1992 the European Union, national governments and major international organisations signed up, at the Rio Earth Summit, to sustainable development strategies. In 1997 they also signed up, at the Kyoto Conference, to greenhouse gas reduction strategies.

The aviation industry was specifically excluded from the Kyoto agreement. However, section 5 of this report, which draws on work since Kyoto by the Inter Governmental Panel on Climate Change, or IPCC, has shown the extent to which aviation emissions are implicated in climate change. Therefore the aviation industry can reasonably be expected to play its part in delivering these strategies.

Other industries have begun to respond to the challenge of global warming and sustainable development. In recent years there have been major changes in land-based transport, where traffic reduction is now a part of most policy agendas. The construction industry has begun to address the challenge of sustainable development. This is taking place within a framework that appreciates the need to limit the use of virgin raw materials, to increase the energy efficiency of buildings, to recycle land and to utilise compact city concepts[20]. Individual organisations, such as the British Council, have adopted challenging environmental policies that include a commitment to reduce the amount of air travel by staff.

The need for a new national aviation policy is clear, and the government is consulting on one at present. Existing policy, which dates from the mid-1980s, is now out of date. However, the new policy is unlikely to appear until after the decision on whether or not to allow a fifth terminal at Heathrow, even though this decision will have a considerable impact on UK aviation. Similarly, a number of regional airport studies now under way will arrive at their conclusions without a national policy framework. There is therefore a danger that the national policy will be determined by the piecemeal accumulation of a large number of site-specific and geographically specific decisions.

This section proposes a new approach to aviation policy, the main elements of which are dealt with under four main headings: transport demand management, regulation, planning, and information and monitoring.

7.2 Transport demand management and the aviation industry

The starting point for this discussion is the logical necessity of moving towards a strategy of transport demand management for aviation. There are no policies in place to state that the aviation industry has a special, protected or unusual status in relation to sustainable development and greenhouse gas reduction. The industry must therefore be expected to play its part at an international and national level in greenhouse gas reduction. It must also address the serious issues of noise pollution and local air pollution that were raised in sections 3 and 4 of this report.

However, the aviation industry does have some distinctive characteristics that have a bearing on the design of a demand management strategy:

1 In relation to long-distance travel, aviation serves a market for which there is no alternative form of transport. For short-haul air travel, substitutes are available.

2 A large proportion of the demand for aviation is from the tourism and leisure sector. Experience of this travel sector (e.g. moderating the use of cars for journeys to National Parks in the UK) suggests it is harder to introduce demand management schemes in this area than, for example, in commuter travel.

3 Aviation brings with it deeply embedded lifestyle connotations, which both support rapid aviation growth and make air travel resistant to arguments for demand management.

None of these characteristics represents an argument against demand management. They point to the need for careful timing, education and awareness campaigns, as well as linkage with other policy areas, especially in relation to tourism and business travel.

With tourism, the growing concern about the ecological and cultural damage that tourism causes is already creating a climate of opinion that can embrace alternatives to the traditional flight-based package holiday. With business, although travel is an important part of business itself, many of the routine exchanges that take place can be achieved by substituting electronic media for the air journey. A demand management policy in the aviation industry is far more likely to prosper alongside a tourism policy that encourages alternatives to flying, and a business development policy that encourages creative use of electronic media.

The remainder of this section concentrates exclusively on aviation sector policies.

Approaches to transport demand management

There are two main policy methods that can be used to manage demand in the aviation industry. One method is to increase the price of air travel by levying a charge of some sort. The other is to put an upper limit on the total emissions generated by aviation and to allow emissions trading.

7.21 Pricing policies

The demand for aviation can be moderated by policies that build into the cost of a flight (or a unit of freight/passenger travel) the full cost of that flight. This would include the cost of air and noise pollution. Such a policy is known as the internalisation of external costs (See panel). It involves the community making some sort of charge on the polluter that reflects the costs of pollution. The resulting increase in the price of air tickets would reduce the level of demand for air travel.

The European Union has already decided that this approach is appropriate for the transport sector as a whole, and the internalisation of external costs and the

Internalising external costs and the ‘polluter pays’ principle

Internalising external costs is the term used to describe a situation where all those costs of an activity currently carried by someone other than the person carrying out the activity are introduced as a charge or a tax that bears directly on the person pursuing the activity. Costs that were ‘externalised’ become ‘internalised’. For instance, in the case of a car journey those costs might include the costs of air pollution (e.g. respiratory disease), noise pollution, road construction and maintenance, as well as the police, the courts and the National Health Service.

The ‘polluter pays’ principle is closely related to the concept of internalising external costs. It is a mechanism for ensuring that pollution costs are made transparent and are then carried by the polluter. Internalising external costs is wider and more embracing than the polluter pays principle. It includes not only pollution costs, but also takes in all costs that can be identified as directly generated by the activity.

'polluter pays' principle are agreed European Union policy[21]. More specifically, the European Union has agreed that the level of all taxes and duties paid by lorries should be set in relation to the total external costs of lorry activity, as part of a phased programme of harmonisation of all taxes and duties on lorries[22].

With the aviation industry, the internalisation of external costs can be achieved by a number of methods. These include fuel charges, landing charges, seat/ticket charges and charges based on emission levels. Internalisation can be achieved in full or in part, depending on the objectives of the policy and depending on how sensitive demand is to changes in prices. A Europe-wide system of charges to internalise external costs is feasible. It is already European Union policy to introduce a system of tariffs for airport infrastructures for the period 2001-2004, to ensure that these tariffs are harmonised on a European Union basis and that the tariffs deliver the 'user pays' principle[23].

The Study by the Dutch Centre for Energy Conservation and Environmental Technology[24]

In 1998, the Dutch Centre for Energy Conservation and Environmental Technology carried out a study into the feasibility of a European Union aviation charge aimed at reducing the air pollution that is caused by this sector. Its objective would be to reduce the impact of aviation on climate change, the ozone layer, acidification (from emissions of nitrogen oxides and sulphur dioxide) and ground-level ozone formation. The Dutch Centre's study concluded that a European Union aviation charge would be 'both environmentally effective and feasible'.

It identified five ways of applying an environmental charge, but concluded that a charge on calculated emissions is likely to be the most efficient. It would be least likely to distort competition or to precipitate a transfer of passengers and/or operations to airports just outside European air space. The charge would apply to all aircraft emissions during flight, including take-off and landing. A charge level equivalent to 0.20 US$/litre of fuel (0.27 euros per kg of fuel) is expected roughly to halve the projected growth in emissions from civil aviation in Europe.

The authors of the study also concluded that the emission charge would not infringe the Chicago Convention regulating international civil aviation, often quoted as a barrier to the introduction of charges of any kind. This is an important conclusion. Taxes on aviation fuel are currently prohibited under the Chicago Convention, which is binding on the UK and all other participating states. However, an emission charge is not a tax and could therefore be introduced throughout the European Union under existing competencies.

Brockhagen and Lienemeyer study on environmental charging[25]

In 1998 research carried out by Brockhagen and Lienemeyer, independently of the Dutch Centre for Energy Conservation and Environmental Technology, arrived at similar conclusions. They investigated a number of alternative models of pricing and charging to achieve the objective of reducing the global warming impact of aviation in line with Kyoto Protocol decisions. Their conclusions were:

1 An environmental charge on aviation is the only convincing instrument to achieve this objective.

2 The charge should be implemented at the European Union level.

3 The rationale given by the aviation industry for all current tax exemptions on air transport is not justified. It underestimates the ecological necessity for a charge and exaggerates the problems in international law. The Chicago Convention and bilateral air service agreements do not represent an obstacle to the introduction of a specially designed European air transport charge.

4 The environmental charge should take the form of a charge on greenhouse gas emissions from commercial jets. The charge would have two elements: one for carbon dioxide emissions and the other for nitrogen

oxides. The amount of the emissions would be determined by measuring the fuel consumed and by subsequent calculations.

5 The charge would be applied to all airlines – including those based outside the European Union – for all flights connected with an airport in the European Union. The 'polluter pays' principle points to the airline as the organisation that should pay.

6 The design of the charge avoids distortions of competition, as it will apply to all flights. It removes the possibility of undesired consequences associated with other charges. For example, a charge on fuel rather than on emissions would encourage 'tankering'. This would be where aircraft fill up with fuel outside the European Union, and therefore carry more fuel than necessary and produce more pollution as a result.

7 The charge complies with Article 130r-t of the Treaty of European Union, 1992, which states that the polluter should pay for environmental damage.

8 The introduction of the proposed charge is politically feasible. It can be implemented by the co-decision procedure under the Amsterdam Treaty, and only requires qualified majority voting in the Council of Ministers. The charge does not require unanimity since it is not a tax in the sense of Article 130s.

9 The revenue generated by the charge should be used to create a European fund for greenhouse gas abatement measures.

Brockhagen and Lienemeyer suggest a carbon dioxide charge of 0.09 euros per kg of fuel consumed, to be increased by 0.03 euros per year until a limit of 0.3 euros is reached after seven years. For nitrogen oxides emissions, the charge would depend on the amount of fuel consumed multiplied by the nitrogen oxides emission index for the particular type of aircraft. The charge levied would be 4.3 euros per kg of nitrogen oxides, increasing by 1.43 euros per year until after seven years a limit of 14.31 euros per kg of nitrogen oxides is reached. (See panel for a worked example of how the charge would operate.)

A worked example of how the Brockhagen and Lienemeyer emission charge would operate (when fully implemented after seven years)

A flight from London Heathrow to New York
Distance: 5,700kms
Aircraft: Boeing 747-400 of American Airlines with 310 passengers on board
Actual fuel consumed: 57,000 kg

Carbon dioxide charge: 57,000 x 0.3 euros = 17,100 euros

Nitrogen oxides charge: according to the AERONOX report, the nitrogen oxides emission index for this aircraft with its particular engines on a distance of this magnitude is 14.3 g/kg, or 0.0143kg/kg. Therefore the final nitrogen oxides charge is:

57,000 x 0.0143kg/kg (nitrogen oxides emission index) x 14.31 euros/kg = 11,664 euros.

The total charge is 28,764 euros and is levied on the departing aircraft (i.e. at Heathrow). As there is no equivalent US aviation charge the full charge has to be paid by American Airlines to the British authorities. On the return flight the same amount would be due again. If the USA introduces an equivalent charge, the EU would forego 50% of the total amount. If the charge were passed on in full to passengers, it would result in an additional cost per person of 92.8 euros (£56.60) on the one-way transatlantic flight.

7.22 Emissions trading

An alternative approach to transport demand management in the aviation industry is to create a market for emissions. A report for the Institute of Public Policy Research proposes a closed emissions trading system for the aviation industry[26] . Under this, upper limits for emissions would be set for the aviation industry and for individual airlines. Airlines would be allowed to buy from each other unused emission allocations, giving market incentives to reduce emissions. This would, it is argued, allow the sector to be brought within the Kyoto agreement and give real incentives for emission reduction. The report argues that a closed system is necessary to avoid the aviation industry being able to buy reduced emissions from other sectors without making any effort to reduce its own emissions.

7.23 Removing fiscal distortions and unfair competition

A European aviation charge is an important step in the direction of 'full and fair' pricing, a European Union policy goal. It does not however address the state support received by the aviation industry, which puts it in a very privileged position. The aviation industry in Europe receives very large amounts of direct and indirect state financial support at regional, national and European Union levels. This state support comes in the following forms:

a) Transport infrastructure for airports provided from public funds

It is normal for airports to be connected at public expense to the public road and rail systems and for those systems to be expanded when demand rises (e.g. motorway widening in the vicinity of Heathrow Airport and extensive railway infrastructure to connect German airports to their adjacent city centres). More recently there has been a trend towards the aviation industry funding its own infrastructure requirements, as in the case of the £450 million Heathrow Express service to London-Paddington, funded entirely by the British Airports Authority.

b) State subsidies to airlines and for air traffic control facilities

Airlines receive large amounts of state support from their national governments for 'restructuring', and air traffic control costs are funded partly if not wholly from the public purse (including European Union research & development funds). The support for airlines can be direct payments, as in the case of state subsidies to Air France and Olympic Airways, or may be indirect, as with the slots (the rights to particular routes) at Heathrow airport that are allocated to British Airways. These slots, which are a valuable commodity, are conferred under a system of historic 'grandfather rights', rather than being allocated by some kind of market mechanism.

c) State support for aircraft research, development and manufacture

Aircraft research, development and manufacture receives substantial state subsidy. For example, the UK government has recently offered approximately £500 million to British Aerospace to develop the next generation of very large aircraft.

d) Finance for aviation provided under favourable terms by the European Investment Bank

The European Union is deeply involved in funding the expansion of aviation facilities. The majority of this funding is in the form of loans from the European Investment Bank, which in 1998 provided 957 million euros (£583.5 million) for aviation[27]. This amount is much larger than the total annual loans of 600 million euros made to all small and medium enterprises in Europe in all sectors of the economy. In the UK alone, the European Investment Bank provided 152 million euros (£92.7 million) for aviation, for expansion and modernisation at Edinburgh, Heathrow and Gatwick airports.

These large sums of money are provided under very favourable terms and conditions. The European Investment Bank is prepared to extend the terms of loans, to postpone payment of interest and repayment of capital, and to provide a variety of means for reducing the risk suffered by the organisations involved in the borrowing. This system of favourable loans made in support of European Union policies on aviation acts as both an insulator from the normal rigours of free market financing and as a strong force pushing up the supply of infrastructure and stimulating growth in demand.

All these methods of shifting the costs of aviation away from users and on to the taxpayer – whether or not he/she flies – are economic distortions and should be ended. The aviation fuel tax exemption and zero-rated VAT on airline tickets should also be ended. The Dutch group 'Right Price for Air Travel' campaigns on aviation issues. It has calculated that European Union taxpayers subsidise the aviation industry by 45 billion euros (£27.4 billion) per annum[28]. This figure excludes state funds spent on public road and rail systems for airports. The removal of these unnecessary privileges and subsidies is a key component of any strategy to reduce the demand for flying.

The elimination of state subsidy and the removal of fiscal distortions have also been proposed by the European Federation for Transport and the Environment as part of their programme for introducing sustainability into the aviation sector[29]. The Federation argues for:

1 A European ban on any form of direct or indirect financial support to the aviation sector. This is in line with economic theory, European Union policy and ecological efficiency.

2 The abolition of all tax benefits for the air transport sector. This would mean ending the VAT exemption for air tickets and the excise duty exemption for aviation fuel. This is in line with competition rules and the 'polluter pays' principle.

7.24 Substitution

The market for air travel is far from homogeneous and there are some possibilities for substituting alternative forms of transport or alternative methods of exchange for the air journey.

On the face of it, high speed rail provides an effective substitute for short-haul flights. The availability of high speed rail in France has produced a well documented decline in internal air travel, and Eurostar services between London and Brussels/Paris have had a similar effect on air travel on these routes.

However, this substitution of rail for air journeys has not reduced the overall level of demand for air transport[30]. Instead, because the skies were already getting congested before the advent of high speed rail, it has allowed other forms of air journey (e.g. longer-haul and package holidays) to grow faster than they would otherwise. A study by the Aviation Environment Federation suggests that there would be environmental benefits from transferring short-haul aviation traffic to rail. But it draws attention to the need to take account of the impacts of the airport slots thus freed being used to serve long-haul destinations[31]. A shift from air to rail will only yield environmental benefits if the aviation industry is prevented from making use of the freed-up capacity to operate new services.

It should also be noted that the introduction of high speed rail services is in itself bad for sustainability and damaging to the environment. It encourages people to make more journeys over longer distances by encouraging economic activity to spread out, consumes large amounts of energy and makes demands on land.

The possibilities for substituting electronic means of exchange for the physical journey have been discussed in several publications[32,33]. There is evidence that, for many forms of interaction, the use of e-mail, data transfer, video link-up, etc, can reduce the need for physical travel, especially over the distances served by air transport. These electronic means are also cheaper and make better use of time. Evidence on the extent to which this substitution is happening is scarce. However, the experience of telework in the European Union, where the substitution is for the car journey to work, shows that the potential is there to be exploited, when the cultural and organisational issues have been resolved[34].

7.3 Regulation

There is a continuing and urgent need to develop cleaner engines and quieter aircraft[35]. However, this must be done within a demand management framework, so that the gains generated are not cancelled out by growth in aviation activity.

In the UK, there is also an urgent need to remedy the anomaly whereby airports are excluded from the provisions of the Integrated Pollution Control system, introduced by the 1990 Environment Protection Act. As demonstrated in section 4, airports are very significant sources of emissions and air pollution, and environmental protection would be much enhanced by their inclusion in the Integrated Pollution Control system.

There is also a need to overhaul the system of allocating slots at Heathrow airport on a historic basis, rather than by using a market mechanism. The current system confers substantial commercial advantages on the recipient airline, and acts as a stimulus for higher levels of demand for air journeys. It is encouraging that the Secretary of State for the Environment, Transport and the Regions has recently announced that the UK government will be asking the European Commission to make various reforms with regard to airport slots. The government will propose that member states should be allowed to auction newly created slots, that airlines should be allowed to trade slots and that grandfather rights should be reviewed.

7.4 The Planning System

The UK's sustainable development strategy makes it clear that the planning system has a major role to play in delivering sustainable development[36]. There are worrying indications that, in relation to the aviation industry, the planning system is not concerned with sustainable development. The public inquiries into Manchester Runway 2 and Heathrow Terminal 5 were unsatisfactory in many respects.

In the case of Manchester's Runway 2, both the inspector and the government minister were of the opinion that the environmental damage from this development was acceptable when compared to the economic advantages. Such a view was only possible because climate change was ignored and exaggerated claims for the resulting economic gains were accepted without question. The land use planning system needs to change to ensure that independent auditing of economic justifications can take place, and that full weight is given to climate change and human health issues. The global impact of aviation growth should be a key issue when an individual proposal is under consideration.

For the same reasons, any growth in capacity at Heathrow airport should be set in an overall policy context that is determined by the need to reduce greenhouse gas emissions and also local air pollution. The Terminal 5 proposal is intended to allow Heathrow's capacity to grow from 52 million passengers per annum to over 80 million passengers per annum. But the proposal gives no clear indication of the likely limits to this growth, either at Heathrow, or in the south-east of England.

In the UK there is still no regulation of emission levels around airports. There is a real need to apply what is known as the 'bubble concept' or 'air quality capacity constraints'[11]. The bubble concept sets specific emission limits for a defined geographical area around and including an airport. Such a system is currently in place at

Zurich Klotten airport and Stockholm Arlanda airport. Specific limits are set for health-threatening emissions as well as greenhouse gases, and it is then up to the industry to decide how to achieve these. This gives maximum flexibility to the industry, whilst delivering clear environmental improvements for local communities.

The planning system can also intervene (as it did in the case of Heathrow airport in the discussion around Terminal 5) to set terms and conditions for developments (using section 106 agreements). Demanding targets can be set requiring airports to ensure, over time, that an increasing number of journeys to and from the airport are made by public transport rather than by car. Similar demanding targets could be set for heavy goods vehicle traffic to and from airports, which is also rising very steeply.

7.5 Monitoring and information

Bubble concepts and basic environmental protection require improved monitoring and environmental data. It is a source of concern that it is easier to obtain these data for Frankfurt or Dusseldorf airports than for Manchester or Gatwick airports. Information on air pollution, emissions, greenhouse gases and noise footprints is an important element in the public debate about aviation and airports. This information is also a primary requirement of any stake-holding exercise that is conducted in pursuance of Local Agenda 21 strategies (e.g. a forum of local residents, environmental groups and the airport authorities). A minimum requirement must be the provision of independently verified databases, accessible by local residents.

Summary

Part 1: The impact of aviation on the environment

Aviation is growing very rapidly and, if left unchecked, will continue to grow at a very high rate. Mid-range forecasts suggest that by 2015 passenger kilometres flown will more than double (compared to 1995), and by 2050 they could grow by 820%.

Even at current levels of activity, aviation generates levels of noise pollution that represent a serious threat to the health of those who live and work near airports. It seems likely that about one in eight people in the UK are affected by aircraft noise. Maximum noise levels recommended by the World Health Organisation to protect human health are regularly exceeded in the vicinity of airports. With aviation forecast to continue growing rapidly, the damage to human health is set to become even more serious.

Airports and their aircraft produce large quantities of toxic emissions, all of which are a threat to human health. In particular, they produce very large quantities of nitrogen oxides and volatile organic compounds (VOCs). Research in the USA has linked VOCs generated by Chicago-Midway airport to elevated rates of cancer in its vicinity. The building of a fifth terminal at Heathrow airport to accommodate ever-increasing air traffic would lead to a doubling of nitrogen oxides emissions. It would also mean that Heathrow would remain one of the country's main producers of VOCs.

Aviation is already a significant source of greenhouse gases, which cause climate change. However, the aviation industry's very rapid growth means that it is forecast, by 2050, to become one of the single biggest contributors to global climate change. Radiative forcing is a measure of the amount of climate change that results from particular emissions. In the early 1990s aviation contributed 3.5% of total new man-made radiative forcing. Mid-range forecasts suggest that the radiative forcing effect of annual aviation emissions will increase by 700% by 2050. On this basis, 10% of all new man-made radiative forcing would be coming from aviation by 2050.

These serious environmental problems point to the need to consider restricting the growth of the aviation industry. It has been argued that restricting aviation growth would have serious effects on economic growth. However, examination of these arguments shows them to be questionable or flawed, and it seems possible that limiting aviation traffic may deliver positive economic benefits.

The aviation industry is causing serious environmental damage, and is threatening the health of people who live and work near airports. If aviation is allowed to grow unchecked, the scale of the damage will escalate dramatically. This is of particular concern in relation to aviation's contribution to climate change. These concerns point to the need for a fundamental change in public policy towards the aviation industry.

Summary

Part 2: A new aviation policy.

John Whitelegg's personal view on a new aviation policy

Transport demand management for aviation should be implemented through the introduction of the following two measures:

1 An environmental charge based on emissions – this would moderate demand for aviation. It would also ensure that the price of flying reflects some or all of the associated environmental costs.

2 The ending of all state subsidies and tax exemptions – the removal of these unnecessary privileges and subsidies is a key component of any strategy to reduce the demand for aviation.

These two measures should be accompanied by a supporting package of policy initiatives that includes:

- More stringent noise and emission standards for aircraft and for geographical areas around airports
- Better environmental monitoring and local environmental data around airports, to inform local populations about air and noise quality
- More research and best-practice guidance on using alternatives to the air journey.

These measures should be introduced in an incremental fashion, to give the industry and consumers time to adjust to the changes.

Informed choice must also be a key component of transport demand management and environmental policy. There will be many airline customers who have never considered the damaging environmental effects caused by aviation. Information should be made widely available so that these groups have the background facts to understand the changing circumstances of aviation.

Appendix 1

Forecasts of demand for aviation (in billion passenger-kilometres)

	1970 (actual)	1995 (actual)	2015	2050	Passenger fleet+ 2050 (numbers of aircraft) (1990 = 10,000)
Forecast 1	551.3	2,536.6	4,596.1	7,817	15,000
Forecast 2	551.3	2,536.6	5,638.6	13,934	21,000
Forecast 3	551.3	2,536.6	6,115	23,257	35,000
Forecast 4	551.3	2,536.6	9,647	33,655	~42,000
Forecast 5	551.3	2,536.6	n/a	18,106	30,000

+ Freighter fleet: 1347 in 1995. Extra 8,000 - 19,000 by 2050, depending on growth rate assumptions.

n/a: data not available

Sources: *Aviation and the Global Environment* (1999), Special Report, Inter Governmental Panel on Climate Change, Geneva[1]; Gorrisen, N, Original contribution for this report[3]; author's calculations

Notes on the forecasts

Forecasts 1 to 4 were selected by the IPCC for evaluating the environmental impacts of aviation. Forecast 5 was developed independently by the UK Department of Trade and Industry (DTI). Forecasts 1 and 2 were produced by the International Civil Aviation Organisation (ICAO), while forecasts 3 and 4 are the work of the US-based Environmental Defence Fund (EDF). All four forecasts were generated using a common set of scenarios for the growth of the global economy (global Gross Domestic Product) and worldwide population growth. The three scenarios used in these forecasts were:

– low economic and population growth: c
– medium economic and population growth: a
– medium economic growth and low population growth: d

Forecast 1: ICAO scenario c
Forecast 2: ICAO scenario a
Forecast 3: EDF scenario a
Forecast 4: EDF scenario d
Forecast 5: DTI

Although forecasts 2 and 3 are based on the same economic and population growth scenario (scenario a), it can be seen that forecast 3 gives a significantly higher rate of growth in aviation. This is because EDF used a different methodology from the ICAO. For example, the EDF forecast differentiated among five economic country groups and took into account the different state of maturity of markets in these different groups, assuming that today's developing countries would experience very fast economic growth.

Appendix 2

Forecasts of carbon dioxide and nitrogen oxides emissions of global aviation, 2015 and 2050 (million tonnes)

	1992		2015		2050	
	CO_2	NO_x	CO_2	NO_x	CO_2	NO_x
NASA	440.5	1.67	975	4.12	n/a	n/a
DLR	408.8	1.8	901	3.57	n/a	n/a
Forecast 1	440.5	1.67	n/a	n/a	1490	7.2
Forecast 2	440.5	1.67	n/a	n/a	1540	5.5
Forecast 3	565 (1990)	1.96 (1990)	1182	3.28	3610	7.88
Forecast 4	565 (1990)	1.96 (1990)	1870	5.19	5370	11.64
DTI	n/a	n/a	n/a	n/a	2000	4.45

Carbon dioxide - CO_2 Nitrogen oxides - NO_x

n/a: data not available

Sources: *Aviation and the Global Environment* (1999), Special Report, Inter Governmental Panel on Climate Change, Geneva[1]; Gorrisen, N, Original contribution for this report[3]; author's calculations

Notes

Forecasts 1 and 2 use NASA data as a baseline for 1992 and projections for 2015.

The forecasts for emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_x) are based on forecasts for passenger aviation. Assumptions have been made about how improvements in aviation technology will affect emissions of CO_2 and NO_x. Various different technology scenarios are envisaged: A, B, C, D and E.

Forecasts 1 and 2 were produced by the International Civil Aviation Organisation (ICAO), while forecasts 3 and 4 were produced by the US-based Environmental Defense Fund (EDF). Different scenarios for economic growth and population growth were used to produce the forecasts.

Forecast 1: ICAO - medium economic and population growth. (Technology scenario A)
Forecast 2: ICAO - medium economic and population growth. (Technology scenario B)
Forecast 3: EDF - medium economic and population growth. (Technology scenario C)
Forecast 4: EDF - medium economic and low population growth. (Technology scenario C)

Also included are forecasts produced by the US National Aeronautics and Space Administration (NASA), the German Centre for Air and Space Travel (DLR - Deutches Zentrum fur Luft-und Raumfahrt), and the UK Department of Trade and Industry (DTI):

NASA (Technology scenario D)
DLR (Technology scenario E)
DTI (Technology scenario C)

Appendix 3

Summary of forecasts of carbon dioxide and nitrogen oxides emissions of global aviation: 2015 and 2050

	Carbon dioxide (million tonnes)	Nitrogen oxides (million tonnes)
Average of 1992 estimates	476	1.78
Average of 2015 forecasts	1232	4.04
Growth 1992 to 2015	159%	127%
Average of 2050 forecasts	2802	7.33
Growth 1992 to 2050	487%	312%

Sources: *Aviation and the Global Environment* (1999), Special Report, Inter Governmental Panel on Climate Change, Geneva[1]; Gorrisen, N, Original contribution for this report[3]; author's calculations

Note

These figures are derived from the figures in Appendix 2.

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Biographical details

Professor John Whitelegg is Managing Director of Eco-Logica Ltd, a transport and environment consultancy based in Lancaster. He is also Professor of Environmental Studies at Liverpool John Moores University. He has worked extensively on the environmental problems of aviation, including a period as consultant to British Airways on their environmental training programme. He gave evidence at both the Manchester Runway 2 public inquiry and the Heathrow Terminal 5 inquiry. He is the author of 10 books, including *'Transport for a Sustainable Future: The Case for Europe'*, Wiley, 1993.

Nick Williams is a self-employed environmental and housing consultant. Formerly a Senior Lecturer in Geography and the Built Environment at Aberdeen University, he is an associate of Eco-Logica Ltd.

Chris Evans is a freelance editor specialising in environmental issues. He has edited reports for Transport 2000, the British Trust for Conservation Volunteers and the Fabian Society.

The Ashden Trust
9 Red Lion Court
London
EC4A 3EF

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