Parliamentary Office of Science and Technology

Aviation and the environment

April 2003

Summary

Air travel is forecast to grow, possibly trebling by 2030. The Government is consulting on whether and where this demand should be met, and a White Paper is due at the end of 2003. Growth in air travel affects the environment locally through noise, air pollution, and damage to wildlife, heritage and landscapes. More widely, emissions from aircraft engines contributes to global warming.

This report examines the environmental effects of civil aviation, and the options available to mitigate these effects. The main findings of the report are that:

- historically, technology has been able to reduce the environmental impacts of aviation, but, in the face of forecast growth, cannot continue to offset all impacts
- there is scope to reduce impacts through operating procedures (e.g. flight paths) and land use planning
- there is broad agreement that the aviation industry should meet its environmental costs, although it is unclear how these costs should be defined, how they should be met, and whether this will reduce impacts
- considerable differences of view remain over what might be considered ‘sustainable’ in terms of aviation, and so there is scope for a wider public debate over the future of aviation growth in the UK.

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1 Introduction

1.1 Background to this report

Air travel is forecast to grow, with the numbers of passengers passing through UK airports each year possibly trebling by 2030[1]. However, increases in air travel affect the environment at a local level through noise and effects on local air quality. Similarly, the use of land for airports can affect nature conservation, architectural and archaeological heritage and landscapes, and can shift the patterns of urban development. At a larger scale, emissions of greenhouse gases from aircraft engines contribute to global warming.

In July 2002 the Department for Transport (DfT) began a consultation on how much new airport capacity should be provided over the next 30 years, and where. The consultation sets out various scenarios for growth in demand depending on the extent, if any, of demand management. Seven regional consultation documents (including a second edition of the document covering the south-east of England[2]) set out the consequences of these national policy scenarios for different parts of the UK, and propose options for where increased capacity could be provided.

The Government has asked for views on the different scenarios, how much new capacity should be provided, and which of the options should be adopted in individual regions. Comments are also invited on provision and funding of surface access to airports. The consultation period closes on 30 June 2003. Responses will be analysed and the results will contribute to the formulation of the White Paper setting out the Government's 30 year aviation policy. The White Paper is expected towards the end of 2003.

This report discusses the environmental effects of civil aviation and the options available to mitigate these effects[3,4]. It also outlines wider issues such as how environmental, social and economic factors related to aviation interact and can be combined in decision-making to achieve agreed environmental outcomes cost-effectively.

This report has been published during the Government's consultation on the future development of air transport in the United Kingdom and in advance of the White Paper on aviation. It will inform an inquiry on aviation by the House of Commons Transport Select Committee[5] which is expected to report by summer 2003. While environmental issues are not the only concerns raised by the forecast growth of aviation in the UK, it is hoped that this report will be of use to Parliamentarians and others in their consideration of environmental factors alongside economic and social considerations.

Aviation in the UK – chapter 2

By way of background, Chapter 2 examines the place of aviation in the UK economy. It also sets out the regulatory framework, both national and international, within which the UK aviation industry operates. Air travel in the UK and internationally is forecast to grow significantly over the next 30 years and the latter part of this chapter outlines the forecasts and the assumptions on which they are based.

[1] *The Future Development of Air Transport in the UK: A National Consultation,* Department for Transport 2002.
[2] Issued in response to a High Court decision that the Government should include Gatwick in its consultation.
[3] In discussion of the environmental impacts, the report focuses on the impact of use of aircraft in flight operations. It does not analyse any environmental impacts of aircraft manufacture or disposal.
[4] *Environmental and Health Impacts of Aviation*, European Parliament Directorate General for Research, STOA (Scientific and Technological Options Assessment), Options Brief and Executive Summary, PEnr296-693 January 2001
[5] House of Commons Transport Committee press notice, 22 November 2002.

Noise – chapter 3

For many living around airports, noise is the most evident environmental impact of aviation. Community action groups have been established at many of the UK's airports. particularly where noise is an issue of considerable concern. Chapter 3 examines the sources of noise from airports, the effects of noise on people and the implications of the forecast growth in aviation. Potential technical and policy options to reduce aircraft noise are outlined.

Local air quality – chapter 4

Aircraft engines and braking systems emit a range of substances that can affect air quality. Emissions are greatest during landing and take-off, but total emissions from engine idling or taxiing can also be significant. As well as the aircraft themselves, emissions are also produced by ground transport at the airport, such as baggage handling vehicles and transfer coaches. Road transport to an airport is often a significant contributor to air pollution around busy airports. This chapter discusses the nature and relative contributions of the different sources of air pollution at airports, and the potential impacts of these pollutants on health. It describes the current and future state of air quality around the UK's airports, and options to mitigate adverse effects.

Other local environmental effects – chapter 5

The presence of an airport, in effect a large and busy industrial facility, inevitably takes land that could be used in other ways. Airports require land for the airport infrastructure itself and for the local transport links. In addition, airports generate demand for land from other uses such as housing or businesses and ultimately can alter the wider pattern of urban development. This affects local wildlife habitats and watercourses and can affect landscape, architectural and archaeological heritage. The large numbers of people using airports can also strain local infrastructure for water supply, sewerage and waste disposal. Chapter 5 outlines the effects of an airport on its local environment and discusses some means to mitigate these effects.

Effects on the global atmosphere – chapter 6

Aircraft emissions contain carbon dioxide (the main greenhouse gas) and other pollutants which can also have a global warming effect, particularly water vapour and nitrogen oxides (NOx). The impacts of water vapour and NOx emissions at high altitude are not well understood, so their effects on the global atmosphere remain uncertain. Chapter 6 draws on previous studies in this area by the Intergovernmental Panel on Climate Change (IPCC) and the UK's Royal Commission on Environmental Pollution (RCEP) as well as some more recent research to summarise what is known about the effects of aviation on the global atmosphere. It also examines current international and European developments to address these issues, and prospects for UK action.

Overarching issues – chapter 7

The environmental effects of aviation do not always fall neatly into the subjects outlined in chapters 3 to 6, but often arise as more complex and interrelated topics. In some cases addressing one environmental effect, such as noise or local air pollution, may have a detrimental effect on others, such as greenhouse gas emissions. This chapter examines how far technology can be applied to address these effects and discusses the means to appraise the environmental impacts of aviation. It concludes by examining what the concept of 'sustainable development' might mean in relation to aviation.

A note on distance measurements in aviation

By convention, aviation uses non-metric units to measure distance. The altitude of an aircraft and the distance between aircraft are measured in feet (one foot = 0.3048m), and distances from runways (e.g. on approach or take-off) are measured in nautical miles (one nautical mile is 1.15 statute miles, or 1.85 kilometres).

2 Aviation in the UK

This chapter provides a context for the later discussion of the environmental issues raised by aviation. It considers the structure of the UK's aviation industry, its contribution to the UK's economy and the regulatory framework. This chapter also outlines national and international forecasts of aviation growth.

2.1 The UK aviation industry

Airports

The UK has around 140 civil licensed airports. The largest are around London, with Heathrow handling around 1,250 flights a day, around 64 million passengers per annum (mppa), and serving direct flights to 170 destinations. Gatwick and Stansted handle around 30mppa and 16mppa respectively. Early in 2003, Stansted received planning permission to increase its terminal capacity to handle up to 25mppa. The largest airport outside London is Manchester, which handles around 18mppa. Beyond these, is a number of smaller regional airports, such as Glasgow, Edinburgh, Birmingham, Leeds-Bradford, East Midlands, Humberside, Bournemouth and Cardiff. Moving down in size even further are small airfields and airports such as Biggin Hill in Kent or Wick in Scotland and even some sites that handle only a few flights per week.

The bulk of airport activity in the UK is centred on the London airports, and indeed, taking Heathrow, Gatwick, London City, Stansted and Luton together, these airports represent the largest air transport system in Europe, handling nearly 100 million passengers in 2000/01[6]. Heathrow alone, with its four terminals and two main runways[7], is one of the largest airports in the world and is by far the largest in the UK. However, Heathrow (until Terminal 5 is built) and Gatwick are now at their full capacity for much of the day. Manchester's second runway (which opened in 2001) was the first full-sized runway to be built in the UK for over 50 years. European competition with Heathrow has recently started to increase with the development of the three other main hubs at Paris Charles de Gaulle (4th runway under construction), Amsterdam Schiphol (5th runway opened in 2003, although only two can be operated at any one time) and Frankfurt Airport (3 runways). As a result, the number of destinations served by Heathrow and Gatwick has declined relative to these other major airports.

Some airports in the UK are owned and operated by the private sector. The largest single owner is BAA plc which owns seven airports nationwide – Heathrow, Gatwick, Stansted, Glasgow, Aberdeen, Edinburgh and Southampton. Others, particularly regional airports, are owned by local consortia; Manchester Airports Group owns Manchester, Humberside, East Midlands and Bournemouth. Local authorities or regional development agencies are often shareholders in their local airport. Ten airports in Scotland are owned by the Scottish Executive (through ministers) and run by Highlands and Islands Airports Ltd.

Regional airports

Flights from regional airports fall into four main categories: domestic point to point services connecting UK cities, 'feeder' services to the South East airports, scheduled shorthaul flights to Europe and charter services[8]. With increased congestion at London airports and the development of new 'no-frills' airlines, the number of international destinations serviced by regional airports has risen. The combined effect of these developments has meant that many transfer passengers

[6] Ten year statistics, BAA plc (see www.baa.co.uk/main/corporate/about_baa_frame.html).
[7] Heathrow does have a third runway, but this is very much smaller than the two main runways and is rarely used.
[8] Some regional airports also operate intercontinental flights (e.g. from Birmingham to the Indian subcontinent).

are opting to change to connecting international flights outside the UK at other European hubs. Passenger numbers at regional airports grew by 78% during the 1990s, compared with a 66% rise in London during the same period.

Air freight

The handling of air freight at some regional airports has also increased. Nine-tenths of all the air freight handled in the UK in 2001 passed through the top five cargo-handling airports: Heathrow, Gatwick, East Midlands, Stansted and Manchester[9]. Heathrow is the market leader; in 2001, Heathrow's World Cargo Centre handled almost 1.2 million tonnes of freight (just over 55% of all air freight carried in the UK[10]).

Airspace

In the UK, air traffic control (ATC) services are provided by National Air Traffic Services Ltd (NATS). NATS controls virtually all civilian flights over UK airspace[11] and the Eastern North Atlantic. Control towers at individual airports ensure safe landing and take-off, while at higher levels aircraft are passed to one of the 4 national ATC centres based at Swanwick (in Hampshire), West Drayton (in London), Prestwick (near Glasgow) or Manchester. NATS raises revenues by charging for use of UK airspace and through provision of airport ATC under contract to airport operators.

Air traffic control in the UK, as in the rest of the developed world, uses radar tracking of aircraft on fixed flight paths. Flight paths may not provide the most direct routing between two points, but their use allows air traffic controllers to focus their attention on a limited number of air corridors. Increases in air traffic over western Europe have led to increasing challenges for ATC, leading to a recent decision to halve the minimum vertical separation between aircraft from 2,000ft to 1,000ft, with safety standards maintained through advanced technology. Since it was introduced in January 2002, this development has increased capacity across Europe.

However, such increases in the capacity of flight paths cannot overcome congestion caused by constraints on an airport's operational capacity. In particular, landings are not currently permitted where the horizontal distance between aircraft would be less than 3 nautical miles (reduced to 2.5 nautical miles under limited circumstances at some airports). Delay is an inevitable consequence of running an airport for maximum throughput. Where delays to landings occur, ATC require aircraft to fly in vertical holding areas (stacks) at some distance from the airport. Once separation from the previous arrival is established, ATC will direct an aircraft to descend from the bottom of the stack to land, and all other aircraft descend to the next level in the stack. Should stacks become congested, more stacks can operate further from the airport.

Airlines

In 1999, a report by Oxford Economic Forecasting (OEF) on the contribution of aviation to the UK economy estimated that the aviation industry directly employs 180,000 people in the UK[12]. This includes people employed by airlines, agents, aircrew, check-in staff, maintenance staff, airport operations staff, people employed in retail and catering concessions and others such as freight handlers, immigrations and customs staff, and people employed in on-site ancillary services such as hotels. UK airlines themselves employed just over 82,000 people in 2001[13], with around three quarters of these jobs located in the southeast of England.

9 The top five airports for cargo, given the quantities carried in 2001.
10 Civil Aviation Authority Data Unit, *Airport Statistics 2001*.
11 Low level airspace over some smaller aerodromes is controlled directly by those aerodromes.
12 Oxford Economic Forecasting, *The contribution of the aviation industry to the UK economy* ,November 1999.
13 Civil Aviation Authority Data Unit, *UK Airline Personnel Employment in GB 2001*.

Indirect contributions of aviation to the UK economy

Tourism

Aviation both brings overseas tourists to the UK and allows UK citizens to holiday overseas. Indeed around two-thirds of inbound tourists arrive by air, and these people account for three-quarters of all expenditure of inbound tourists. However, UK citizens spend even more on overseas holidays, thus generating a tourism deficit. The British Tourist Authority found from surveys that inbound tourists were more likely to be deterred from entering the UK if airfares were higher, so constraints on airport capacity could widen the tourism deficit. However, it is beyond the scope of this report to consider this issue.

Aerospace

Airlines need new aircraft and aircraft maintenance, repair and servicing services. The aerospace industry is one of the UK's manufacturing strengths, having two major UK companies (BAE Systems and RollsRoyce) providing 'best in class' services in airframe and aircraft engine manufacture respectively. Aerospace exports accounted for 7% of all goods exported from the UK in 2001, with a balance of trade surplus of £2.8 billion[14]. Around 147,000 people are employed in the civil aerospace industry in the UK in 2001. The turnover for the entire industry at the end of this year was over £18 billion, with the civil market accounting for approximately 68% of this.[15] Research and development are regarded by the industry as highly important. In 2001, it invested approximately 8.2% of its annual turnover in R&D[16]. This amounts to about 12% of all investment by manufacturing industries in this year[17].

Business and regional development

The services provided by the aviation industry have other consequences for businesses, both in corporate travel and the movement of goods. By providing transportation links, businesses can access larger markets, allowing greater scope for economies of scale and exposure to competition. Regional development authorities and the CBI also argue that good air transport links are important in attracting inward investment. Although the connection between air transport services and regional development appears plausible, there is little evidence for this – although island communities such as the Isle of man and the Channel Islands report that aviation is vital for their development. Moreover, improving transport links to a region does not necessarily improve economic prosperity in that region.

Trade

Air freight accounts for approximately 30% of goods traded by value[18]. This is because it is particularly suited to carrying high-value, low-density items, such as electrical goods and pharmaceuticals. Around 30% of airfreight is currently carried in aircraft specifically designed for cargo transportation, while the majority is placed in the holds of passenger aircraft.[19] Aircraft also have the advantage of being able to offer high-speed transit, which is particularly beneficial to those moving perishable goods and businesses that rely on 'just-in-time' deliveries. Another large category is mail, in particular express documents and packages. Specialised air freight is centred mainly at East Midlands airport.

In the 'traditional' scheduled market, British Airways accounts for almost half of all UK airline activity[20]. However, in the past few years major changes have taken place, with the emergence of the low-cost airlines such as EasyJet, Ryanair and BMIbaby. Due to congestion and difficulties in obtaining slots at the larger southeast airports, low-cost carriers operate predominantly from airports where capacity is not so constrained and fast turn-around times are possible. By undercutting established airlines on particular routes and operating some routes that had previously been unprofitable for air travel operators, these airlines have opened up new travel destinations from regional airports. Low-cost airlines now make up around a sixth of UK air travel. In addition to the domestic airlines, many overseas-owned airlines provide services from UK airports, although the majority are supported by the London airports (e.g. over 90 airlines operated services at Heathrow in 2001). There is also a competitive market in chartered flights in the UK, with the main airlines carrying over 30 mppa[21].

[14] Department of Trade and Industry, *UK Aerospace Statistics: Data supplement.*
[15] Society of British Aerospace Companies, *UK Aerospace Facts and Figures 2001.*
[16] ibid
[17] DTI website: http://www.dti.gov.uk/sectors_aerospace.html
[18] Ecotec, *The Economic Impact of the UK Aviation Industry*, June 2000, Page 11.
[19] Civil Aviation Authority Data Unit, *Freight by aircraft configuration, 2001*.
[20] Civil Aviation Authority Data Unit, Size of Airlines by Available Capacity, 1999.
[21] The five principal UK charter airlines rank 2nd, 4th, 5th, 6th and 8th in size (by passenger numbers) among UK carriers.

2.2 Aviation and the UK economy

The economic development of the United Kingdom in the last few decades and the general rise in average income levels has led to an increase in demand for all goods and services. Demand for aviation has been particularly strong and this, combined with decreases in the cost of air travel in real terms, has resulted in the aviation sector growing faster than any other form of transport in recent years.

In the last 20 years the number of passengers travelling in and out of the UK has increased three-fold. Typical annual growth rates over this period have been around 6%. Similar growth levels have been experienced in most developed countries. Average annual growth rates have declined recently: BAA reported growth of only 3.9% for 2002. However, it is unclear as to the causes of this trend (e.g. the effects of the attacks on the World Trade Centre, or the result of constraints on airport capacity).

Aviation contributes directly to the UK economy through the turnover and profits of airports and airlines. The OEF study estimated that in 1998 these sectors contributed approximately £10.2 billion – around 1.4% of gross domestic product (GDP) – and directly supported around 180,000 jobs. It also pointed out that aviation also contributes to the UK economy indirectly through:

- tourism
- the manufacture of aircraft and components
- regional development through improved transport links
- trade, particularly through handling air freight.

The box on the previous page outlines these contributions. OEF estimated that these indirect contributions gave rise to an additional 370,000 jobs – bringing the total contribution of the aviation sector to around 550,000 jobs. In addition, the ways in which many people run their lives and businesses have themselves changed since the growth of aviation. For example, overseas travel is seen by some as essential for business and commerce, for cultural exchange, etc. However, placing an economic value on these less tangible factors is problematic. Further, it should be noted that the OEF study did not take account of the tax status of the aviation industry, the external costs of aviation (see section 7.4), or the economic contribution of charter airlines.

2.3 The regulatory framework

UK aviation policy is influenced strongly by a range of regulations and standards originating from international bodies and the European Union. This section provides a brief overview of the regulatory framework for the aviation industry.

International regulation

The Chicago Convention of 1944 established the International Civil Aviation Organisation (ICAO) under the auspices of the UN. ICAO sets common international standards for operating procedures and technical specifications of aircraft. Member states are bound to implement ICAO standards, and breaches of these standards can lead to legal action against the offending state by ICAO. The UK is represented at ICAO by the Government. The airline industry participates as an observer through the International Air Transport Association (IATA), the manufacturing industry through the International Coordinating Committee of Aviation Industry Associations (ICCA/A), while environmental NGOs are represented through the International Coalition for Sustainable Aviation (ICSA). Environmental issues are addressed by ICAO though its Committee on Aviation Environmental Protection (CAEP), which has responsibility for formulating policy and standards on aircraft noise and emissions.

European regulation

The European Civil Aviation Conference (ECAC) was established in 1955 to provide a forum for discussion of civil aviation issues in Europe and includes among its 38 member states all European Union states and the accession states. It works to harmonise aviation policies across Europe. For EU member states, the European Commission (EC) is playing an increasingly important role in aviation policy. EU legislation to implement ICAO and ECAC initiatives has led to the EC assuming competence over some technical, safety and economic aspects of the airline industry.

Role of the UK Government

The UK Government ensures that domestic policy and regulation meet international requirements. National policy areas include negotiating bilateral air service agreements with countries outside the European Economic Area, taxation, powers of airports (for example to set landing charges or to require their users to meet environmental standards), consumer and competition issues, and some aspects of technical, safety and environmental regulation. In practice these regulatory functions are largely discharged by the Civil Aviation Authority (CAA) which is responsible for safety regulation, economic regulation, consumer protection and airspace policy. The CAA was established in 1972, and receives no direct Government funding; its costs are met by charges on the UK aviation industry.

The CAA is required (under section 70 of the Transport Act 2000) to take account of guidance given by the Secretary of State on controlling and mitigating the impacts of civil aviation. Directions given under section 60 of the Act require the CAA to take into account "*the need to reduce, control and mitigate as far as possible the environmental impacts of civilian aircraft operations, and in particular the annoyance and disturbance caused to the general public arising from aircraft noise and vibration, and emissions from aircraft engines*".

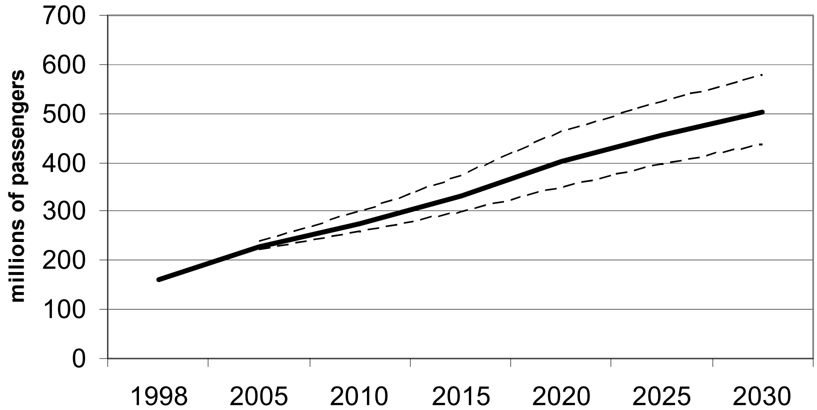
In addition, the CAA is required to "*maintain its capability to provide expert technical advice to the Secretary of State on environmental matters*" and to "*provide a focal point for receiving and responding to aircraft-related environmental complaints from the general public".* It also undertakes research and provides technical support regarding the environmental impacts of aviation for a range of clients including the DfT and regional airports such as Manchester and Birmingham.

Under the Civil Aviation Act 1982 the Government can designate certain airports for closer supervision by the Secretary of State. Currently Heathrow, Gatwick and Stansted are classified as designated airports for noise purposes. This enables the Government to put in place noise control and mitigation measures and to require the airports to administer operating restrictions, such as on night flights. These three airports, together with Manchester, are also designated for the purpose of charging[22], i.e. the Civil Aviation Authority (CAA) sets a price cap for these airports to limit the amount that can be levied in airport charges for a five year period. Other airports are not bound by this regulation. Most set their individual charges in consultation with their users. However, under the Airports Act 1986, users are able to complain to the CAA if they feel their charges are unreasonable.

The role of local authorities in relation to the planning of airports is discussed in Chapter 7.

[22] Under the Airports Act 1986.

Forecast growth of aviation in the UK, 1998 to 2020



source: Department of the Environment, Transport and the Regions, Air Traffic Forecasts for the UK 2000

2.4 Growth forecasts

Passengers

The Government produces periodic forecasts of future demand for air transport in the UK. The most recent. *Air Traffic Forecasts for the United Kingdom 2000*[23], are used in the DfT's consultation on the future development of air traffic in the UK. To arrive at the forecasts, the DfT assessed key drivers behind air traffic growth and models of how these are likely to evolve in future to arrive at a forecast of future air traffic levels. The principal drivers are:

- gross domestic product (GDP) growth in the UK
- GDP growth overseas
- growth in world trade
- reductions in the real terms cost of air travel.

Different sectors of the market are modelled separately, reflecting their different dependencies on the drivers given above. Although actual air travel rates may differ from those forecast in the short term, perhaps due to economic recession or international instability, in the long term growth is expected to follow the forecasts. An example is provided by the fall in air travel in 1991, due to the Gulf War. Although air passenger movements dipped then, by 1993 movements increased above 1990 levels and were back within the range of the forecasts.

The forecasts for growth over the next 30 years are illustrated in the figure above. They assume unconstrained growth in air travel, i.e. that airport and airline capacity is provided to meet all demand. They show an average annual growth rate of around 4.25%, compared with average annual growth rates of around 5% during the 1990s. This reflects the increasing maturity of the aviation market. Uncertainty in the forecasts arises both from uncertainties in evolution of the drivers described above, and also because of the possibility of changes in the relationship between these drivers and air travel over time. DfT points out, however, that past forecasts have often underestimated demand, with demand either following the 'high' forecast growth curve, or even exceeding it; particularly for forecasts made before the emergence of the low-cost airlines in the later 1990s.

The figure shows that air passenger numbers are predicted to more than double between 2000 and 2020, and under the high forecast, could almost treble by 2030. This equates to capacity equivalent to that which can be handled through five new runways – with three of these needed in the south-east of England. While growth at regional airports is expected to be marginally

[23] Department of the Environment, Transport and the Regions, *Air Traffic Forecasts for the United Kingdom 2000*.

stronger than in the south-east, partly because the regional market is less mature than the London market, unconstrained demand in the southeast is expected to double by 2020, and again, under the high growth forecast, to nearly treble by 2030.

Spare capacity exists at some airports (particularly at Stansted[24] and Luton) so some of the forecast growth could be met without additional infrastructure. However, this spare capacity is likely to be used up in the next decade, so if it were decided to provide capacity to meet the forecast growth, new infrastructure would be necessary. Within the overall expected growth, long and short-haul international travel are expected to grow at about the average rate over the period. Domestic air travel is expected to grow more slowly (low-cost airlines 15% per year until 2005, and then more slowly thereafter).

Freight

Air freight has been rapidly expanding over the past few decades but is expected to expand still more quickly in the coming decades, driven largely by growth in the express cargo industry. Global predictions by Airbus and ICAO suggest annual freight growth rates of 5.5% or 6% per year over the next 20 years respectively. In the UK, air freight is expected to grow rapidly, by around 8% per annum, over the next decade, with growth rates decreasing subsequently. Since these growth rates are greater than those for passenger air travel, meeting this demand (if this is seen as desirable) would mean increasing freight services using dedicated aircraft, rather than continuing to rely heavily on passenger aircraft carrying freight in the hold[25].

Uncertainties in the forecasts

The cost of air travel

Since preparing the 2000 forecasts, the DfT has acknowledged that its estimates of likely reductions in the real cost of air travel have changed. The 2000 forecasts assumed a 1 % reduction in real terms costs of air travel per year. However, the DfT now believe that this may have been an underestimate. Historically, real costs have fallen by around 2% per year, and the increasing competition brought about by the rise in low-cost airlines, together with increasing market liberalisation internationally, suggests that this trend may continue. This would increase demand by a further 20%, with the growth forecast for 2028 appearing earlier, by 2020. Events such as the terrorist attacks on 11 September 2001, the war in Iraq and the SARS virus may affect these trends.

Effect of including the costs of environmental damage

The forecasts also estimate the effect of a hypothetical global warming tax (see chapter 6) which could add 10% to airline costs. This was estimated to result in a 10% reduction in demand. If the real cost of air travel continues to decrease at a rate of 2% per year, a global warming tax adding 10 % to the cost of air tickets would still fail to halt a doubling of demand by 2020.

Unconstrained and constrained growth

The forecasts published in 2000 outlined above are the most recent undertaken by the Government. They are based on unconstrained growth grounded in historical trends in the underlying demand for air travel. This unconstrained growth assumes that "*there is no restriction on the amount of additional airport and airspace capacity necessary to meet any level of future demand.*" The DfT points out in its current consultation that there are inherent uncertainties in these forecasts, not least that deviations in the long run trend could occur in any given year as a result of changes in the economic cycle.

[24] There is room for growth at Stansted outside of peak hours
[25] At present 70% of freight is carried in the holds of passenger aircraft.

However, DfT points out that using the government's forecasts does not imply a commitment to the 'predict and provide' approach (i.e. ensuring that all forecast demand is met). Thus forecasts are suggested as a starting point for assessment – enabling consideration of the implications of meeting fully the increase in unconstrained demand. DfT points out that these forecasts could then enable an appraisal of "*the positive and negative impacts of that additional capacity, and only then come to a view on what, if any, degree of expansion is appropriate.*" Beyond this, the Government will decide where the expansion should take place, but will not itself bring forward any specific proposals for providing airport infrastructure – this is the role of the airport operators. Thus, the Government's role is to appraise the possible impacts of potential options in meeting unconstrained growth, and to decide the level of acceptable growth in each region in view of the likely impacts. Specific proposals will be subject to normal planning control procedures within the framework of the Government's overall policy for airport expansion (see chapter 7).

3 Noise

3.1 Noise from aircraft

The Government acknowledges that noise can *be one of the most objectionable impacts of airport development*[26]. The quality of life of many people living under approach or departure flight paths can be affected by aircraft noise. These effects arise from the effect of noise on concentration or sleep and from feelings of anger, frustration and powerlessness to control the noise. However, while many people have expressed concerns over aircraft noise, there remain considerable uncertainties over the precise nature of its effects. This chapter outlines the sources of aircraft noise, how it can affect local communities and the options available to reduce noise or mitigate its effects.

Noise is usually defined as unwanted sound (see box). However, people's reactions to particular sounds are highly individual and depend on many factors such as its loudness and pitch; how often the sound occurs; its similarity to background sounds; and a range of social factors. Noise from aviation largely comes from aircraft approaching or taking off from airports. Individual aircraft have become quieter but flight frequencies have increased, and so noise from aircraft is giving rise to increasing community concern. In particular, landing noise is increasing in importance, and has become the dominant reason for complaints at some airports.

In addition those living close to very large airports may experience 'ground noise' from sources on the airport such as taxiing aircraft, aircraft engine tests, generators or airside vehicular traffic. Transport links to an airport, particularly private vehicles and trains, can also make a significant contribution to noise around airports.

Measuring aircraft noise

As outlined in the box, the DfT estimates current and future impacts of aircraft noise by determining the area exposed to average sound levels of 57dB(A) or more during the 16 hours between 7am and 11pm. This 57dB(A) contour was chosen as an indicator of the onset of what is known as *community annoyance* in the daytime, following a study in 1985 which showed a good correlation of this figure with annoyance[27] (see the annexe to chapter 3). The evidence base for annoyance is being reviewed, particularly to examine whether there have been any changes in the perception of aircraft noise since the previous study. For instance, it is apparent that the mix and types of aircraft, their frequency of overflight, the social and economic circumstances of affected people and general levels of environmental awareness and sensitivity have changed since the early 1980s. The Government has therefore commissioned a three year study to provide a firmer basis for the relationship between aircraft noise and annoyance. The first results from this new study should be available towards the end of 2004.

3.2 Impacts of noise on people

Although very loud noise levels can cause hearing damage and deafness, the levels of sound exposure experienced by the general public living near airports are extremely unlikely to cause such effects. Rather, concerns focus mainly on annoyance and sleep disturbance, and on the extent to which these affect general health and wellbeing.

[26] Department for Transport 2002, *Guidance to the Civil Aviation Authority on environmental objectives relating to the exercise of its air navigation functions*.
[27] Brooker *et al, United Kingdom Aircraft Noise Index Study (ANIS)*: *main report – DR Report 8402.* Report for the Civil Aviation Authority on behalf of the Department of Transport, January 1985.

Measuring sound and noise

There are two main characteristics of sound:

- **volume** (or loudness) – the level of energy in the sound wave: the higher the energy, the louder the sound. This is measured on the scale of decibels (dB)
- **frequency** (or pitch) – the rate of change of energy in the sound wave: the greater the frequency of the sound waves, the higher the pitch of the sound that is heard.

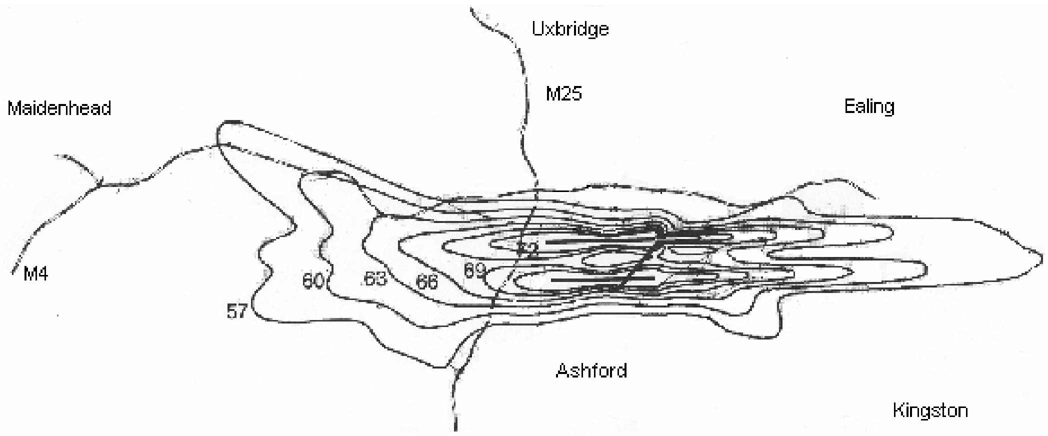
The human ear does not detect all pitches of sound equally efficiently. Most sound measurement therefore uses a scale which weights different pitches or frequency of sound according to human sensitivity to them. This scale, known as the A-weighted decibel scale - dB(A) - is commonly used in assessment of environmental noise. On this scale, an increase or decrease of 10dB(A) is perceived by the human ear as a doubling or halving of the loudness of a sound. Sounds detected in the environment, however, are seldom pure tones of a given volume or frequency, but are mostly mixtures of different sounds of various (and varying) volume and frequency. Combinations of pitch and volume from a number of sources create the tone, or quality of the sound – e.g. the 'roar' of an aircraft engine or the 'swish' of passing traffic. Indeed, aircraft noise is measured with reference to the Effective Perceived Noise Level (EPNL) which has been devised to take account of the different tones of aircraft noise as well as the time duration of the noise events. Thus, all noise metrics referred to hereafter are based on the EPNL definitions.

To quantify sound levels which vary with time a scale known as **equivalent continuous noise level** or $\mathbf{L_{eq}}$ is used. L_{eq} is a measure of the average sound level over a particular time period. For example, an L_{eq}, 24h of 57dB(A) indicates that the sound energy produced by the noise source is equivalent to a constant sound of 57dB(A) over 24 hours. Variants of L_{eq} measure the average sound over particular time periods, such as the 16 'daytime' hours between 7am and 11pm. Other variants, such as L_{den}, try to take account of increased sensitivity to noise at certain times by giving an increased weighting to noise events occurring in the evening or at night. L_{max}, measures the maximum sound level of a particular event.

Aircraft noise at airports

The Government considers noise to have the potential for *community annoyance* above a level of 57dB(A) L_{eq} 16 hour. Contours of noise from airports are drawn, showing the area exposed to average sound levels of 57 dB(A) or more between 7am and 11pm (see figure). Contour areas are then compared with population data to determine the number of residents within that contour. Contours are calculated by summing and averaging the noise from arriving and departing aircraft. Calculations of future noise exposure must also take account of the known or planned flight paths to and from the airport and, since different types of aircraft make different amounts of noise, the known or estimated fleet mix at that airport.

Noise contours around Heathrow airport in 2001 (Leq, 16hr average mode)



Source: Department for Transport

Annoyance

Noise can lead people to feel stressed and angry. It may interfere with conversations and leisure activities in the home, disrupt activities requiring concentration, and discourage people from using outdoor spaces. In addition to the pitch and volume of the noise itself, a number of other factors may affect whether it is viewed as 'annoying':

- **occurrence of exposure** – if exposure to noise occurs often throughout the day, this may be more annoying than exposure to a small number of particularly noisy events, even where the total sound energy is the same.

Noise annoyance

The passion and frustration which aircraft noise may elicit are reflected in the views of some individuals exposed to aircraft noise. Responses to social surveys around airports and to airport expansion plans indicate that many people are annoyed by aircraft noise. It is worth noting that the comments below are from people outside of the 57 dB(A) contour threshold for community annoyance.

Some residents' views (source: HACAN Clear Skies and "Flying into Trouble", Airport Watch)

- "Each time I hear the increasing decibels of an approaching aircraft it builds up like a slow torture, especially in the early hours of dawn….. The lack of government control over this monster motorway in the sky is the worst aspect." (Resident of Greenwich)
- "For me there was no problem until some time in 1999 when, without any warning I was put on the flight path into Heathrow, with the planes passing about every two minutes. Each plane starts with a dull whine from afar which builds to a distinct roar as it gets close. This is often incessant throughout the day. By this I mean that I get woken between 5am and 6am and the noise continues more or less unbroken until sometime between 10 and 11pm." (Resident of Blackheath).
- "Aircraft passing overhead in the middle of the night cause me to awake suddenly. Often I am unable to get back to sleep before I hear the next aircraft. This is a regular occurrence every night of the week, and it is worse in the summer unless I keep my window firmly shut." (Resident living several miles from East Midlands Airport).
- "When we moved here 16 years ago it was a beautiful quiet rural area. But now we have a huge number of aircraft flying low overhead, destroying our peace and tranquillity." (Resident of Edenbridge, 10 miles from Gatwick).

Conversely, others report satisfaction with aircraft noise:
"As I write, I have my French windows open and I enjoy watching the planes coming in, feeding the life of the London I love. With Heathrow just down the road, I know I can easily catch a plane myself, experience the pleasure of visiting friends abroad or having a holiday before flying back again over my house….and for the benefit of any newcomers to our city, planes these days seem to be a lot quieter than they were back in the Sixties." (Inhabitant of west London. Evening Standard letters, 30 April 2002).

- **fear of accidents** – concerns about air crashes may increase some people's sensitivity to aircraft noise. For example, annoyance around Amsterdam's Schiphol airport was greater than at other comparable airports, due partly to fear of crashes following an accident in 1992 where an aircraft crashed into a residential building in an Amsterdam suburb. Similarly, noise complaints at Heathrow rose following the terrorist attacks of 11 September 2001.
- **fear of the future** – especially about future growth in air travel and potential increases in the frequency of flights. A key factor here is whether local people feel they can trust an airport to stick to its commitments about the numbers of passengers and flights it will handle.
- **lack of control** – inability to alter or escape from the noise source may make it more annoying. Vacuum cleaners are noisier than an aircraft overhead, but can be switched off at will.

Aircraft noise provokes highly individual and often emotional responses, examples of which are given in the box above. The subjectivity of responses to aircraft noise makes it difficult to quantify the relationship between noise levels and annoyance. However, there is general agreement that noise levels below 50dB(A) L_{eq} are unlikely to cause community annoyance but that some people will be severely annoyed at levels of 55dB(A) L_{eq}[28]. In the UK, the DfT uses a level of 57dB(A) L_{eq} as an indicator of the onset of community annoyance in daytime[29].

There are however, some questions over the strength of the relationship between annoyance and L_{eq}, with some evidence for a more robust relationship with the maximum sound level (L_{max})[30]. Thus the World Health Organisation (WHO) has called for long term studies to determine the best noise indicator. Similarly, there are people inside the contour who will not be affected by the

[28] World Health Organisation, *Guidelines for Community Noise,* 1999.
[29] DfT states that this is equivalent to the WHO level of 55 dB(A), the difference being in how it is measured and how adjustments are made for the fact that noise from airborne sources behaves differently from those on the ground.
[30] Hume K. and Watson, A., The human health impacts of aviation. In: Upham, P *et al* (eds) *Towards Sustainable Aviation*. Earthscan, 2003.

noise, and also those outside who will be affected. It should not be used, therefore, as a precise gauge of who will and who will not be affected.

Sleep disturbance

Interference with sleep patterns is frequently reported by those living near airports operating night flights. A recent study of residents in high noise areas close to Heathrow, Gatwick, East Midlands and Coventry airports found 1 in 5 respondents were 'extremely annoyed' by aircraft noise at night, with between 1 in 5 and 1 in 10 often reporting difficulty getting to sleep or being woken early[31]. The European Court of Human Rights has ruled that the UK Government's procedure for decision-making about night flights was flawed, and that this flaw amounted to a "*violation of the respect for private and family life and the home*" under the European Convention on Human Rights. This judgement did not state that night flights themselves were a violation of human rights. The Government is appealing against the court's decision.

Definitive relationships between noise levels and sleep patterns have yet to be established outside laboratory conditions. There is also considerable uncertainty as to how, if at all, sleep disturbance affects long term health. Although laboratory studies have demonstrated that noise can effect sleeping patterns (time to fall asleep, changes in sleep pattern, night time waking) and have physiological effects during sleep (increased heart rate and blood pressure), studies in sleepers' homes demonstrate much less disturbance from noise, possibly due to sleepers getting used to night time noise. One study suggested that the average sleeper was woken by aircraft noise events of over 80dB(A) on only 1 in 75 occasions[32]. It also found a wide variation in responses to night noise – the most sensitive people could be disturbed twice as often as the average and the least sensitive half as often as the average. Moreover, focusing mainly on awakenings may be misleading as a sleeper's perception of whether he or she has had a good night's sleep also depends on the time taken to fall asleep, the total number of hours sleep and the time of awakening in the morning. However, the study found that people's subjective indications of their quality of sleep corresponded well with measured disturbance. This suggests that this method provides more reliable evidence than 'one-shot' special survey methods.

The World Health Organisation guidelines on community noise recommend that if all negative effects on sleep are to be avoided, indoor noise levels should be 30dB(A) L_{eq}, while no single noise event should exceed 45dB(A). Noise levels in many suburban and urban areas already exceed such levels, with indoor L_{eq} noise levels in urban areas at night being typically around 40dB(A). Average indoor noise levels from individual aircraft movements were recorded as around 52dB(A) in a recent study of aircraft noise at night in the Manchester area[33]. Overall, aircraft noise affects some people at night, although the evidence suggests that the level of sleep disturbance is minor for most people exposed to noise levels around the 57 dB(A) threshold for community annoyance. However, questions remain over whether it is fair to expose these few people to noise that will disturb them while the majority sleep soundly. This became a *cause celebre* is Sydney (see the Annexe to chapter 3), where such 'noise concentration' was described by a Senate Committee as "*a form of discrimination*". Nevertheless, significant uncertainties still remain over the relationship between noise and sleep, and the effects of sleep disturbance on long term wellbeing[24].

[31] Department of the Environment, Transport and the Regions, *Perceptions of Aircraft Noise, Sleep and Health*, December 2000.

[32] Ollerhead *et al*, *Report of a field study of aircraft noise and sleep disturbance*, Civil Aviation Authority for the Department of Transport, 1992.

[33] Department of the Environment, Transport and the Regions, *Aircraft Noise and Sleep – 1999 UK Trial Methodology Study Report*, November 2000.

Effects on health

Most investigations of the effect of noise on adult health other than hearing have focused on potential effects on the cardiovascular system. Individual loud noise events cause a temporary increase in blood pressure and heart rate. Whether frequent exposure to noise events has a long-term effect on these factors is open to question. According to the World Health Organisation, evidence suggests at most a "*weak link*" between long-term exposure to noise of around 65dB(A) L_{eq} and cardiovascular effects. However, the WHO also cautions that if large numbers of people are exposed to this sort of noise level, even a small increased risk could result in significant numbers of extra cases. WHO suggests that current evidence is as yet inconclusive and that further research is necessary before it can offer any guidelines. There is also some limited evidence that environmental noise is related to the development of existing mental health disorders, although noise is not believed to cause mental illness.

Effects on educational achievement

There is evidence to suggest that environmental noise may affect children's school performance. A study in Munich reported poor reading performance and long term memory among pupils near the airport. Performances improved after the airport closed, but test scores of children living near a new replacement airport fell. Similarly, a study in New York found reading impairments in schoolchildren exposed to over 65 dB(A) L_{eq}. But a study of test results from children around Heathrow airport was inconclusive, once socio-economic factors had been taken into account. It is not clear whether the effects could result directly from exposure to noise, or from the cumulative loss of teaching time, if teaching is frequently disrupted by loud noise events.

Overall effects of noise

Much of the research in this area is either contradictory or inconclusive. This is likely to be due to insufficient knowledge in this highly specialised area, and hence many, including the WHO have called for considerably more research. Evidence to date does suggest that most people exposed to aircraft noise are not adversely affected, but that more vulnerable groups may be at increased risk; particularly those with pre-existing sleep problems, stress or mental health problems[24].

3.3 Current and future aircraft noise in the UK

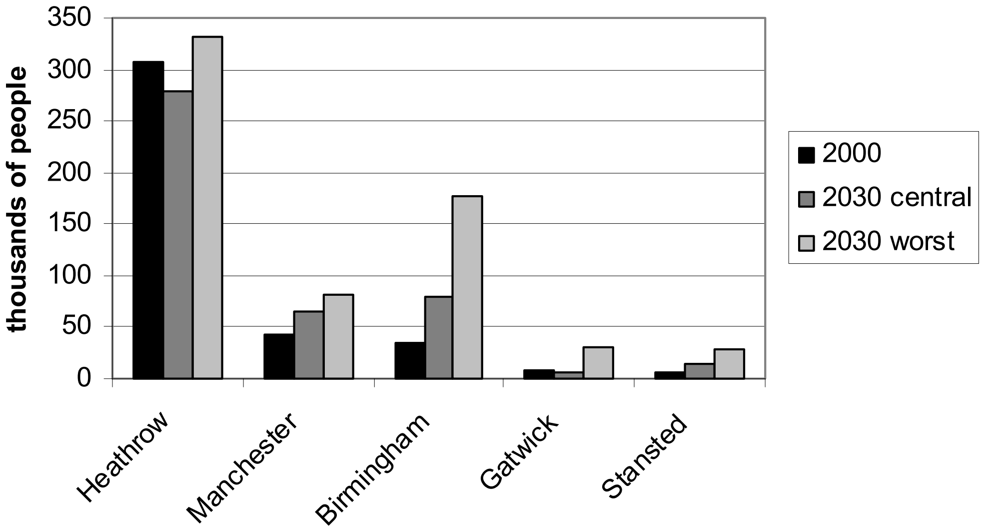
Current noise levels

Over the last 30 years, noise from individual aircraft has reduced. Further, the total numbers of people exposed to excessive noise have declined over recent decades, with some estimates suggesting that in the early 1970s, as many as 2 million people were exposed to noise above the threshold for community annoyance. Therefore, for all but the most rapidly expanding airports, such as Stansted, the effect of gradual introduction of quieter aircraft and phasing out of noisier ones has so far outweighed increases in aircraft traffic, leading to an overall reduction in noise. However, at present, the Government has estimated that close to half a million people in the UK remain exposed to aviation noise levels above the threshold for community annoyance (57dB(A) L_{eq}). Of these, four-fifths are in the south-east of England, with around 300,000 people located within the 57dB(A) L_{eq} contour, and hence potentially affected by aircraft movements at Heathrow. But, as noted above, while some may not be affected living inside the contour, others living outside the contour may well be affected.

Future exposure

The largest airports are already operating close to their operating capacity limits. Thus, with no expansion of infrastructure, the noise climate would be expected to improve over the next decades as quieter aircraft come into service. This is illustrated in the figure on the next page, which shows the noise climate around various UK airports under different growth scenarios.

Forecast noise exposure from expansion at UK airports under three scenarios



Source: based on figures quoted in Department for Transport, The future development of air transport in the United Kingdom: a national consultation, July 2002 (and second edition, February 2003).

However, providing new infrastructure, such as additional runways, would mean that the effects of the increase in aircraft movements could outstrip improvements in technology and thus increase noise exposure. Indeed, the Government's consultation documents estimate that an additional runway at Heathrow would double passenger numbers by 2030, leading to a further 25,000 people exposed to noise levels above 57dB(A) L_{eq} , even with quieter aircraft.

In contrast, European noise policy aims to ensure that, on average, there should be no short term increase in the numbers of people exposed to high levels of noise and that these numbers should be reduced in the long term. Thus, if the numbers of people exposed to aircraft noise increase in line with the forecasts, compliance with EU policy would require equivalent reductions in the numbers exposed to noise elsewhere (and perhaps from other sources). There is at present no statutory requirement to comply with this policy.

3.4 Reducing the impacts of noise from aviation

Regulating aircraft noise

There are three main tiers of regulation governing aircraft noise in the UK: international, EU and national (see box). At international level, the International Civil Aviation Organisation (ICAO) sets progressively tighter certification standards (known as chapters) for noise emissions from civil aircraft. In addition to these specific requirements, the ICAO requires members to adopt a "*balanced approach*" to noise management which looks beyond individual aircraft to :

- reducing aircraft noise at source
- land-use planning
- changes to operational procedures
- restrictions on the use of the noisiest aircraft.

Reducing aircraft noise at source

As explained above, all subsonic aircraft[34] currently operating in the EU must comply with the ICAO Chapter 3 noise standard agreed in 1977. From 2006, all *new* aircraft must also comply with the tighter Chapter 4 standard, which represents a reduction of 10dB on measurements for Chapter 3 aircraft.

[34] with a take-off weight of more than 34 tonnes – i.e. excluding light aircraft.

Regulating aircraft noise in the UK

International

The International Civil Aviation Authority (ICAO) sets standards, known as 'Chapters', for the noise emitted by civil aircraft, to which member countries' fleets must conform. The chapters set maximum acceptable noise levels for different aircraft during landing and take-off. Since 1st April 2002, Chapter 2 aircraft (weighing more than 34 tonnes) have been prohibited from operating in the EU unless granted specific exemptions. However, some civilian aircraft were converted from older and noisier Chapter 2 aircraft by retrofitting of 'hushkits' to the engines, and only just conform to the Chapter 3 noise standards. The ICAO has recently agreed a new 'Chapter 4' standard which will be mandatory for all new aircraft manufactured from 2006. Although best available technology already enables aircraft to achieve 18dB below the current Chapter 3 standard, the Chapter 4 standard has been set at only 10dB below that of Chapter 3. Furthermore, this 10dB reduction is an aggregate of reductions in noise measured at three standardised locations close to an airport, and so corresponds to a smaller reduction at each measurement point.

European

The EU is increasingly assuming responsibility for the regulation of aircraft noise standards. For example, an EU directive banned Chapter 2 aircraft from landing in the EU from 1st April 2002. Two further EU Directives are relevant to aircraft noise:

- EC Directive 2002/30 repealed an earlier directive which had sought to ban 'hushkitted' aircraft from operating in the EU on the grounds that their Chapter 3 compliance was marginal. Considerable protests, largely from US airlines operating hush kitted Chapter 2 aircraft, led to its repeal. However, this replacement directive does enable large or city-based airports to prevent aircraft which only just meet the Chapter 3 standards, such as hushkitted aircraft, from landing and taking off. However, other possible mitigation methods must also be considered, as in ICAO's balanced approach. The directive must be implemented in the UK by end of September 2003.
- EC Directive 2002/49 ('environmental noise directive') requires member states to create 'noise maps' of noise from all transport sources in urban areas by 2007, and to adopt action plans to manage noise by 2008. The directive also aims to harmonise methods for measuring noise across the EU.

National

The Government takes the view that in most cases airport operators, working in conjunction with local airport consultative committees, are best placed to resolve any local noise issues. Unless any conditions on noise are imposed on the airport concerned as part of the planning system, most UK airports are not required to impose any noise limits. However, the 1982 Civil Aviation Act does grant the Government powers to introduce noise control measures, including mitigation, if the Government believes local solutions are not succeeding. Based on their national significance, Heathrow, Gatwick and Stansted are currently 'designated airports' where the Government is responsible for noise matters – for example imposing restrictions on night flights. BAA can fine aircraft which breach noise limits.

Most aircraft coming into service now already comply with Chapter 4. However, these standards are regulated with reference to the sum of measurements taken at three separate locations. Thus, in terms of perceived loudness at any one measurement location, Chapter 4 compliance could correspond to a reduction in noise energy of around 3dB – i.e. a halving of the sound energy. Aircraft are replaced roughly every 20-35 years (although in Europe the average is around 8 years), and hence further reductions in noise at source will require restrictions in the use of the noisiest Chapter 3 aircraft or incentives to use quieter, Chapter 4 compliant aircraft. However, there is no agreed date for phasing out Chapter 3 aircraft.

Over the past 30 years, improvements in aircraft technology have resulted in a reduction in noise of around 20dB. These improvements are continuing, with modern aircraft being successively quieter than their predecessors. Around a fifth of the current fleet already achieves a noise target 14dB below the new Chapter 3 standards, and around half of all British Airways' aircraft coming into service now achieve noise levels of 14 dB below the Chapter 3 standard. By 2004 British Airways expects 90% of its fleet to meet these levels of performance. Indeed, RollsRoyce reports that modern aircraft can achieve 18-24dB below the Chapter 3 standard. However, further improvements beyond the forthcoming Chapter 4 standards will be increasingly difficult to achieve, although there is much pressure to develop aircraft with significantly lower noise level than is currently possible.

Aircraft noise arises from both engines and the movement of turbulent air over the physical structure (airframe) of an aircraft. To date, noise reduction has focused mainly on reducing engine noise. This is now sufficiently low that tackling noise from the airframe, which may be more challenging to reduce, is becoming as important. The Advisory Council for Aeronautics Research in Europe (ACARE) is a group bringing together the key players in Europe's aerospace industry. ACARE has set a target for the industry to halve perceived aircraft noise by 2020. However, there is no guarantee that this target will be met. Current technology points to the target being achievable, but translating laboratory-tested concepts into a fully functioning aircraft raises challenges – not least that the noise performance of a new aircraft is difficult to characterise fully before it is built and flown.

There is general agreement within the industry that substantial noise reductions beyond the current ICAO required reduction of 10 dB (from Chapter 3 to Chapter 4 standards) will be difficult to achieve without radical changes to aircraft design. However, such a technological breakthrough is likely to need substantial research funding to succeed, and questions arise over the ability of current drivers to encourage substantial further investment in noise reduction technologies. The fact that most aircraft currently being manufactured already meet the 2006 Chapter 4 noise standard, suggests that international standards for aircraft noise now follow, rather than drive, technological developments. Although the aviation industry might argue that the *expectation* of stricter international standards in future acts as a driver to research, experience to date indicates that ICAO is unlikely to introduce standards which are not already achievable. Thus, unless greater incentives to reduce noise are introduced (e.g. noise-related landing and take-off charges), the current regulatory regime is unlikely to motivate a substantial increase in noise research.

Land-use planning

Many UK airports are already located in densely populated areas so the potential for land-use planning to reduce exposure to noise from existing airports is limited. However, planning does have a role to play in considering new developments near airports or development of new airports, and indeed, airlines and airport operators argue that its role has been largely neglected to date, and that more could be done under the ICAO balanced approach. Section 7.3 of this report outlines how the planning system can tackle some of the environmental issues associated with airports. The remainder of this section deals specifically with how planning can address noise.

Government planning guidance advises that planning permission for housing should normally be refused in areas exposed to noise from any source louder than 66dB(A) L_{eq} during the day (and 57dB(A) at night). At noise levels between 57 and 66dB(A) L_{eq} mitigation measures should be a condition on planning permission, but noise below 57dB(A) L_{eq} need not be considered[35]. Planners are required to consider possible future changes to the noise climate. As outlined in section 3.3, areas around some UK airports are projected to experience an improvement in noise climate over the next decade, followed by a deterioration thereafter. Thus, in considering the potential for new airport development, future noise exposure is likely to feature as a key issue.

Another option could be to zone areas of land around airports as being unacceptable for domestic habitation given current or expected future noise levels. Here, for existing developments, compensation could be paid, sound insulation provided, or assistance in relocating could be offered. While the last option could increase pressure on land elsewhere, and mean longer travel distances to the airport, it could also release areas of land for uses that are less noise sensitive

[35] Department of Transport, Local Government and the Regions, *Planning Policy Guidance note 24: Planning and Noise*, August 2001.

than housing – such as offices or commercial development, which may increase the efficiency of travel from these facilities to and from the airport. For future developments, it might be possible to zone land-uses to exclude residential areas and other noise sensitive land-uses such as schools and hospitals, and to encourage commercial developments.

Changes to operational procedures

Take-off

The management of airspace for safety, navigation and logistical reasons leads to a concentration of air traffic along a small number of specific airways. In addition, the CAA points out that it has long been acknowledged that concentrating departures along the least number of possible routes generates the best environmental outcome. However, the Sydney airport experience (see Annexe to Chapter 3) raises questions about whether this assumption still holds true. The area on the ground affected by noise from departing aircraft depends both on the flight path followed, and on the rate of ascent of the aircraft. Take-off flight paths in the UK generally follow noise preferential routes (NPRs), which are chosen to overfly the least populated areas after take-off (although the CAA has suggested that some cases military airspace could prevent optimum NPRs from being used in some circumstances). Climb rates depend on the performance of different types of aircraft[36]. In some cases airspace design considerations may prevent ideal take-off paths from being followed. For example, an NPR for aircraft heading south after take-off from Heathrow passes to the west of Gatwick airport. Flights on some of Gatwick's NPRs are therefore prevented from climbing too rapidly as they have to pass under the Heathrow traffic.

At an airport with little population close to the end of the runway, noise impacts will be minimised by using maximum thrust on take-off, despite the extra noise this generates close to the runway. On flight paths which overfly residential areas soon after take-off, overall noise impact may be reduced if less thrust is used, despite the slower climb rate. Hence the optimum take-off procedure in noise reduction terms for any one airport will depend on the land-use and environment around that airport, and on whether that airport's policy is to concentrate noise on a small number of residents (as is usual) or to distribute it more widely (as in Sydney).

An alternative may be to move away from the traditional notion of concentrating departing traffic into a small number of tracks and to allow them to fan out after takeoff along many different tracks. This would have the effect of reducing the noise burden and the frequency of overflying for those living under current flight paths. This would expose people within a wider area to some level of aircraft noise that they had not experienced before. If this 'noise sharing' pattern were to be adopted (as it has in Sydney), the CAA would need to be assured that it complied with the Government's directions on environmental objectives, while also meeting their requirements for operational safety and efficiency.

Landing

The Government acknowledges that where airports are close to populated areas, landing noise is increasingly regarded as a more serious problem than departure noise, due to the need for final approach paths to operate in straight lines, thus giving little flexibility in deciding which areas will be overflown. As aircraft must align their final approach paths at some distance from a runway, it is not currently possible to develop noise preferential routes for arriving aircraft. Procedural improvements to reduce noise from arriving aircraft have therefore focussed almost exclusively on a procedure known as continuous descent approach (CDA). A CDA is an approach path in which an aircraft descends smoothly from around 6,000ft, usually at an angle of around 3 degrees, rather than descending through a series of level flight and steeper descents.

[36] At Heathrow, for example, after passing a point 6.5 km from the point on the runway at which most aircraft began their roll for take off, they must achieve a maximum climb rate of 4%.

The CDA allows aircraft to operate on low power and with low drag, and hence it minimises noisy changes in engine tone which may be annoying on the ground, and reduces average noise on the ground by up to 6dB(A). The main benefits are felt between 12 and 30km from touchdown. CDA also ensures that on the initial approach to the airport, the aircraft is no lower than is strictly necessary. At the designated airports (Heathrow, Gatwick and Stansted), considerable effort has been devoted recently to increasing use of CDAs. At Gatwick, for example, around 70% of daytime approaches now use CDA, while at Heathrow the figure is 75%. This improvement has been achieved largely through air traffic control, airports, airlines and pilots working together to increase awareness of the importance of CDA[37]. At night, CDA adherence is better. Although safety and operational reasons may restrict opportunities to follow a CDA, there is clearly scope for further improvement. This needs good co-operation between ATC, airport operators and pilots (some of whom may be unfamiliar with CDA).

A further possible option could be to move towards steeper descent angles so that aircraft are higher at any particular distance from the airport during their final approach, although this is unlikely in the short term. Larger civil jets cannot land at steeper descent angles than the standard 3 degrees without compromising safety, but future generations of these jets may be designed to allow steeper approach angles. However, many smaller aircraft can follow steeper final approach paths (as at London City airport), so they also require shorter runways, which might then be an option. However, current air traffic control procedures would find it difficult to manage aircraft approaching at different angles safely, so even if future aircraft designs and safety regulations did allow steeper approaches, it would be challenging to use these procedures while older and larger aircraft were using the same runway. Thus, it could be feasible to use longer runways for larger aircraft approaching at 3 degrees, while also using shorter runways for smaller aircraft approaching at say 5 degrees.

In guidance to the CAA on its environmental objectives, the Government anticipated that final approach tracks will, for the foreseeable future, remain aligned with the runway. However, it does suggest that if technologies were developed that allowed curved approaches or variable rates of descent, these could only be considered if they did not lead to a significant loss of capacity. In the meantime, relocating stacks to less noise sensitive locations may be an option worth considering.

Restrictions on the use of the noisiest aircraft

Clearly restricting use of the noisiest aircraft would reduce the noise burden around airports. As described in the box on the previous page, the designated airports already impose restrictions on certain categories of aircraft at night. However, under the new EU directive on aircraft noise (see box on page 23), restrictions on the noisiest aircraft can be introduced only after the various other possible options (such as land-use controls and changes in procedures) have been considered.

At Heathrow, British Airways voluntarily banned departures of its aircraft after 11.30 at night and is aiming to avoid arrivals before 4.45 in the morning. In addition, British Airways has stated that the opening of Terminal 5 at Heathrow will not lead to any further night flights. The box on the next page outlines the noise controls at Heathrow, Gatwick and Stansted.

Mitigating noise

In addition to controls on aircraft take off and landing, another approach is to minimise the impact of noise within buildings. This can be achieved through sound proofing. Also, providing compensation to those affected or, in extreme cases, offering to purchase affected properties can

[37] Indeed, BAA has specified in its contract for air traffic control services with Nats certain performance indicators that require where possible approaching aircraft to operate on CDAs.

Noise control at Heathrow, Gatwick and Stansted

As designated airports, noise control measures at Heathrow, Gatwick and Stansted are under the direct control of the Department for Transport. A variety of measures has been put in place at these airports to encourage or require minimum noise procedures. These are monitored and enforced by use of a noise and track keeping (NTK) system. The NTK system matches data from noise monitors to radar data on aircraft flight paths to monitor the noise levels and track keeping of individual aircraft.

Take-off noise
Aircraft must reach a minimum height of 1,000ft by 6.5km from the start of their take-off roll, and must not exceed a certain noise limit as measured by a noise monitor at that point. Airlines whose aircraft breach these conditions are fined (BAA imposes fines of £500 or £1,000, depending on the seriousness of the breach), with the money used for noise mitigation or donated to local community funds. The airports also monitor how well aircraft keep to the noise preferential routes (NPRs) after take-off. There are possible sanctions against aircraft which do not keep to the tracks, but these have generally not been needed. Instead, airports work closely with the airlines, publish data on airlines' track-keeping performance and encourage the sharing of good practice between airlines. Airports report that this approach has resulted in improvements in track-keeping. At Gatwick less than 1% of departing aircraft now leave the designated routes. The figure for Heathrow is 3%. This is undoubtedly improves the noise climate for those not living under the NPRs; whether those living under the tracks view it as an improvement is questionable.

Landing noise
The Government has concluded that setting noise limits for arriving aircraft is not feasible. Instead, aircraft are strongly encouraged to adopt CDA procedures, and a Code of Practice (with considerable support from the airlines) sets out procedures which should be followed to minimise arrivals noise.

Night noise
There are restrictions on the total number of aircraft movements at night (11.30pm-6am), the types of aircraft which can be used at night and a noise 'quota' for the total noise allowed at night at each airport over a whole season (summer or winter) – in effect, the noisiest aircraft are banned between 11pm and 7am. Aircraft used for night movements are assigned points according to how noisy they are, which count towards the noise quota. This can provide a powerful incentive to airlines to operate aircraft in the lowest categories possible for the size and type of aircraft, particularly for long-haul routes to the Far East, whose flights leave the UK in the late evening and arrive in the early morning.

Industry concerns
The departure noise limits described above date from December 2000, when noise limits were tightened from previous levels. Introducing the tighter regulations was fraught. An attempt by the Government to tighten the noise limits in 1996 was challenged by the International Air Transport Association (IATA); a new 1997 Government consultation paper was also challenged by IATA; a supplementary consultation paper followed in 1999 and the new noise limits were finally brought introduced early in 2001. Principal industry concerns were that the noise restrictions would not necessarily reduce overall noise impact on departure. Also that meeting the noise restrictions and height targets would require reductions in take-off weight for larger, long haul aircraft, resulting in greater costs per passenger for the flight. The industry has argued that some flights might no longer be financially viable. On night restrictions, the British Air Transport Association (BATA) has commented that, despite aircraft at Heathrow becoming quieter (and hence attracting fewer quota points), no additional night flights have been allowed. Thus BATA reports that there is little incentive for airlines to operate fewer or quieter aircraft than the current regulations require. Indeed, the A380 aircraft which will soon come into service at Heathrow will operate with fuel efficiency reduced by a few percent to comply with night-time noise requirements. This increases costs of these aircraft operating at all times.

On 8 April 2003, the Department for Transport announced a consultation on the night noise restrictions, proposing to extend the arrangements until October 2005.

mitigate the impacts. Each of these options raises difficulties in determining the 'cut-off' above which the compensation is offered. The box on page 28 outlines the sound insulation scheme around Manchester airport.

Further measures to reduce aviation noise

A number of further policy instruments could be used to reduce noise from aircraft, including:

- **voluntary agreements** e.g. airport/local community agreements on number or types of day and night flights, airport/airline agreements on procedures to minimise noise
- **regulation** e.g. statutory and operational requirements on track keeping, take-off noise limits,

Manchester Airport sound insulation grant scheme

Manchester Airport has operated a sound insulation grant scheme since 1972. The scheme provides financial assistance towards the installation of soundproofing glazing in areas most affected by aircraft noise. The scheme boundary is based on a 'noise contour' that identifies those areas which are said to be affected by moderate to high levels of noise. The scheme currently includes 26,000 domestic properties.

In 1999, following wide-ranging discussions with its neighbours, local councillors, the airport consultative committee, environmental health officers and acoustic industry specialists, the sound insulation grant scheme was reviewed. The new scheme continues to offer secondary glazing to over 26,000 properties within the boundary, However, in response to the consultation feedback received, an 'inner zone' of nearly 1,000 properties are now eligible for repeat grants, an option of replacement high performance double-glazing and acoustic loft insulation.

or number of night flights, possibly enforced via fines on offending airlines or airports

- **economic instruments** e.g. landing charges varying according to the noise performance of aircraft, or airline record on track keeping.

The designated airports (Heathrow, Gatwick and Stansted), where noise control is the responsibility of the Government, have already introduced a number of such measures to reduce noise impact. These, described in the box on page 27, provide an example of the sorts of regulatory measures which could be introduced more widely and the difficulties encountered in implementing them. In addition, the Government produced a consultation paper in 2000 on control of noise from civil aircraft[38] which set out a number of options to give more powers to local airports or local authorities to take action on aircraft noise. The Government's conclusions following the consultation will be published with the forthcoming white paper on air transport policy. The main consultation proposals, and responses to them, are described in the box on the next page. Responses to the consultation provide a useful overview of the different stakeholders' attitudes to regulation on aircraft noise. The key questions raised are discussed below.

Local or national control

Current Government policy is that noise problems should be resolved at a local level. Only where this has failed should Government step in to take direct control of noise mitigation measures, or where airports are of national importance (as with the major London airports). This policy acknowledges that the noise impact of any particular aircraft type or procedure will vary from airport to airport. For example, the number of people overflown during landing and take-off at Heathrow may be a hundred times more than that at a regional airport. Moreover, possible mitigation procedures vary from airport to airport. At some airports, air traffic management considerations or physical obstacles may restrict use of CDA procedures or noise preferential routes. In addition, the balance to be struck between environmental protection and the social and economic importance of flights may vary across regions.

On the other hand, a local approach can give rise to a proliferation of many different local regulations and requirements that could require airlines to follow different procedures at different airports. Because operating procedures are already highly constrained by international standards, airlines may not in practice have much freedom to alter their procedures to fit the requirements of particular airports. The development of regulations introduced at the London airports themselves has drawn on advice from the DfT's Aircraft Noise Monitoring Advisory Committee (ANMAC) concerning the feasibility of the proposed measures, which are introduced only after extensive consultation. Smaller airports may not have the expertise or resources to devise noise mitigation practices of their own.

38 Department of the Environment, Transport and the Regions, *Consultation paper on control of noise from civil aircraft*, August 2000.

Consultation on control of noise from civil aircraft

The consultation paper in 2000 proposed giving new powers to airport operators to require their users to follow noise reduction practices. In particular, the paper proposed:

- giving airports stronger powers to enforce noise control arrangements, for example by imposing penalties on aircraft which do not keep to noise preferential routes on take-off
- requiring airports to prepare strategies to tackle noise, with local authorities having enforcement powers
- making clear that airports may vary charges depending not only on the levels of aircraft noise but also on compliance with mitigation efforts, for example compliance with noise preferential routes.

Consultees' comments

Environmental and residential organisations generally supported the proposals, although with reservations on some practical aspects. Local authority responses were mixed, with some considering that it was not their role to enforce noise control schemes. Airlines and airport users supported the current, largely voluntary schemes. Key issues raised by consultees included:

- **planning** – planning applications may be granted subject to conditions relating to noise. New requirements on noise could conflict with these
- **local or national control** – some argued that a national or regional framework for noise mitigation was better than a local approach, both to provide longer term certainty for airlines and to avoid distortion of competition between airports
- **competition** – noise limits which some aircraft types would have difficulty in meeting could conflict with ICAO regulations forbidding unfairly favouring one aircraft type over another
- **enforcement** – there were concerns that local authorities did not have the necessary technical expertise to enforce noise schemes, or might have a bias either supportive or antagonistic towards the schemes (the latter could be a particular concern for those local authorities who are shareholders in their local airport). Some argued that the CAA, rather than local authorities, should have responsibility for enforcing noise amelioration schemes. Equally, some felt it unreasonable to expect airports to impose sanctions on airline customers, or to be accountable for the airlines' actions.

Sources*: Control of noise from civil aircraft,* Department of the Environment, Transport and the Regions, August 2000, and *Summary of Responses to Control of Noise from Civil Aircraft,* Department of Transport, Local Government and the Regions, 2002.

It is also possible that different local amelioration schemes could alter the relative competitive positions of airports – although environmental groups argue that larger fees for using airports with greater noise impacts ensures that airlines would pay towards the environmental costs of using that airport. This issue is discussed further in section 7.4. Overall, noise mitigation schemes need to be tailored to address the specific circumstances of each airport. However, some have suggested that national guidelines may be needed when an airport introduces noise mitigation measures. Some airlines and airports have proposed that only airports above a certain size should be required to take action on noise. However, the size of an airport does not necessarily reflect its noise impact; for example Belfast International airport currently handles around a third more flights than Belfast City, but Belfast City's noise impact is almost seven times as great. Instead, requirements to introduce noise mitigation schemes would depend on the noise impact of the airport – e.g. in relation to the numbers of people exposed (or expected to be exposed) to more than a certain noise level such as the 57dB(A) L_{eq} threshold for community annoyance. This issue is discussed further in section 7.2.

Equally, airports have argued for a nationally agreed 'toolkit' of potential mitigation measures. This could reduce the need for technical expertise, although some expertise would still be needed to suit local circumstances. For example, a list of takeoff noise limits realistically achievable by different aircraft types could ensure regulatory measures were feasible and reassure airlines that 'unfair' schemes could not be introduced. Questions remain, however, over who would compile, update, disseminate, monitor and evaluate such guidance. There are many options for this, ranging from the DfT itself (or its advisory committee, ANMAC), through the Civil Aviation Authority, a range of professional bodies (such as the Chartered Institute of Environmental Health), or through an independent body comprising representatives from a range of interests, including lay representatives – this may be some variant or amalgamation of airport consultative committees. The forthcoming white paper is expected to put forward suggestions on this topic.

Voluntary agreements or regulation

CDAs represent an initiative that has already played a role in tackling noise at the designated airports. In principle, they are mandatory, although there is no punitive regulatory regime under which they can be enforced. Airlines receive regular feedback on their performance in achieving CDA, track keeping and noise infringements. This information is also made publicly available, giving the opportunity for scrutiny to create further pressure for continued good performance. Other airports around the country have expressed an interest in using the CDA code of practice to improve their procedures. Airlines argue that raising awareness of noise impacts and sharing best practice, backed up with voluntary agreements, is adequate to deal with noise problems, and that a more formal regulatory system would be less effective.

CDA procedures allow airlines to reduce noise for little effort, and also offer economic and environmental benefits from being more fuel efficient than approaches containing segments of level flight. However, although the potential already exists for voluntary agreements on many noise related procedures, few (other than the major airports) have established any. It is widely acknowledged that voluntary agreements have a role to play, but also that supporting regulation would provide an incentive to encourage airports, airlines and ATC to work together reduce noise.

Regulation has also provided a powerful incentive in driving aircraft technology (see chapter 7). In making aircraft purchasing decisions, some airlines will want their long haul fleets to meet Heathrow's most stringent night noise restrictions to enable them to take advantage of the lucrative and scarce night slots at the airport. Here, national regulations (such as night noise quotas) are driving innovation more strongly than the ICAO 'chapters', notwithstanding BATA's suggestion that these provide little incentive to go beyond current regulatory limits. Thus, many point out that, without stricter national regulation there is little incentive for aircraft manufacturers to strive to exceed the ICAO Chapter 4 standard, mandatory for new aircraft from 2006, and which most new aircraft designs easily meet now.

The role of economic incentives

The ICAO does not prevent states from introducing noise-related landing charges. Some UK airports, such as Heathrow, already vary landing charges according to noise certification of the aircraft. Time-variable charges could also levied to reflect the additional disturbance caused by landing or take-off in the evening or at night. However, it remains unclear whether such charges would provide sufficient incentive for airlines to use quieter aircraft than at present.

An alternative or complement, suggested by the Government, is to allow airports to set charges according to compliance with noise mitigation procedures, as a less 'heavy handed' approach than regulation, but charges would have to be set sufficiently high so that airlines were deterred from wilfully violating the procedures on profitable routes[39].

Moreover, while variable landing charges related to procedures, such as track keeping, sticking to CDA, and staying within noise quotas create incentives for *airlines* to reduce noise, they do not create direct incentives for *manufacturers* to act proactively to improve the noise performance in new aircraft. Responding to community concerns, airport operators can encourage airlines to exert pressure on manufacturers, through the supply chain, to bring about more substantial noise reductions than have been suggested by ACARE are achievable.

[39] This might penalise less profitable routes. An element of a noise charge based a route's profitability may be possible. However, charging on the basis of a route's profitability may be discriminatory.

3.5 Overview

Aircraft noise already has the potential to affect the quality of life of at least half a million people living close to UK airports – with four fifths of these living close to the major airports in the southeast of England. This chapter has outlined a number of potential policy mechanisms that could provide incremental improvements in the noise climate around airports. However, the forecast increase in air traffic movements, if realised, is likely to outstrip any progress in making individual movements quieter. Thus, the unconstrained rate of aviation growth forecast is likely to worsen (see figure on page 22) the noise climate around many of the UK's airports over the next few decades. Larger numbers of people would be exposed to the risks of sleep disturbance, annoyance and possible health effects of aircraft noise.

The Government itself recognises noise as "*one of the most objectionable impacts of airport development*" and that "*for many airports, taking effective measures to control and mitigate aircraft noise is fundamental to their sustainable development*."[40] This suggests therefore, that unless substantial improvements to the noise climate around certain airports are made, aircraft noise could well become a significant factor in constraining future airport expansion.

[40] Department for Transport, *Guidance to the Civil Aviation Authority on environmental objectives relevant to the exercise of its air navigation functions*, January 2002, para 28.

4 Local air pollution

Aircraft, airport vehicles and road traffic to access airports emit air pollutants, such as nitrogen oxides (NOx), fine particles (PM_{10}), carbon monoxide (CO) and volatile organic compounds (VOCs). This chapter examines the sources of air pollutants in and around airports, their contribution to local pollution levels, possible adverse effects, and options to reduce emissions.

4.1 Air pollutants and their sources

Aircraft engine emissions

CO and VOCs are a product of incomplete combustion of fuel, while NOx is produced primarily from the oxidation of air at high temperatures within internal combustion and gas turbine engines. In addition, engines also emit fine solid particles referred to as PM_{10} (these are particles with a diameter less than 10 microns – 10 millionths of a metre). The emission of these pollutants depends on how an aircraft operates – i.e. idling, taxiing, taking off, or landing. NOx emissions dominate during take off, climb and landing, while during taxiing and descent the engine is not as efficient and produces more CO and hydrocarbons. While some particles are formed during the combustion of aviation fuel, the main sources of PM_{10} are wear on the brakes and tyres during landing and take-off.

Air pollutants from aviation are (by convention) measured over a reference landing and take-off cycle (LTO), which covers aircraft emissions up to an altitude of 3,000 feet (915m). On average, the LTO cycle describes 20-30% of the NOx emissions of an entire flight and even up to 90% of the VOC emissions.[41] However, once an aircraft has climbed to an altitude of around 1,000 feet, its contribution to air pollution on the ground is negligible.

Airport operation

Most major airports have their own electricity generators to heat, light and power terminals, runways and operational buildings. However, the extent to which these are used, as opposed to using electricity from the local grid, depends on the relative costs of electricity. For example, Manchester airport has a number of combined heat and power plants, but due to the relative cost of electricity from these units compared with purchasing electricity from the local grid, they are not used very often. Combustion of gas or diesel leads to air pollutant emissions. In addition, most aircraft have an auxiliary power unit (APU), which is an onboard turbine that provides power for the aircraft and cabin air conditioning. APUs are powered by aviation fuel, and thus give rise to emissions of air pollutants. However, it is now general practice for aircraft to use fixed electricity supplies from the terminal building while alongside rather than APUs.

Airside vehicles such as baggage trolleys, catering trucks, tankers, tugs and coaches to transport passengers and freight to the aircraft can contribute to airport emissions. Such vehicles are characterised by travelling short distances at low speed and are used for long time periods. They emit 5 to 10% of the total airport NOx emissions. Other sources of air pollution at an airport include fire training exercises, aircraft maintenance, engine testing and de-icing. The storage and delivery of fuel can give rise to VOC emissions from storage tanks, fuel lines and refuelling facilities through evaporation and natural loss.

[41] Zurich Airport Authority, *Aircraft Engine Emission Charges*, Jan 2000. However, evidence from studies at Heathrow suggest that the LTO cycle may overestimate the contribution from aircraft in flight, and hence may be a source of error in modelling local air quality around airports.

Transport links

A major contribution to air pollutant emissions comes from road traffic to and from the airport. This includes cars, taxis, coaches, heavy and light goods vehicles, and light and heavy rail. Together, these sources contribute about 10% of airport NOx emissions. In many cases, road transport emissions exceed aircraft emissions in the vicinity of airports[42].

The majority of passengers, staff and freight currently arrive at airports by road. Motor vehicles account for the largest single contribution to airport pollution levels. This kind of air pollution depends on the location of the airport as well as its accessibility by public transport. For example, in 2001 50% of passengers to Gatwick airport arrived by private car and only 30% by rail or bus[43]. At Heathrow, 36% of passengers arrived by private car in 2001. A survey in 1996 at European airports showed that only 8% (Hamburg) to 35% (Munich) of all trips to the airport in one year were on public transport. The figure for Zurich airport was 39%. Emissions of NOx are linked with the occurrence of another pollutant, ground-level ozone, which is formed in the atmosphere by a series of chemical reactions between NOx, VOCs and oxygen in the presence of sunlight. Ozone may remain in the atmosphere for several days before breaking down, and can be transported downwind, thereby causing high concentrations to build up in rural areas rather than in urban areas, where the ozone is rapidly broken down by other pollutants.

4.2 Health effects

Health effects from air pollution form the basis for European and national targets for controlling the emission of air pollutants (see POSTnote 188). Effects of exposure to air pollutants include headaches, asthma and respiratory complications. During certain weather conditions, levels of air pollutants can rise significantly leading to the premature death of already weak and vulnerable people. In 1995/1996 up to 24,000 deaths were *"brought forward"* in the UK due to the short term, or acute effects of air pollution from all sources combined[44]. It is not possible at present to disaggregate these figures by specific sources. Research indicates that long-term exposure is thought to have an even greater impact, although this has been difficult to quantify. Poor air quality, however, not only affects people, but also other animals, plants buildings and materials (e.g. blackening and corroding historic buildings). These effects can occur at lower levels than specified for human health protection. Thus controlling air pollution to protect human health may not necessarily reduce the vulnerability of these other potential targets.

4.3 Reducing air pollution from aviation

International action

The International Civil Aviation Organisation (ICAO) deals with environmental effects through the Committee on Aviation Environmental Protection (CAEP). Resolution A33-7 addresses noise and emissions and the problem of limiting exhaust pollution from aircraft. ICAO has set engine certification standards in the Convention on International Aviation (Annex 16 – Environmental Protection, Volume II – Aircraft Engine Emissions). These limit the emissions of unburned hydrocarbons, CO, NOx and smoke during the LTO cycle up to an altitude of 3,000 feet. ICAO standards are constantly reviewed and in 1999 it mandated further NOx reduction of 16% on all aircraft jet engines certified after December 2003. However, aircraft typically operate for up to 25 years, so it will take some time to replace the existing aircraft fleet.

[42] European Federation for Transport and Environment, *Aviation and Its Impact on the Environment,* 1999.
[43] BAA Gatwick Airport, *Transport Report, 2002*.
[44] Committee on the Medical Aspects of Air Pollution, *Quantification of the effects of air pollution on health in the UK, 1998*. 'Deaths brought forward' means that vulnerable people might have lived longer if air pollution was not a factor.

European action

The 1996 Framework Directive on Ambient Air Quality (96/62/EC) and subsequent associated 'daughter' directives set mandatory limit values for a range of pollutants including NO_2, and PM_{10}. EU limits for overall NO_2 are binding from 2010, PM_{10} from 2005 with mandatory further tightening from 2010. If the EU limits are exceeded, the government is liable to legal action by the European Commission and could be fined.

The UK also belongs to the European Civil Aviation Conference (ECAC), the regional grouping of ICAO member states. ECAC has an environmental committee on the Abatement of Nuisances Caused by Air Transport (ANCAT). While ANCAT has proved useful in getting a European consensus on emission reporting, certification and charging matters, its effectiveness at international level is limited as it must negotiate alongside similar groupings covering four other regions of the world.

UK action

ICAO standards are implemented in member states through national legislation. In the UK, this is through the Air Navigation (Environmental Standards) Order 2002. In addition, there are Air Quality Strategies (AQSs) for England, Scotland, Wales and Northern Ireland[45] that set health-based air quality targets for eight key pollutants to be achieved between 2003 and 2008. The AQSs incorporate the legally binding EU limits and also include stricter national targets for some pollutants. Pollutants controlled under the AQSs are benzene, 1,3-butadiene, CO, lead, NO_2, ozone, PM_{10}, and SO_2.

Local authorities are required to monitor and assess local air quality. In areas where targets are likely to be exceeded, local authorities have to declare an Air Quality Management Area (AQMA) and work towards achieving the targets through the local air quality management process and in collaboration with major operators where necessary. In most cases AQMA areas have to be declared due to high NO_2 levels. Such an AQMA has already been declared covering a large part of the area around Heathrow – although this was generally as the result of emissions from traffic along major roads in the area. Similarly, NO_2 levels at Gatwick airport are very close to breaching the AQS target. Industrial emissions are regulated by the Environment Agency in England and Wales, the Scottish Environment Protection Agency and local authorities under the Integrated Pollution Control (IPC) regime. While airports as a whole are specifically excluded from IPC, combustion plants at the airport are regulated.

Aircraft emissions can add to already high levels of pollution from road traffic and so cause air quality limits to be exceeded. It is widely acknowledged that NO_2 and PM_{10} are the most challenging pollutants for airports to control, and around the busiest airports achieving compliance with the limit values for 2010 will be very challenging, regardless of any future expansion. Indeed, in 2001/02 air quality close to access roads at Heathrow and Gatwick failed the annual average daily NO_2 objective. Monitoring has also shown several breaches of the PM_{10} daily average objective. This is not unique to airports, and common to many urban areas.

Although elevated air pollutant concentrations may occur in and around an airport, people are not necessarily affected by these ambient concentrations. Thus, the effect of air pollution on people is assessed with reference to the actual exposures that people are likely to experience. Modelling studies can use monitoring and emission data to calculate levels of exposure in areas around an airport. The box on the next page outlines typical exposure at Heathrow. Meeting air quality objectives is likely to be difficult at Gatwick, but straightforward at all other airports in the UK.

[45] first published as a single National Air Quality Strategy in 1997

Air pollution at Heathrow

More than half of the current NO_2 concentrations in the vicinity of the airport are estimated to be from aircraft. In the near future, the Terminal 5 approval depends on an action plan provided by BAA to show how it intends to minimise the emissions of pollutants from, and attributable to, Heathrow.

Further ahead, modelling indicates that up to 35,000 people could be exposed to air pollution that exceeds the EU limit on NO_2 in 2015 if a third runway were built. If no new runway were built, 14,000 people would be exposed in 2015.

Thus, meeting the EU limit for NO_2 at Heathrow will be challenging even without the addition of a third runway. An additional runway cannot be considered unless the Government can be confident that levels of all relevant pollutants could be contained within EU limits. Thus, achieving European air quality targets could present a constraint to airport growth at Heathrow.

Reducing emissions from aircraft engines

Aircraft manufacturers and airlines report that the threat of regulation is the major driver behind the development of new technologies to improve environmental performance, including advances in aerodynamics, efficient engine design, especially combustor design. BAA supports the development of incentives to encourage low emissions technology for aircraft and lobbies for improvements of aircraft emissions performance through more stringent manufacturing standards.

Aircraft emissions depend to a large extent on fuel efficiency and combustion technology. One problem is that NOx emissions increase with improving combustion efficiency. However, this problem was partly overcome by the introduction of staged engines using different combustion technologies. These combustors already fulfil the new ICAO standards for NOx, which have to be applied to new aircraft by 2004 and could reduce NOx emissions per kg of fuel burnt by up to 30% compared with current designs[46]. British Airways operates half of its fleet of 747 aircraft with these new combustors. ACARE has set a target of an 80% reduction in NOx emissions in new aircraft by 2020, which will require improvements in combustor technology.

At present, and for the foreseeable future, kerosene still appears to be the ideal aircraft fuel in terms of density, weight and safety and can easily be stored in the wings of an aircraft. Consideration is also being given to using hydrogen as a fuel for aircraft[47]. However, the benefits of kerosene may not be achievable with hydrogen and would require novel aircraft designs. Safety, economic and technical considerations make it uncertain whether such aircraft could begin operation within the next 20 to 25 years. In addition, emissions from a hydrogen powered aircraft would contain water vapour. As chapter 6 discusses, emission of water vapour at high altitude exacerbates the greenhouse effect, and so would have an impact on the global climate.

Market-based measures.

ICAO has a long-standing policy that there should be no tax on aviation fuel used for international services. However, the opportunity remains for DfT to focus more on reducing emissions through emissions charges, based on calculated aircraft emissions. To help to introduce the charge and minimise any competitive distortions from unilateral charges, a revenue-neutral scheme might be most appropriate, e.g. with revenues being recycled to airline companies to enhance further environmental improvements. For instance, charges for traffic generated around airports could be used specifically to expand and improve public transport. The box on the next page outlines the emissions-based charging scheme operated at Zurich airport.

[46] Air Transport Action Group, *Industry as a partner for sustainable development, 2002.*
[47] *Prospects for a hydrogen economy*, POSTnote 186, Parliamentary Office of Science and Technology, 2002.

Aircraft engine emission charge at Zurich airport
In September 1997, Zurich airport introduced an emission charge based on engine emission and performance parameters to reduce emissions of NOx and hydrocarbons. The aim of the charge is to promote and accelerate the introduction and use of the best available aircraft engine technology. Aircraft engines have been classified according to engine emission factors. Depending on the class, a charge of between 0 and 40% of the landing fee has to be paid. All aircraft were given a general reduction of the weight-based landing fee of 5%. Thus the airport is not increasing its revenue by the emission charge. The revenue will be used to cover costs for emission reduction measures, such as an air pollution monitoring station, on site power stations and additional taxiways to reduce taxi-times. Although results of this scheme are unclear at present, Zurich airport expects improvements in the long-term. It is noteworthy that IATA unsuccessfully challenged the NOx charge at Zurich, and now a similar scheme operates at Geneva and Bern. Airports in Sweden also operate emission charges.

Aircraft operations

Operational improvements at an airport, such as a timely implementation of new systems for communications, navigation, surveillance and air traffic management (CNS/ATM), have the potential to reduce the amount of fuel burned by between 6% and 12% by 2050[48]. CNS/ATM is a global satellite navigation system intended to optimise flight routings and eliminate congestion problems, which is planned to reduce delays and flight times. It could also reduce the use of kerosene across Europe by up to 1.5 million tonnes each year. Improvement of approach trajectories could optimise the flight paths with regard to fuel consumption. Furthermore, the increasing use of continuous descent approach (CDA) is reducing emissions of arriving aircraft by reduction in staged descent (see chapter 3). Another option to reduce emissions during aircraft operation is to reduce thrust during take-off, and indeed, BATA reports that 90% of departures already use this technique. However, long runways are required and weather conditions (such as strong tailwinds) might not allow such procedures.

Airport operations and surface access

There is potential to reduce airport emissions by using airside vehicles powered by cleaner fuels, or by different means (e.g. low emission buses will be introduced at Heathrow by 2005 - see box on next page). Such an approach is strongly supported by BAA, which also uses emission abatement technology for vehicles operating within airport boundaries. Although not currently easy to determine, a substantial contribution to local air pollution around airports currently comes from road traffic accessing the airport. Improvements in vehicle emissions have already led to improved urban air quality (see POSTnote 188) and this is expected to continue for the next few decades.

Information needs

Despite considerable work in this area, further information is still necessary to give a more reliable picture of the extent and significance of air pollution from aircraft:

- improved characterisation of aircraft engine emissions during the landing and take-off (LTO) cycle to improve emission inventories
- more information on the sources, emissions and effects of particles from aircraft and vehicles
- guidance for local authorities on improved monitoring and modelling to enable assessment of emissions related to aviation and airports[49].

The DfT is supporting research into a technique for attributing sources of hydrocarbons in deposits around an airport. While this research is still at an early stage, if successful it will enable the sources of hydrocarbons present in the atmosphere or on the ground to be identified,

[48] *ICAO: Aircraft engine emissions: Definition of the problem*. See also Intergovernmental Panel on Climate Change, *Special Report: Aviation and the global atmosphere*, 1999.
[49] BAA has called for independent, validated modelling and monitoring data, to ensure all emissions are accounted for.

Surface access at Heathrow

The bus and coach station at Heathrow is the busiest in the UK with 16,000 vehicle movements a day. A surface access strategy was launched in 2002, which includes the introduction of alternatively fuelled airport vehicles and electric cars and bikes for staff journeys. The aim of the strategy is for 40% of passengers to use public transport to access the airport by 2007 - the current figure is 34%. One measure being considered to promote public transport is to reduce the availability of parking places at the airport. The Mayor of London is considering introducing a congestion charge at Heathrow airport.

so resources could be directed more efficiently towards tackling the dominant sources. Ultimately, this could have implications for international performance standards for aircraft, airline fleet purchase decisions, and airports as well as for local authorities' action plans.

4.4 Overview

With continuing improvements in the emissions from road vehicles, set alongside the forecast growth in air travel, emissions from aircraft are likely to become more significant as a source of air pollution around airports. If the current trend in improved engine technologies continues, developments would cause an overall reduction in emissions from each source of about 20% by 2015, compared with 1992 levels. However, even if the full potential of technical and operational measures to reduce emissions were achieved, overall levels of emissions from an increased number of all sources would still be expected to increase. The numbers of people potentially affected by these emissions would depend on their proximity to the pollution sources and the local conditions that affect how pollutants are dispersed.

5 Other local environmental impacts

Previous chapters have considered several environmental impacts arising from aviation. This chapter outlines a number of other potential impacts and how they could be mitigated, in particular:

- **land take** and the implications for wildlife habitats, landscape and heritage
- **water pollution**, particularly from de-icing aircraft, runways and aprons
- **waste management**, particularly waste generated inside terminal buildings.

Many of these impacts are generic to most large infrastructure developments. However, it is beyond the scope of this report to compare the impacts of aviation development with those from other modes of transport, or any other large infrastructure project. POSTnote 173 outlines the key aspects of the appraisal of major infrastructure projects.

5.1 Land take

The expansion of existing airports or the creation of new ones requires large amounts of land and can have considerable effects on the local environment. Land is needed for runways, aprons, airport buildings, car parks, etc. Also, airports generate related industries (such as cargo handling facilities, hotels, conference centres, etc.), and land is need for access to the airport. A new or expanding airport may also generate the need for new housing, schools, hospitals and commercial development. The degree of land take will relate to the existing infrastructure and the extent of development required. To a large extent this depends on the characteristics of the aircraft likely to use an airport, the frequency and number of aircraft movements, and the numbers of passengers passing through the airport each year. As well as land needed for the airport itself, residential and other properties may also be taken for safety reasons.

Effects on wildlife habitats

Land-take associated with development can result in the loss or break up of wildlife habitats. The significance of such effects depends on the area of land lost, the ecological value of the habitat and the degree to which species depend on it, the ability of species to migrate and survive in other areas and the extent of fragmentation. Fragmentation is an important impact related to land-take because it interferes with the movement of animals, decreases habitat size and reduces interaction between wildlife communities, possibly leading to a decrease in the diversity and abundance of species.

Habitats and species can also be disturbed or damaged by traffic noise and light, vehicle emissions, contaminated runoff and oil discharges. Direct mortality can result from vegetation destruction and trampling, and from road traffic. The release of pollutants into the environment can also affect natural habitats because some pollutants can be toxic – either killing or weakening certain species, while other, more resilient species can flourish. Airport developments can also affect flooding, and the balance of moisture in the soil (e.g. waterlogging or soil drought). Removing vegetation can also affect the stability of soils on a slope, and this can exacerbate flooding, increase erosion and hence the amount of sediment entering watercourses, thus potentially damaging habitats.

Mitigating effects on wildlife

One of the oldest and most common measures for the protection of wildlife and habitats is to designate areas for protection. These exist at statutory and non-statutory designated sites, where species and habitats are considered to be valuable at a range of levels: from international, through European, to national and sub-national down to local interest. Nevertheless, many of the options for airport expansion outlined in the Government's consultation documents are likely to encroach on green belt areas, designated conservation areas or local nature reserves. However, there are many ways in which the ecological effects of land-take can be mitigated:

- changing a project's location, alignment, design or construction and operating procedures
- designing facilities to incorporate measures to minimise pollution, soil erosion and run-off
- creating buffer zones and modifying site boundaries to take account of sensitive sites
- providing features, such as road underpasses for badgers, that reduce fragmentation of habitats
- ensuring minimum ecological damage during construction
- designating protection zones and protecting adjacent habitats by erecting boundary fences.

Other mitigation measures are remedial or compensatory measures, which can be important when the destruction or damage to habitats is unavoidable. Such measures include:

- translocation – rescuing species from the development site and moving them to another environmentally suitable site, i.e. a site that has a similar soil type, hydrology and climate
- habitat restoration – repairing a damaged ecosystem, including management of the existing system and using rescued species to repair or enhance a community that is not affected by a development
- habitat creation – usually proposed as a compensation measure for the loss of a valuable habitat.

Effects on landscape and heritage

When land is taken for development there may be a significant impact on the landscape. There are many elements that make up a landscape including physical elements such as geology, landform, climate, drainage, soil, vegetation and human elements such as archaeological remains, land use, buildings and settlements, as well as other historical and cultural associations. These combine in many ways to create aesthetic landscape values.

Vegetation damage or removal, or changes to the landform of an area can affect the character of a landscape. Inherent in such character are issues such as tranquillity, cultural heritage, sense of place and land cover. However, other important considerations include the recipients of the benefits of landscape character (e.g. visitors, residents, people passing through, etc), the scale of the landscape and the potential effects of development, and wider considerations of landscape importance, for instance, through designations as Areas of Outstanding Natural Beauty.

The use of land can result in damage to or the loss of historic buildings, archaeological sites and monuments. In addition to effects on known assets, previously undiscovered artefacts may be affected. An airport can change its surroundings into an urbanised setting, replacing previously rural characteristics with a more urban, built-up commercial and industrial landscape, which in turn, provides a catalyst for further urban development. Furthermore, lighting can create a glow in the night sky above a large development, which can be viewed from up to 10km away. However, the extent of any effects are dependent on the physical planning of the airport, the characteristics of the infrastructure and the nature of the pre-existing landscape.

Mitigating effects on landscape and heritage

New developments in sensitive landscapes can be designed in a way that reflects traditional patterns and styles, and to fit in (as far as possible) with the existing landforms and landscape features. Many airports are planned, designed and managed with the aim of creating an attractive environment, with vegetation planting to minimise the perception of noise, light disturbance and odour, and to soften the more urban appearance. Such screening can

Environmental management at Manchester Airport

Among its environmental policies, Manchester airport aims to provide best practice habitat and landscape management and create new and improved existing habitats and landscape. The airport occupies a total of 860 hectares – of which 520 hectares comprise the runways, taxiways, buildings, airfield grassland and landscaping, and 340 hectares is of agricultural and/or ecological value. As part of the approval for the second runway, the airport developed a 15-year landscape and habitat management plan, which details how land will be managed to improve ecological habitat such as hedgerows and ponds, while maintaining viable agriculture.

Landscape on the airport site is also carefully managed, with no use of peat and minimal use of pesticides. Green waste is minimised through the use of mulch mowers and woodchippers allowing grass cuttings and pruning waste to be reused within the site.

To mitigate the impacts of the second runway, a detailed £17 million environmental management plan was developed. This includes planting six new trees for every one removed, providing or improving two ponds for every one lost, planting or restoring over 36km of hedgerow, and creating new areas of wild flower grassland and woodland. Additional special measures have been undertaken to deal with the protected species identified within the site. Progress is monitored and reviewed by a Nature Conservation and Landscape Steering Group, which meets regularly and brings together the Airport Company, local authorities, specialist bodies (e.g. English Nature) and representatives of the local community. Work included:

- relocation of over 30,000 amphibians, including 4,000 newts to the 40 new and improved local ponds
- construction of 3 new bat barns which are now being used
- captive breeding at Chester Zoo of a rare mud snail found on the site, to be returned to the area once the construction works are complete
- successful relocation of a family of badgers to a new artificial sett
- translocation of 15 areas of grassland and woodland, and creation and improvement of 27 hedges
- recording, dismantling and planned reconstruction of two listed buildings
- undertaking an archaeological survey which uncovered a walkway in the Bollin Valley (dated to 1730) and evidence of bronze age settlements
- improvements to the River Bollin downstream of the second runway site.

incorporate existing woodland and other vegetation, particularly around car parks, terminal buildings and access routes. Additional screening through sensitively designed earth mounds, planting or noise barriers may also be required. Archaeological remains and buildings of historical importance can be avoided, or in extreme circumstances, artefacts can be excavated, or buildings can be relocated or reconstructed following construction. The box above outlines some of the key features of the measures taken to manage local environmental impacts at Manchester airport, particularly those related to the impacts of building the second runway.

5.2 Water pollution

Effects on water

Land-take associated with development can have a major impact on water resources and water quality which can directly and indirectly affect wildlife habitats. In particular, stormwater runoff and de-icing (see the box on the next page) are considered to have a potentially significant effects. Adverse effects can result from changes in the flows of water, and the amount of water passing through the soil into groundwater. As mentioned above, pollutants and nutrients can enter the water, and water temperatures may be increased[50] (this will reduce the amount of oxygen in the water, and thus present a risk to many aquatic species). These changes can affect wildlife and habitats.

The natural drainage patterns of an area can be affected by developments because they generally increase the area of impermeable ground, resulting in greater volume and rate of surface water runoff. Lining watercourses with concrete, channel realignment and diversion of streams through culverts also increase flows, with an increased risk of flooding which can affect habitats.

[50] Due to the heating effect of sunlight on large expanses of concrete across which surface water can flow.

De-icing at airports

Snow, ice or slush on aircraft and runways can result in hazardous conditions that can lead to accidents, delays, diversions and cancellations. In general, airlines are responsible for the de-icing and anti-icing of aircraft and airports are responsible for the de-icing of runways and airfields. Globally, chemicals such as ethylene or propylene based glycol mixtures, containing between 10 and 20 percent additives, are the most common methods of de-icing and anti-icing, with approximately 300-400 gallons of de-icing/anti-icing fluid used per aircraft. BAA airports do not use ethylene glycol for de-icing. Additives, such as dioxane, formamides, and acetaldehyde, among other chemicals, can be used as wetting agents, corrosion inhibitors, surfactants, dyes and thickeners. Estimates have suggested that at least 80% of the de-icer/anti-icer chemicals applied to aircrafts do not remain on the aircraft but spill onto the ground or spray into the atmosphere.

De-icing and anti-icing chemicals can contaminate groundwater and surface water supplies if allowed to flow from airport facilities to storm drains or waterways. Ethylene and propylene glycol based chemicals are very soluble and can rapidly breakdown in a process that consumes oxygen and threatens aquatic life.

Urea-based de-icing agents are also frequently used and, when released into the environment, increase the nitrate content of soil. As with glycol based de-icing/anti-icing chemicals, urea based chemicals reduce the oxygen levels of water resources and can be directly or indirectly toxic to aquatic organisms. Although nitrate pollution from airports is not comparable with the nitrate pollution caused by agriculture, it can lead to significant local pollution. Nitrates are harmful to humans when they enter the human body because they are converted into the carcinogenic nitrosamine.

To comply with pollution control regimes in the UK, airport operators must minimise and control potential water pollution from de-icing. Thus, they use tanks or ponds to hold run-off so that it can be released during high flow periods, when mixing of the runoff with high water volumes minimises effects on aquatic systems. Many airport operators filter the runoff through equipment that removes the pollutants. Other methods include de-icing pads, the use of vacuum sweeper trucks to capture de-icing or anti-icing chemicals and the use of a common stormwater system, sanitary sewer system or another dedicated drainage system. Another option is to use less harmful chemicals or techniques for de-icing/anti-icing operations, such as potassium acetate or calcium magnesium acetate which have no significant impact on water quality. In the US one airline is testing a system based on forced air and a smaller amount of de-icing fluid, which requires half the amount of de-icing fluid than previously. Another airline is using a new method for de-icing aircraft that uses an infrared technology inside a hangar. This technique is still in its early stages of development but at present appears too slow to be of use at busy airports.

Reductions in the rate of groundwater recharge can also reduce residential and municipal water supplies and affect local wetlands that rely on groundwater to maintain wet conditions during dry periods. Lower stream flows can affect aquatic habitats and the ability of a watercourse to dilute toxic spills.

Mitigating effects on water

In addition to the de-icing measures outlined earlier, other measures to mitigate the effects of airport developments on water quality include:

- mandatory consents to discharge potentially polluted surface water
- engineered schemes to prevent discharges until certified as being of an acceptable quality
- sewers and pipelines of adequate sizing and state of repair
- biological pollution control measures such as reed beds and settling ponds
- surface water control mechanisms such as balancing and storage ponds
- restoration, and where possible enhancement of habitats
- recycling and reuse of some materials and specialist disposal of others
- operating emergency procedures for accidents and spills.

5.3 Waste management

Airports generate every day wastes such as food and packaging in amounts proportional to the numbers of people passing through and working at the airport. Contaminated wastes are also produced from engineering facilities such as aircraft and vehicle workshops and cargo areas, and

Managing airport wastes

Waste is often temporarily stored in bins, skips or compactor units at or near where it is generated, and then transported directly to an off-site disposal facility such as a transfer station, landfill or incinerator. The waste management service for the collection and disposal of solid waste is often contracted out by the airport operator to one contractor, but tenant companies in other areas of the airport may control their own waste management operations. As a result, an airport's waste management may be controlled by many contractors, resulting in more commercial vehicle traffic at airports than necessary and complications in its the monitoring and control. A waste audit of a large UK airport discovered that more than 30 waste management contractors were operating on site.

Manchester airport operates a number of waste initiatives. There is a waste minimisation club for terminal catering companies, an induction training pack for terminal catering and retail staff to encourage recycling, a terminal cleaning project to encourage cleaners to collect newspapers left by passengers, recycling bins in the terminal to encourage passengers to segregate newspapers and skips to collect wooden pallets from the cargo centre. Manchester airport's policy is to control waste through purchasing policy, reduction of waste, reuse of materials, segregation and recycling. For airport waste initiatives to succeed, all companies that operate on the airport site need to be actively involved, with the airport plc providing a co-ordination, management and information role.

require specialist segregated facilities. Sources of waste at airports include the aircraft, terminal and office cleaning, retail, aircraft and terminal catering, engineering work and waste from construction activities. Historically, the main objectives for waste management at airports have been to ensure that wastes were not obtrusive, did not cause a nuisance, did not present health and safety hazards and that facilities for management occupied a minimum amount of land. However, airports and airlines increasingly recognise and understand the problems generated by waste and acknowledge that action is necessary to minimise and recycle all types of waste (see the box above). However, airports often point out that most waste is produced by sources that are outside of their direct control, so waste minimisation techniques are rarely implemented.

6 Effects on the global atmosphere

Previous chapters have considered the effects of aviation on the local environment around an airport. This chapter considers the environmental impacts at a wider scale, in particular the effects on the global atmosphere of greenhouse gases emissions from aircraft engines. The chapter sets out how aircraft exhausts may contribute to global climate change and how this could change with forecast growth in air travel both globally and in the UK. Options to address such effects are outlined.

6.1 Aviation and climate change

Overall, the Intergovernmental Panel on Climate Change (IPCC) estimated that aviation may contribute around 3.5% of the total contribution of human activities to global warming[51]. Aircraft engines emit a mixture of gases, with carbon dioxide (CO_2), nitrogen oxides (NOx) and water vapour among the most relevant when considering effects on the global atmosphere (see the box on the next page). While CO_2 is a major contributor to any climate change effects from aviation, the effects of water vapour, which is also a greenhouse gas, remain more uncertain. Further, the potential to create condensation trails (contrails), and possibly induce high altitude (cirrus) clouds may also be significant.

Factors affecting aircraft emissions

The emissions from any particular flight depend on a number of factors, such as the length and altitude of the flight, the payload the aircraft is carrying and the design of the aircraft. The Royal Commission on Environmental Pollution (RCEP) has pointed out that fuel used for each kilometre travelled varies with the length of flight involved[52]. Taking off and landing use relatively more fuel compared with the cruise phase of a flight, so short haul flights use more fuel per kilometre than long haul flights. As the length of a flight increases, the fuel used during take-off and landing phases become a smaller proportion of the total, and the amount of fuel per kilometre decreases. However, fuel efficiency does not increase indefinitely with distance flown. Beyond 4,000km, the weight of fuel which must be carried for very long flights starts to become a significant factor[53]. Nevertheless, the RCEP found that half of the fuel used globally is generated by flights of less than 1200 nautical miles (2,300km), and thus concluded "*short haul air traffic has disproportionate environmental impact*".

Moreover, the distance for which an aircraft is designed to fly also affects its fuel efficiency. An aircraft designed for long haul flights will need to be strong enough and large enough to carry the large amount of fuel necessary. This in turn will increase the weight of the empty aircraft. Using an aircraft designed to fly a particular distance will therefore usually be more fuel efficient than using an aircraft designed for a longer distance.

6.2 The scale of the effects

International

In 1992, global CO_2 emissions from aircraft were around 140 million tonnes of carbon (140 MtC), constituting 2.4% of total carbon dioxide emissions from human activities. For comparison, this figure equates closely with the UK's total CO_2 emissions.

[51] Intergovernmental Panel on Climate Change, *Aviation and the global atmosphere*, 1999.
[52] Royal Commission on Environmental Pollution, *Environmental effects of civil aircraft in flight*, 2002.
[53] a 15,000 km flight may require as much as 120 tonnes of kerosene, and a substantial fraction of this will be used in the first third of the journey to carry the fuel necessary for the last two-thirds.

Climate change effects of subsonic aircraft[54]

While uncertain, current understanding points to a series of complex interactions between many components of the exhaust gases from aircraft engines. For example, NOx reacts in the atmosphere to produce ozone and destroy methane, while water vapour can freeze to produce the characteristic contrails (condensation trails) seen behind high flying aircraft. Different exhaust gases also vary in their distribution - whether they are rapidly mixed throughout the atmosphere to give global effects or remain localised over a particular region - and in their longevity in the atmosphere. For example, although carbon dioxide usually remains in the atmosphere for around 100 years, water vapour is typically removed by precipitation (rain, fog, snow) within a few weeks. In addition, some effects vary with the geographical region where the exhaust gases are produced, with the time of year, the altitude of the aircraft and even the weather during the flight.

Carbon dioxide (CO_2) allows ultraviolet and visible radiation from the sun to reach and warm the earth's surface but prevents heat from escaping, hence trapping radiation in the atmosphere and warming the earth. The global warming effect of CO_2 is well understood. The amount of CO_2 produced in aircraft exhaust relates directly to the amount of fuel used. After production it is rapidly mixed throughout the atmosphere and remains there for around 100 years. Its effects are therefore global and cumulative.

Nitrogen oxides (NOx) are produced by reaction of atmospheric nitrogen and oxygen in the high temperatures and pressures of aircraft engines. At the altitude of most jet aircraft NOx reacts with atmospheric oxygen to increase concentrations of ozone, which is a very effective greenhouse gas at this altitude. The IPCC estimated that ozone makes a greater contribution to aviation's greenhouse effect than CO_2, and more recent research has suggested that even this may have been an underestimate. Since the lifetime of ozone in the atmosphere is a matter of days, its effects are concentrated around the most heavily used flight paths i.e. over the US, North Atlantic and Western Europe. The IPCC report estimated that ozone concentrations in these areas at aircraft cruise altitudes were 6% higher than they would have been without aircraft. Although other aircraft exhaust products such as soot and water may destroy ozone, these effects have not been characterised. There are therefore still considerable uncertainties as to the exact contribution that ozone makes to aviation-induced global warming. NOx also destroys atmospheric methane, another greenhouse gas, but research published since the IPCC report suggests that the IPCC may have overestimated the scale of this effect

Water vapour emitted at altitude is a greenhouse gas and makes a small contribution to the overall global warming impact of aviation. More significant are:

- **contrails** –the white condensation trails seen behind aircraft at high altitudes. These are ice crystals formed when exhaust water vapour freezes. Their formation is highly dependent on flight altitude and the weather at the time of the flight. They can spread out sideways to cover several kilometres and become almost indistinguishable from natural cirrus clouds (see below). The IPCC reported that satellite imagery showed that in 1996 and 1997, contrails covered on average 0.5% of the area over central Europe. Contrails, like other clouds, trap heat and therefore contribute to the greenhouse effect (albeit on a regional, rather than global scale). Cooling from the reflection of sunlight from the top of the clouds is also a possibility. Overall, however, the magnitude of the effects of contrails remains highly uncertain.
- **cirrus cloud -** there is growing evidence that persistent contrails can develop into or induce cirrus clouds i.e. the thin, high, wispy clouds visible on clear days. Like contrails, cirrus cloud has a warming effect. Although the magnitude of this effect is currently very uncertain, it could be one of aviation's most significant effects on global warming and would again be a regional occurrence.

Aerosols are small particles of soot and sulphates produced in aircraft exhausts. Soot aerosols have a warming effect while sulphate aerosols have a cooling effect. These may approximately cancel out each other's effect. However, aerosols influence cloud formation and could contribute to contrail formation and cirrus coverage. Aerosols may also be involved in destruction of the powerful greenhouse gas ozone (see nitrogen oxides section). These mechanisms are poorly understood at present.

Due to the effects of greenhouse gases emitted at high altitude, the IPCC estimated that in 1992, aviation produced 3.5% of the contributions to climate change from human activities. However, this figure discounted the effects of cirrus cloud induced by aviation, due to the uncertainty about these at the time. Further research has since indicated that their effect is likely to have been less than previously thought[55]. However, considerable uncertainties remain.

[54] The IPCC report estimated that supersonic aircraft, which cruise in the stratosphere at an altitude of around 19km, have a global warming effect around five times that of the equivalent subsonic aircraft. At present the only supersonic aircraft in regular use, Concorde, forms an insignificant proportion of the total civil aviation fleet.

[55] Schumann, U. and Strom, J. Aviation impact on atmospheric composition and climate. In: *European research in the stratosphere 1996-2000*. Directorate General for Research, European Commission EUR 19867, 2001.

The IPCC report considered the climate change impacts of various possible scenarios for future growth in air traffic worldwide. These ranged from a low growth scenario of 2.2% per year through a 'reference scenario' of average annual traffic growth of 3.1% to a high growth scenario of 4.7% per year[56]. All scenarios assume increases in fuel efficiency and improvements in technology leading to reduced NO_x emissions. In the reference scenario CO_2 emissions would approximately triple by 2050 (compared with 1990), and climate change impact from CO_2 would increase around fourfold. Recent work has suggested that current worldwide growth in air traffic is more in line with the IPCC's high growth scenario. According to this scenario, CO_2 emissions would increase tenfold and total climate change impact eleven-fold between 1990 and 2050. Aviation would also represent an increasing proportion of the total human contribution to climate change - growing from 3.5% in 1992 to around 5% in 2050.

National

Under the 1997 Kyoto protocol[57], the UK is committed to a 12.5% reduction in emissions of greenhouse gases between 1990 and 2010. This includes emissions from flights within the UK and from airports, but excludes international aviation[58]. Current emissions projections indicate that the UK will meet its Kyoto target (possibly achieving a 15% reduction overall). In addition to the Kyoto target, the Government has also set a domestic target to reduce CO_2 emissions by 20% by 2010[59]. This corresponds to an annual reduction in emissions of 20 millions of tonnes of carbon (MtC). In 2003, the Government stated a long term ambition to reduce national emissions of CO_2 by 60% by 2050.

Against this backdrop, the Government's current consultation forecasts increases in CO_2 emissions from domestic aviation and surface access of around 1 MtC by 2010[60]. Emissions from all other sectors (except road transport) are expected to decline. However, looking beyond the confines of the definition of UK emissions to include emissions from international flights to or from the UK, produces a very different picture. Emissions from international flights into or from the UK are projected to increase by 30 to 40 MtC between 2000 and 2030, depending on the rate of growth in aviation. This indicates that the reductions achieved by the Government's domestic CO_2 emissions reduction programme are likely to be negated by emissions from the growth in international air travel to and from the UK.

6.3 Reducing effects on the global climate

The quantities of CO_2 and water vapour emitted from aircraft engines are proportional to the amount of fuel used. Thus, a key to reducing emissions is to increase the fuel efficiency of aircraft. Even without the environmental issues described above and in previous chapters, as fuel costs represent around 10% of the running costs of an airline, economic drivers provide some incentive to seek improvements in efficiency. Potential for fuel efficiency gains is concentrated in two areas: technological options (such as improvements in engine efficiency, using alternative fuels and power sources and improvements in aircraft aerodynamics); and operational procedures (such as changes to air traffic control practices and flight arrangements).

Technological options

Engines and fuel

Between the 1960s and 1980s, the efficiency of aircraft engines more than doubled. Since that time, however, the rate of improvement has slowed, reaching around 0.5% per year in the 1990s

[56] The RCEP considered IPCC's reference scenario to be conservative.
[57] to the 1992 UN Framework Convention on Climate Change.
[58] Although the Kyoto Protocol set no targets for the reduction of greenhouse gas emissions from international aviation, it did require action to be taken by contracting parties, working through ICAO, to reduce emissions from aircraft.
[59] Department for the Environment, Food and Rural Affairs, *Climate Change: The UK programme*, February 2001.
[60] CO_2 emissions from domestic aviation 2000 and 2030 are based on estimates by the DfT (pers comm.).

as existing aircraft engine technologies have begun reaching the limits of their capability. This led the European aviation industry body ACARE to state that conventional aircraft designs could not deliver further significant improvements in fuel efficiency by 2020 and so "*unconventional solutions will have to be evaluated"*.

Hydrogen is increasingly being proposed as a fuel for transport. It could power fuel cells, increase efficiency (reducing CO_2 emissions in flight) and reduce local air pollution[61]. Current thinking on hydrogen-powered aircraft envisages the aircraft still using a combustion engine, rather than fuel cells. Producing hydrogen itself uses energy. If this is derived from fossil fuel sources, CO_2 emissions will still occur. In addition, burning hydrogen produces large quantities of water, which (as discussed above) is a greenhouse gas and contributes to cloud formation. Further, as hydrogen burns at a higher temperature than kerosene, using hydrogen in a jet engine is likely to give rise to higher levels of NOx, which, at high altitude also has a potent effect on climate change. It is by no means clear, therefore, whether a hydrogen-fuelled aircraft would have significant environmental benefits in relation to climate change over one fuelled by kerosene. Moreover, hydrogen has a very low density, so a hydrogen-fuelled aircraft would need to carry a much greater volume of fuel than a kerosene-fuelled aircraft. This would require a major redesign of the aircraft shape, which would carry significant extra costs.

Airframes

While incremental improvements on existing designs offer some scope for improvement of aerodynamic efficiency, more radical designs would be required for significant fuel efficiency gains. Both ACARE and the Greener by Design group[62] have highlighted an aircraft design, based on the 'blended wing body', essentially a triangular aircraft in which body and wings are merged. This design offers the potential for lower drag and hence greater efficiency than conventional designs. The RCEP also highlighted this design as one worth pursuing, although with the caveat that (even if proved environmentally preferable) it would be many decades before such an aircraft could make a significant contribution to the civil aviation fleet. In addition, current ideas for blended wing body aircraft suggest that the aircraft will be considerably larger than current aircraft, hence their operation at existing airports would be limited. If these aircraft were to make substantial inroads into the aircraft fleet, radical redesign of airport infrastructure would also be necessary.

Limits to technological solutions

Although technological research to produce step changes in engine and airframe performance is ongoing, translating this from theoretical or laboratory models into fully safety-tested aircraft designs ready for commercial sales is a major challenge. Given that it takes around 20 years to design a new aircraft for commercial use, replacing even a modest proportion of the current fleet with novel, significantly more efficient aircraft is unlikely within the next two decades.

Operational procedures

Air traffic management (ATM)

Aircraft rarely fly directly to their destinations; instead they follow pre-planned routes based on a fixed route network. Flight paths are routed to avoid zones used by military aircraft and historically have relied on passing over fixed navigation beacons on the ground. In Europe each country is responsible for ATM in its own airspace. This leads to some inefficiencies in the use of airspace which means that aircraft use more fuel than optimum. There is widespread agreement that ATM efficiency improvements could lead to savings of around 6% in fuel efficiency over the

[61] *Prospects for a Hydrogen Economy*, POSTnote 186, Parliamentary Office of Science and Technology, October 2002
[62] Greener by Design is a group comprising, among others, airline, airport and aerospace manufacturing organisations, and the Royal Aeronautical Society. It worked within the Department of Trade and Industry Foresight programme.

next 20 years. Achieving these gains depends not only on new technology such as satellite navigation, but also on organisational change. In Europe, for example, improvements in ATM are hampered by differing national equipment and standards.

Such change will also require the necessary incentives and drivers. The UK's National Air Traffic Services have recently been privatised and must respond to the needs of their airline customers. At airports already limited by operational capacity, customers have required NATS to make the best use of capacity. Given the frequency of flights at busy airports, and that operational difficulties often lead to delays, aircraft can queue before take off and fly in stacks before landing. Unless substantial economic or regulatory incentives are put in place, it is unlikely that these demands will change. An alternative, which the DfT intends to implement, is to place NATS under a statutory duty to consider environmental factors in its work. Indeed, environmental guidance to the CAA suggests that improving operational efficiency from departure gate to arrival gate should minimise flight times and distances, and hence reduce fuel use (and emissions).

Flight paths

The effect of greenhouse gas emissions from aviation depends on an aircraft's latitude, altitude and even the weather during the flight. This is particularly true of the water vapour emitted because formation of contrails and of cirrus clouds is dependent on how much water vapour is already present in the atmosphere, while the direct greenhouse effect of water vapour depends on the altitude at which it is released. The RCEP suggested that aircraft could be routed to avoid areas where contrails or cirrus are likely to form, or to minimise the greenhouse effect of water vapour released. Other studies have suggested that lowering the standard aircraft cruise altitude would reduce the overall greenhouse effect despite the increase in drag and hence higher fuel use at lower altitudes.

However, current understanding of the effects of aircraft emissions on climate changes is not sufficient to form the basis for any worldwide efforts to alter routes and flight paths. Moreover, current ATM systems are not designed to deal with such a situation. However, as knowledge of climate change improves, flight paths could be designed to minimise climate impacts.

Nevertheless, the Greener by Design group pointed out that something could be done now. As discussed above, long haul flights use more fuel per kilometre travelled because they need to carry more fuel - much of it necessary just to carry the fuel itself! Dividing the longest flights into shorter sectors of around 7,500 km could reduce fuel use on these flights by up to a quarter. However, this would create additional safety risks and environmental impacts at the transit airports, and may even mean constructing additional airports to serve such shorter hopping journeys (e.g. in northern Canada to serve transpolar routes) which would bring new risks. Also, passengers would be unlikely to relish longer journey times, so this approach is unlikely without significant regulatory or economic pressures.

Overall potential reductions in greenhouse gas emissions

A number of organisations have attempted to estimate the potential for improvements in the fuel efficiency and greenhouse gas emissions of aircraft. The IPCC assumed increases of fuel efficiency of around 1% per year, leading to about a 50% improvement by 2050. In contrast, a study for the DETR on the potential of new aircraft technologies predicted fuel efficiency improvements of 2% per annum[63]. ACARE has a target of 50% reduction in fuel burn by 2020[64].

[63] Arthur D Little, *Study into the Potential Impact of Changes in Technology on the Development of Air Transport in the UK*, November 2000.

[64] Advisory Council for Aeronautics Research in Europe, *Strategic Research Agenda*, October 2002.

Given the limits to technological options outlined earlier, these targets seem somewhat ambitious. Indeed, the RCEP concluded that, *"we have received no evidence suggesting that technological improvements are in prospect beyond those considered by the IPCC"*. Further, the Greener by Design group believe that the IPCC targets themselves were unlikely to be achieved without incentives beyond the current economic drivers to increase fuel efficiency. However, RollsRoyce points out that on current rates of aircraft replacement, fuel efficiency may improve by around one-third in the next decade (compared with 1990). This would correspond to an improvement rate of 1.5% per year.

6.4 Further incentives to reduce greenhouse gas emissions

Mechanisms have been proposed to reduce greenhouse emissions from aviation and to provide incentives for further technological and operational improvements:

- **voluntary agreements** – where industry and governments collectively agree target reductions in emissions, either at EU or international level. While this could be introduced more quickly than a new fiscal or regulatory scheme, it may set unchallenging reduction targets, based on modest 'business as usual' incremental improvements. However, RollsRoyce has argued that business as usual may represent the optimum situation in terms of what can be delivered cost-effectively.
- **emissions charges** – where airlines or passengers are charged a fee related to the emissions produced by a particular flight. Fees could be retained within the industry, and may be charged according to the levels of greenhouse gases emitted. Since improving fuel efficiency to reduce CO_2 emissions can increase NOx emissions, charging for both CO_2 and NOx would be needed to reduce the overall contribution of aviation to climate change (see box).
- **emissions trading** – where airlines could buy and sell emissions permits related to a capped quantity of greenhouse gas emissions. This system is now being created for CO_2 emissions from other sectors (particularly electricity generation). Here, businesses that find it easiest to make emissions reductions sell their permits to others who essentially then pay for their extra emissions. Issues peculiar to the aviation sector include how permits would be initially allocated, and how the impacts of water vapour and NOx can be included alongside CO_2. If operated internationally and as part of a system open to trading between other sectors, this option is favoured by the Government, the aviation industry and environmental groups.
- **aviation fuel tax** – Both the European Commission and the UK Government have considered introducing an aviation fuel tax for environmental reasons. However, under ICAO regulations, fuel tax cannot be introduced on fuel for international flights. The option exists therefore, for domestic or EU-wide aviation fuel taxes. Were the UK to introduce a such a domestic fuel tax, airlines may be encouraged to fill up outside the UK, resulting in aircraft carrying more fuel than necessary on some journeys and so increasing emissions and noise. Even an EU-wide fuel tax could suffer from such a 'tankering' effect. The Government has estimated that a 100% fuel tax would increase airfares by 10%. However, increasing competition among the low-cost carriers is likely to reduce fares. The overall effect of these opposing trends is uncertain. So it is not clear at what level aviation fuel taxes would need to be set to reduce overall greenhouse gas emissions from this sector. Another question is whether and how proceeds collected by EU governments could be returned to the industry to encourage improvements in environmental performance. The Government has recently held discussions on these issues with industry and environment groups[65].

[65] It is also worth noting that Budget 2003 froze the rate of airport passenger duty, and the Treasury's own assessment of the environmental effects of the budget measures stated that this would lead to a small increase in CO_2 emissions.

Emissions charges for greenhouse gases from aviation

The European Commission recently published the results of a study examining how a charging scheme could be introduced in the EU in practice. The study proposed two options:

- a charge related to the environmental cost of the CO_2 and NOx emissions of the flight concerned
- a revenue-neutral scheme in which airlines would pay a charge or receive a rebate depending on the environmental performance of their aircraft.

The study examined what would happen if the emissions charges were passed directly to passengers. It estimated that, under the first option, ticket prices would increase between 4 and 17 euros for a one-way flight. This, the study predicted, would both suppress demand and encourage fuel efficiency by operators. As a consequence, the study concluded that CO_2 emissions could be up to 13% lower in 2010 than they would otherwise have been, with the exact degree of reduction depending on the level of the charge. Effects of the revenue neutral scheme were predicted to be less clear cut. Ticket prices would be expected to increase or decrease by only a few euros and emissions reductions of around 6% could be expected.

A number of issues would need to be addressed before introducing any emissions charging scheme:

- **the level of the charges** There is still considerable uncertainty about the monetary valuation of the environmental costs of CO_2 and NOx emissions. Thus, rather than focussing on quantifying environmental costs in financial terms, a charge could be set at a level designed to achieve a particular environmental target
- **the extent of the scheme** The study assumed that charges could be imposed on emissions in EU airspace only. Questions remain over whether the resulting charge for long-haul flights would be proportional to the actual emissions.
- **charging related to the fuel used** A charge based on the actual greenhouse effect of a particular flight (e.g. payload, route taken, altitude, design range of aircraft compared with distance flown) would provide the greatest incentive to airlines to adopt more fuel efficient practices. However, the complexity of such a scheme would be likely to make its introduction difficult in the near term.
- **use of revenues** Redistributing revenues raised by an EU scheme among Member States may be complex and controversial. A simpler option, and one likely to be welcomed by the airline industry, would be to reinvest the revenues into climate change reducing projects within the industry, such as ATC developments or research into engine efficiency.

Source: Wit, R.C. et al. *Economic incentives to mitigate greenhouse gas emission from air transport in Europe,* CE Delft, The Netherlands, 2002.

6.5 Overview

The mechanisms described above could contribute to reducing the climate change impact of aviation, but the timescales over which they could be introduced vary. In the short-term, voluntary agreements may be achievable on issues such as increasing the efficiency of air traffic management, and using aircraft most appropriate for specific journeys. However, these options are unlikely to reduce emissions significantly in the medium term. Further improvements in engine design, airframe aerodynamics and an EU-based emissions charge could be effective - although the latter would not reflect the full climate change impact of long-haul flights. In the longer term, it is widely suggested that a move towards an international global emissions trading scheme could stimulate radical innovation and help manage demand.

7 Cross-cutting themes

The previous chapters have considered specific environmental impacts of aviation such as noise, air pollution, and other effects on the local environment around an airport and on the global atmosphere. In considering these further, it will be necessary to examine in more detail the issue of demand management, such as shifting flights onto trains. However, given the space and time constraints of this study, this has not been possible. In a report to ministers in 2001, the Commission fro Integrated Transport recommended that further research would be required to assess the impact of the relative levels of environmental impacts from domestic rail and air travel on the specific routes. It found that such evaluations are sensitive to specific routes and the distances travelled, and to underlying assumptions[66].

Remaining focussed on aviation itself, a number of cross-cutting themes arise from the issues discussed in previous chapters:

- **the rate of innovation** – the extent to which technological development can reduce environmental impacts, set against forecast growth in air travel
- **environmental capacity** – the extent to which aviation growth can be accommodated within the local and global environment
- **operations and land use planning** – in particular, innovations in airport and aircraft operations, and the use of the planning system to minimise and mitigate adverse effects
- **economic instruments** to provide incentives to reduce environmental effects from aviation
- **environmental impacts in a wider context** – in particular looking at the environmental effects of aviation alongside social and economic factors – i.e. examining what 'sustainable development' might mean in relation to aviation.

The issue of demand management, such as shifting flights onto high-speed trains is outside the scope of this report.

7.1 Technological issues

The rate of innovation

Each of the previous chapters has outlined the scope to minimise and mitigate the environmental impacts of aviation using technological means. For instance, aircraft engines and airframes can be made quieter, the emissions of air pollutants and greenhouse gases can be reduced by improving the efficiency of engines, and the environmental impacts of airport operations can be lessened through careful engineering and mitigation (e.g. recycling wastes, ensuring energy efficiency in buildings, locating infrastructure away from sensitive habitats and historical buildings. In some circumstances these can be relocated and reconstructed elsewhere).

Such technological advances require on-going research and development, but an issue arises over the incentives aircraft manufacturers and airport operators have to effect such improvements. In the areas of noise and air pollution, there are regulatory standards in place (ICAO noise and emissions standards, and European and national air quality objectives). Backing up these regulations are threats of financial penalties (on noise) or criminal sanction (for water pollution). The sections of this report on mitigating noise, air pollution and impacts on the global climate all point to the likely diminishing returns of such an approach to mitigating environmental damage from aviation, particularly where air travel continues to grow. Indeed, in these areas, technological improvements to control noise, air pollution and greenhouse gas emissions, even

[66] *A Comparative Study of the Environmental Effects of Rail and Short-haul Air Travel, Advice to Ministers*, Commission for Integrated Transport, December 2001.

when available, or close to being available, will not become widely adopted throughout national or global aircraft fleets within the next 15-20 years. Moreover, were air travel to grow at forecast rates, these improvements would be negated within a decade by the increase in flights and (in the specific case of local air pollution) by the increased numbers of staff and passengers accessing airports.

However, evidence from a broad range of research[67] into what drives businesses to meet or go beyond environmental standards indicates that, while command and control style regulation can stimulate technological improvement, this tends to be slow and progresses in small steps. Overall, it is unlikely that technological improvements will be able to offset environmental impacts for more than a decade or so. Therefore, within the planning horizon for the government's current consultation on aviation (i.e. to 2030), it is highly likely that following a period of relative improvement to around 2015-2020, local environmental impacts from aviation could worsen. Indeed, as shown in chapter 3, growth at Heathrow could lead to 25,000 more people being exposed to noise above the threshold for community annoyance than at present, even allowing for improvements in technology[68]. In terms of climate change, however, a year-on-year increase in emissions is likely as the growth in air travel continues to outstrip technological improvements.

Technological trade offs

Earlier chapters referred to the possibility that, while seeking to reduce one environmental effect (e.g. noise), another can be exacerbated (e.g. air pollution). This raises the issue of whether policy-makers are willing to trade off one potential environmental benefit against another. If so, the question remains over the extent of any trade offs. Further, these complexities point to the need for an integrated approach to research and development for aviation technologies that seek to maximise reductions in several of the areas of potential environmental damage.

7.2 Environmental capacity

Setting local limits

The principle of 'environmental capacity' has been recognised by the European Commission Transport Directorate General, which considered that limited environmental capacity could constrain aviation growth. Such an approach, therefore, requires any future growth to be planned according to the local environmental capacity available in areas around an airport. Indeed, the Government has asked in its consultation *The Future of Aviation*, whether the concept of environmental capacity limits can be successfully applied to UK airports, and, if so, how.

Environmental capacity appears to be an elegant, logical and simple concept. In reality, defining, measuring and evaluating such capacity is far from straightforward. The concept assumes that the natural world possesses certain features and operates with certain processes that can assimilate environmental impacts up to specific limits that can be delineated through scientific study. However, natural systems are inherently uncertain, complex and contain many factors that can make precise and stable predictions very difficult. Added to this, are the uncertain influences of human activities on such systems. Setting environmental capacity limits, therefore, while amenable to scientific investigation to a large degree, also requires subjective judgements, such as the levels of environmental quality desired, and the extent to which social and economic issues are taken into account in deciding these limits. The box on the next page outlines five possible types of environmental capacity limits.

[67] The literature in this area is large, but useful summaries are available, for example, see *Cleaning Up? Stimulating innovation in environmental technology*, POST report 136, Parliamentary Office of Science and Technology, 2000.

[68] Chapter 3 showed, however, that this threshold may not be a precise indicator of the true extent of annoyance, as some living inside the contour will not be affected, while others living outside will be adversely affected.

Types of environmental capacity limits

Thresholds below which no observable adverse effects are observable. An example here would be air quality standards for NO_2 which are based on well-characterised relationships between the concentration of pollutant and its effects. However, at present, identifying the different sources of NO_2 is difficult.
Risk-based limits where the relationship between exposure and effect is less certain, and so limits are set on the basis of an assessment of an acceptable level of risk. This needs to take due account of the need to comply with the precautionary principle[69], which is a key element of EU and UK environmental law. Also, risk-based limits need to respect the doctrine that risk management measures are proportionate to the risks and benefits of exposure.
Legal requirements to maintain environmental pollutants to below certain levels – such as night-time noise restrictions and conditions on planning consents.
Voluntary agreements between airport operators, airlines, local authorities and local communities to maintain environmental burdens within limits derived from forecasts of future growth.
Overarching policy objectives, such as the proposition (endorsed by ECAC) requiring that, on average, in the short term noise nuisance does not worsen, and that it improves in the long term. Here, as the policy is framed in terms of the average, if noise were to worsen around an airport, improvements would be needed elsewhere.

Environmental capacity in practice

To develop the discussion of environmental capacity for aviation to a more sophisticated level, consideration of its environmental impacts compared with those from other modes of transport would be needed. However, as discussed above, this is beyond the scope of this current study, although this report will hopefully inform the wider debate. Nevertheless, another key problem in the environmental capacity approach (applied to any development) is the boundaries within which any such assessment would be made. In relation to aviation in particular, there are clearly activities with a direct impact on the environment, such as noise, land-take and air pollution, but other issues stemming from beyond the immediate boundary of the airport are also apparent (e.g. traffic accessing the airport, the manufacture of aircraft and waste disposal).

Given these difficulties, a useful opening stage might be to consider environmental capacity in a more disaggregated way, concentrating on individual issues as they arise. For example, there may be a capacity constraint that can be defined for noise. Indeed, noise contours (such as the 57dBA L_{eq} threshold for annoyance) is one attempt to do this – notwithstanding the uncertainties over the precise nature of the relationship between noise levels and frequency of overflying, and their effects on annoyance, sleep disturbance and health. Similarly, exceeding air quality objectives may constrain future growth in aviation.

Questions remain, however, over what practical actions could be taken in the event of one or more of these capacity constraints being exceeded. One option may be to curtail the operation of the airport (e.g. restricting flights or surface access by road vehicle). However, it is not clear whether exceeding capacity limits is sufficient in itself warrants curtailing of operations. Such trade-offs need to take account of wider economic and social costs, but should also recognise remaining uncertainties and the need (under EU and UK law) to comply with the precautionary principle..

Similarly, in planning new developments, using the concept of environmental capacity effectively may depend on broader issues, such as other whether and when new developments occur near an airport. For instance, the numbers of people currently adversely affected by noise or air pollution from a rural airport (such as East Midlands airport) are relatively small (compared say with Heathrow), so that airport could be said to be operating within its environmental capacity for

[69] There are many definitions of the precautionary principle, but is widely understood to mean that the lack of full scientific knowledge about a significant environmental risk should not stop cost-effective action from being taken to counter it.

noise and air pollution. However, should new housing be developed close to the airport, even without any growth in air traffic using the airport, larger numbers of people would be at risk of high noise or pollution levels and this could erode or even compromise the environmental capacity of the airport. The precise options adopted to ensure that the fewest numbers of people become exposed to noise above the annoyance threshold, or to air pollution above the air quality objective, would need careful planning adapted to the specifics of each situation.

7.3 Operations and land use planning

Operations

Each of the previous chapters pointed to a number of operational activities that could be brought to bear to reduce specific types of environmental impact, for example using noise preferential routes to reduce noise, or running long haul flights in a series of shorter legs to improve fuel efficiency. While some of these are perhaps more practical than others, it does point to the overall need to consider airport and aircraft operations in a more strategic way, alongside technological developments, for instance, in setting national standards for acceptable noise exposure, and in providing consistent guidance to managing such effects. This points to the need for a partnership between manufacturers, airport operations, community groups, local and central governments, regulators and air traffic controllers to devise and operate strategic plans for environmental management at airports that are matched to local conditions and priorities, but referenced to a common set of principles and guidelines (possibly based on the environmental capacity approach described above, taking account of its limitations).

Overall, there is more scope in the land use planning system to counter the adverse effects of aviation, and indeed, the ICAO's balanced approach to managing aviation noise requires the use of land use planning, rather than relying only on technological and operational improvements. Thus, in the vicinity of an airport, some have suggested the need for flexible planning. In this way, environmental capacity limits would be set in accordance with local circumstances, reflecting the balance between the costs and benefits of aviation that affected communities felt were appropriate.

Financial recompense

Where prevention of environmental damage at source is not practicable, compensation may represent the last resort. Current provisions covering blight enable some landowners to require affected land to be purchased at open market value. Owners whose property is compulsorily acquired are eligible for compensation of the value of their property, as well as disturbance payments to cover the cost of moving and home loss payments worth a further 10% of the property value. The Government is considering new legislation to extend the loss payment scheme to cover businesses and agricultural units and increase the minimum and maximum payments.

A question arises over the extent to which compensation should be available to those who have already purchased properties of lower value in noise-affected areas, as opposed to those who are affected by new airports or new activities at existing airports. One approach may be to make explicit during property transactions the extent to which properties are exposed to current or expected future noise impacts.

Land use planning and appraisal of airport developments

The UK land use planning system regulates the development and use of land in the public interest. Planning aims to ensure that already developed land is used efficiently, development patterns are shaped in ways that minimise the need to travel, and that both cultural heritage and natural resources are conserved, particularly in those areas that are designated as nationally or internationally important. In the UK the responsibility for protecting the environment is spread across many different public bodies, but a key role is played by the regulation of land use through town and country planning.

It is not always necessary to make a specific application for planning permission because certain types of development are covered by general planning permission given through a the General Permitted Development Order, which allows for airport development, but only under a range of restrictions. Planning permission is still required for:

- construction or extension of a runway
- construction of a passenger terminal with floor space in excess of 500 square metres
- extension or alteration of a passenger terminal by more than 15% of the floor space of the original building
- erection of a building other than an operational building
- alteration or reconstruction of a building other than an operational building where its design or external appearance would be materially affected.

Despite the above, airport operators have much discretion to expand their terminal buildings, stands and aprons without having to obtain further planning permission. As a result, the numbers of passengers and aircraft movements can exceed the numbers stated during the planning process. Local authorities argue that this makes a mockery of the environmental statements produced at the time of a planning application, and that some form of more robust legal safeguards should be introduced to restrict the upward creep of capacity. While it is outside of the scope of this report to consider further the particulars of the planning process for airports, the next section provides an overview of the requirements for and methods of assessing the environmental impacts of airport developments.

Assessing the environmental effects of aviation

The primary purpose of environmental planning is to prevent breaches of environmental constraints and to make choices about the required state of the environment. To do this, information is needed about the likely effects of a development on various aspects of the environment, and the extent to which these exceed formal and informal measures of environmental constraints. These may range from statutory standards, such as on water quality, to more esoteric issues such as landscape quality. The annexe to chapter 7 provides more detail on the principles and methods of environmental assessment[70]. It should be noted that developers may use environmental assessment to pre-empt regulatory controls, or merely to achieve the minimum possible compliance.

Environmental assessment needs be able to access and make use of high quality information on the structure and dynamics of environmental systems, the current state of the environment, the pressures on it and its likely response. It is assumed that the easy accessibility of this information should help developers to put in realistic applications, decision-makers to make informed judgements and the public to become actively involved. However, while good quality environmental information is essential for achieving environmentally sustainable use and management of land, it is not always available. Further, the quality of environmental appraisals is not always high and local planning authorities sometimes lack the capacity to make most effective use of them. Thus, the effectiveness of the planning system requires public confidence, improved access to environmental information (see the box on the next page), and rigorous and valid methods of assessment when making decisions about large-scale developments with potentially significant environmental effects.

[70] *Appraising major infrastructure projects*, POSTnote 173, Parliamentary Office of Science and Technology, 2002.

Public participation in environmental decision-making

The importance of providing open access to environmental information has become firmly established in recent years. Available data in a form that can be easily used and understood by the general public will help to raise the level of debate and improve the transparency of decision making. For some decades, legislation covering pollution control, waste sites and discharges to water has contained provisions requiring information on licences and monitoring data to be made available in public registers. Broader provisions were set out in a 1990 EC Directive on access to environmental information. This Directive was later augmented by the 1998 UN Economic Commission for Europe Convention on Access to Information, Public Participation and Access to Justice in Environmental Matters (Aarhus Convention), which placed public access to environmental information at the heart of achieving environmental justice and improving decision-making.

One of the objectives of the Aarhus Convention is to guarantee the rights of the public to participate in certain kinds of environmental decision-making, to contribute to the protection of the right to live in an environment that is adequate to personal health and well-being . The Convention was signed by the European Community on the 25th June 1998 and is considered to be one of the most important efforts to ensure that the public have access to environmental decision-making. To ratify the Aarhus convention, the European Commission has proposed a Directive to establish basic procedures for public involvement and to consolidate and enhance the rights of the public to participate in environmental decision-making.

Proposed changes to the planning system

In December 2001, the Government produced a green paper aimed at promoting fundamental change to the planning system in England. Stemming from that consultation, the Government introduced the Planning and Compulsory Purchase Bill to the House of Commons in December 2002. The purpose of the bill is to speed up the planning system, particularly for major infrastructure projects. It includes provisions to enable the Secretary of State - if he considers a development to be of national or regional importance – to direct that a planning application must be referred to him rather than dealt with by the local planning authority.

7.4 Meeting the environmental costs of aviation

The Government's consultation on the future of aviation asked about aviation's external environmental costs. Environmental groups argued that the 'polluter pays' principle should apply to aviation and that the industry should pay its full external costs. Aviation and travel organisations agreed and argued that aviation should be allowed to expand to meet demand if it paid its external costs. Some respondents claimed that aviation already met its external costs through payment of airport passenger duty. However, environmental groups argued that it was difficult to provide monetary costs for all environmental damage. Thus, where aviation could (or did) pay monetised costs for environmental damage, capacity should still not necessarily be provided, as the full costs of environmental damage were unlikely to be known. Many respondents observed that more research was needed to quantify aviation's external costs.

On the question of how external environmental costs should best be met, many respondents commented that a mix of economic instruments and regulation would be the best approach. Policy instruments put forward included variable noise and emissions related landing charges, tax on aviation fuel or tradable emissions permits. Several also said there should be a statutory body to regulate the environmental effects of aviation. There was support from almost two-thirds of respondents for a national framework within which local environmental effects such as aircraft noise should be tackled, although most agreed on the need for local discretion. Views on voluntary agreements were mixed, with some concerned about their enforceability and others favouring them. The majority of respondents also agreed that it should be possible to vary economic instruments with location and time to reflect the actual impact of the emission concerned e.g. charges relating to noise could be higher at night or in densely populated areas. However, a number of aviation industry respondents opposed this concept due to concerns over effect on prices, competition and ability to schedule flights.

Many commented that the international nature of the aviation industry meant that environmental consequences could most effectively be tackled through international forums. There was also support for using revenues from any environmental charges for mitigation measures or research to improve the environmental performance of the aviation industry in future.

In discussion of the environmental costs of human activities, one issue remains. This is related to the size of environmental costs relative to other costs. In particular, if environmental costs are only a small component of overall costs, business and customers may well be willing to pay these without curtailing or amending their activities in any way. Thus, it is important to recognise that internalising external costs and passing these on to customers, or through the supply chain will not change actual behaviour unless it is at the margin of cost acceptability. This has prompted some to argue that additional government intervention is needed, e.g. through regulation, charging, or further taxation, beyond the immediate external costs. However, others counter that if environmental costs are fully internalised, but nevertheless, consumers choose to incur them rather than change their behaviour, this simply serves to reflect the high value they place on the availability of the goods or services (the 'inelasticity of demand').

The Treasury and DfT have reviewed the use of economic instruments to manage environmental impacts of aviation. The box on the next page summarises the report. Overall, it suggest that the environmental costs from carbon emissions, noise and air pollution total £1.7 billion in 2000, and that this may rise to £5.6 billion by 2030. The cost estimates are dominated by those of the effects of carbon emissions on global warming. There remain considerable uncertainties over the figures and assumptions used in the analysis. In addition, questions remain over whether the costs included in the analysis are able to capture fully the true range of environmental costs – for instance whether the house-price technique used for costing noise impacts takes account of the full range of social costs, such as psychological impacts, and knock-on effects, e.g. on health care costs, productivity and educational achievement. Also, the report is incomplete, insofar as it does not provide estimates of the future costs for noise and air pollution beyond 2000.

The Treasury and DfT are consulting on this report, and asking for comments on what economic instruments could be used to tackle the environmental impacts of aviation. They wish to determine which instruments would be most desirable in terms of providing the best incentives for the aviation industry to take account of its environmental impacts, their administrative feasibility and ensuring that undesirable economic impacts are minimised. The House of Commons Environmental Audit Committee will be examining progress on this issue as part of its scrutiny of the 2003 budget. It is expected to report on this before the summer recess. The Government has said that it will hold discussions on the environmental costs of aviation with industry groups, national environmental groups, public bodies and the expert community, and that it will set out its views in the air transport White Paper expected towards the end of 2003.

7.5 Environmental impacts in a wider context

What is 'sustainable' aviation?

The main focus of this report has been on the environmental impacts of aviation; specifically noise, atmospheric emissions, and other local impacts related to the use of land for airport developments. However, these debates take place in a context where environmental issues are increasingly being seen as part of a wider discussion about the need to reconcile environmental, economic and social implications of developments. This is the so-called 'sustainable development' agenda. This section summarises the range of meanings of this term and how they may relate to aviation. Initially, however, it should be emphasised that there is no single widely agreed definition of sustainable development in general and similarly, no agreed framework within which to discuss it in relation to aviation.

Costing the environmental impacts of aviation

The Government announced in its 2002 Pre-Budget report that it would discuss with 'stakeholders' the most effective economic instruments for ensuring that the aviation industry is encouraged to take account of, and where appropriate reduce, its contribution to global warming, local air pollution and noise, although it also recognised a wide variety of other environmental impacts from the development of airport capacity (particularly impacts on land use, heritage and ecology).[71].

Climate change costs were derived using an estimate of the cost of a tonne of carbon (of £70 per tonne now, and increasing in real terms by £1 per year), based on a valuation undertaken by the Government Economic Service[72]. This valuation took no account of significant uncertainties, including uncertainties in the science of climate change, the broader social impacts of climate change (such as famine and mass migrations), and the choice of discount rate. It suggested that a sensitivity range of £35-£140 per tonne should be used in subsequent calculations. Thus, based on the current and forecast future emissions of carbon from aviation in the UK, the government has estimated a central cost of **£1.4billion per year for 2000**, rising to **£4.8 billion per year by 2030**. However, using the upper and lower boundaries of the sensitivity analysis suggested by the Government Economic Service, these figures could range from £0.7-2.8 billion in 200 to £2.4-£9.6 billion by 2030.

Noise costs were estimated using a mechanism known as hedonic pricing. This uses the difference in house prices between equivalent properties in noisy and less noisy areas (all other things being equal). This method generates the effective 'rent' that a resident pays for living in a less noisy environment. The value of this rent has been estimated from previous academic work in this area[73]. Summing this value over the number of properties affected by noise over the 57dB(A) threshold for community annoyance, yielded a cost of **£25m per year in 2000**. However, the academic work used in the valuation also suggested another more accurate approach, which if used would generate a cost in excess of **£66m per year in 2000**. The valuation by the Treasury and DfT did not include estimates for the costs of noise exposure in 2030.

Air quality costs were estimated using a method set out in a Dutch study[74]. The DfT/Treasury paper did not set out the detail of this method, but estimated the range of costs to be **£119m-£236m per year in 2000**. Again, the analysis does not include any estimates for the costs of air pollution in 2030.

Rather than being able to define what 'sustainable' aviation may mean (either in principle or practice), it may be more useful to point out aspects of aviation that are clearly unsustainable (such as ever-worsening noise impacts[75]), and to indicators that inform policy-makers about whether the sector is moving away from, or towards such unsustainable practices. Underpinning much of the discussion about the environmental impacts of aviation is the question of how the effects can be mitigated, while still allowing growth in aviation.

Analysis of the sustainability of aviation needs to take place within inherent boundaries, described in the box on the next page. Some have argued that it is still possible to at least agree on some general principles against which the sustainability of aviation could be discussed. For example, using more materials and resources (e.g. fuel or concrete) for the same purpose has a higher environmental impact than the use of less material – although this may offset costs, and associated environmental impacts, elsewhere in the economy, e.g. by reducing labour costs. However, focussing on the narrower environmental aspects of aviation, this points towards two possible routes for 'sustainable' aviation:

- **eco-efficiency** – where fewer resources are consumed for each unit of productivity (e.g. less fuel per passenger-kilometre). This reduces aviation's relative environmental impact
- **reducing absolute impacts** – where the absolute quantities of materials and resources flowing into, and wastes flowing out from the aviation system are minimised and do not increase.

[71] HM Treasury and Department for Transport, *Aviation and the environment: using economic instruments*, March 2003.
[72] Government Economic Service, *Estimating the social costs of carbon emissions: Working Paper 140* 2002.
[73] Pearce, B. and Pearce, D. *Setting environmental taxes for aircraft: a case study of the UK*. CSERGE Working Paper GEC 2000-26. University of East Anglia, 2000.
[74] CE Delft, *External Costs of aviation*, 2002.
[75] Or indeed, an ever growing burden of greenhouse gas emissions for the foreseeable future.

Boundaries of sustainable aviation

- **Geography** – sustainability can relate to issues that could be significant on a scale from the local to the global. For instance, the loss of a local wildlife habitat from airport construction could be significant on a local scale, but might be less significant at any larger scale, from regional through national to international. In addition, impacts at one location are inevitably different than at another.
- **Time** – sustainability only has meaning if consideration is given to the timescales over which particular activities or natural features would be sustained. Thus, questions arise over whether sustainability is sought over immediate, short, long or indefinite timescales.
- **System** - it is not necessarily meaningful to ask whether aviation is sustainable either as a system or as a series of components (aircraft and airports). This is because there are a very large number of other components, whose sustainability may itself impinge on that of aviation. For example, the effects on the environment of the extraction of oil and its refining to make kerosene.
- **Knowledge** – decisions about the sustainability of any activity must relate to its impacts on the environment, social systems economic activities. This requires understanding of ecological and human systems and how these interact. Current understanding of these areas is not complete, so considerations of sustainability are limited within the context of what is known and understood. Nevertheless, there is still a need to recognise and acknowledge scientific uncertainties and unknowns.

The Royal Commission on Environmental Pollution (RCEP) concluded that "*it is essential that the government should divert resources into encouraging and facilitating a modal shift from air to high-speed rail*."[76]. To achieve this, the Commission recommended that government should "*restrict airport development to encourage greater competition for, and raise the implicit price of, the available take-off and landing slots, in order to optimise the use of those slots towards longer-haul flights and to increase the prospects for a modal shift to rail for domestic journeys.*" Also, it recommend that government should "*encourage a modal shift to more environmentally benign methods of transport for short-haul flights, including the development of major airports into land-air hubs integrated with an enhanced rail network.*"

By contrast, many airport operators, while concerned to address environmental impacts of aviation, seek to mitigate, but not limit (or even reduce) local impacts. In this way, current environmental management of aviation relates more to the eco-efficiency approach than to the reducing absolute impacts approach.

A sustainable approach to the environmental impacts of aviation would involve trading off of economic, environmental and social benefits[77], according to the relative priorities attached by consumers to each. Some argue that environmental factors need to be given special consideration in this process but this may lead to a less than optimum development path by restricting the efficient use of environmental capacity. This is an issue which is being examined by the House of Commons Environmental Audit Committee[78].

7.6 Overview

The Government is consulting on the future of aviation in the UK over the next 30 years. It will identify which airports should be expanded, or whether new airports need to be constructed. However, it is concerned that any expansion should minimise environmental impacts.

As economic, social and environmental issues often give rise to conflict and the need for trade-offs, the issue remains of how best to make decisions against the backdrop of sustainable development. Here it is important to examine critically the role of economic instruments in seeking to ensure that the full environmental costs of aviation are reflected in the pricing of air

[76] Although providing additional rail infrastructure and services will itself carry economic, social and environmental costs and benefits. A comparison of the costs and benefits of aviation with those of rail is beyond the scope of this report.
[77] Including safety.
[78] Environmental Audit Committee, Fourth Report of Session 2002-03, *Pre-Budget Report 2002*, HC 167. March 2003. London: The Stationery Office Limited.

travel. Such instruments can seek to reflect either the marginal costs of reducing environmental impacts or the real costs of the environmental damage caused. It is important to recognise that these are not necessarily the same. In addition, it can be very difficult, and some would say impossible, to reflect true environmental costs, particularly for environmental resources that are irreplaceable in any reasonable timeframe – and here climate stability is seen as one such resource. Aviation, like all other sources of greenhouse gas emissions, will give rise to environmental costs. Although defining precise values for these costs is likely to prove difficult, it is likely that a broad range of possible prices, and upper limits beyond which damage costs are unlikely to rise, can be identified.

This raises the issue of the extent to which it is possible to define and put in place limits to the growth of aviation based on the ideas of environmental capacity. While limits might be set for local effects, such as noise and air pollution, and there are signs that these might well constrain the growth of aviation in some locations, it is by no means clear how environmental capacity limits could be set for the effects of aviation on the global atmosphere.

Therefore, a key point to finish on is the process of decision-making. Overall, it is for Government to decide in policy terms, whether and how far it will allow the growth in air travel to continue. Some constraints exist due to physical limits in the absence of new infrastructure, but environmental constraints (e.g. for noise and air pollution) are likely without substantial improvements in technology, airport operations or innovative uses of land-use planning. Thus, there is a need to consider the relative importance of environmental impacts alongside local, regional and national economic and social benefits – the fundamental principle of 'sustainable development'.

Public participation in environmental decision-making is now a legal requirement, and this will be strengthened in the coming years with the implementation of the Aarhus Convention. This presents an opportunity for the Government (and the devolved administrations) to embark on a significant debate at a national level on the future of air travel. The current consultation on the options for airport expansion goes some way towards this. However, from recent experience of debates on contentious issues in science and technology, particularly genetically modified crops and radioactive waste[79], there is much greater scope for a broad debate that allows the public to participate more effectively, and to address the range of issues of concern to them. The white paper provides an opportunity for DfT to explore ways in which it might seek to undertake such broader discussions, particularly in listening to the voices of the 'silent majority'.

The forecast growth in air traffic is likely to outstrip technological improvements to reduce environmental impacts. The key question remaining is whether growth should be constrained to stay within environmental limits, or whether the environmental impacts arising from meeting anticipated demand can be justified against other social and economic factors.

[79] *Public dialogue on science and technology*, POSTnote 189, Parliamentary Office of Science and Technology, November 2002. See also *Open Channels: public dialogue in science and technology*, POST report 153, Parliamentary Office of Science and Technology, March 2001.

Annex to Chapter 3: Noise contouring

Contour accuracy

Measuring or modelling aircraft noise accurately is difficult. Noise monitors used for measuring actual noise inevitably detect all noise regardless of its source. They therefore need to be carefully sited and the measured noise compared with data on actual aircraft movements. Modelling of aircraft noise is also imperfect; the noise heard on the ground from a particular arrival or departure will depend not only on the aircraft type and take-off weight, but also on the procedures followed by the pilot, and on the weather and wind speed and direction. High quality noise contours are usually considered accurate to around one decibel. In a densely populated area increasing or decreasing a noise contour by one decibel could increase or decrease the population within that contour by as much as 20%. Hence noise contours, although a valuable tool in analysing noise impact of changes in airport use, cannot be viewed as infallible. Many of those living outside the contour will be disturbed by noise, while some living within it will not. Equally, small errors in noise modelling or in estimates of future airport use could severely over or underestimate the population currently affected by noise, or likely to be affected in future. For this reason, the DfT's recent consultation included indications of both the 57 and 54dB(A) L_{eq} contours for many of the proposed developments.

Criticisms of L_{eq} as a measurement of aircraft noise

Averaging

Community and environmental groups point out a number of limitations with use of L_{eq} as a measure of noise around airports. L_{eq} measures *average* noise levels, and can therefore conceal considerable variations in noise level derived from differences in the way that different runways are operated.

Extremely loud events may have a disproportionate effect on L_{eq} contours. For example, during 2001, when Concorde was grounded following an accident, the population exposed to noise levels above 57dB(A) L_{eq} around Heathrow shrank by 13% compared with the previous year while the number exposed to over 72dB(A) L_{eq} halved[80]. This was despite the fact that Concorde makes only a few arrivals and departures per day from the airport. Given that flights on the approach to Heathrow continued (at the busiest times) at a rate of around one every 90 seconds throughout 2001, it is questionable whether the exposed population viewed the loss of two flights per day, albeit very noisy ones, as a significant reduction in noise. Attitudes to Concorde also provide an interesting illustration of the subjective nature of responses to noise; despite Concorde being louder than most other aircraft, some residents view a Concorde flying overhead as an exciting event rather than a nuisance. British Airways announced in April 2003 that Concorde flights would cease permanently from October 2003.

Relationship between noise levels and annoyance

Another difficulty is that discussion of noise exposure which focusses purely on the threshold level of 57dB(A) L_{eq} may hide consideration of how badly those within the noise contour are affected. For example, a doubling in the number of flights approaching an airport, which is likely to be perceived by those affected as a doubling in noise, results in a 3dB average increase in L_{eq}. Although this increase in noise would considerably expand the 57dB L_{eq} contour around the aiport concerned, looking at the 57dB(A) L_{eq} contour map alone would not indicate that all those already within the contour had experienced a doubling in aircraft noise. A complete picture of

[80] Civil Aviation Authority, *Noise Exposure Contours for Heathrow Airport 2001*, prepared on behalf of the Department for Transport, May 2002.

aircraft noise around an airport therefore necessitates looking not only at the 57dB L_{eq} contour, but also at further contours at intervals of, say 3dB up to 72dB(A), and this is precisely what DfT does for the designated airports (Heathrow, Gatwick and Stansted).

However, the principal concern of environmental and community groups with L_{eq} is the 57dB(A) level which the Government has chosen to use as a tool in policy making. They point to a World Health Organisation study, *Guidelines on Community Noise*[81], which proposes 55dB(A) as the level above which there will be serious annoyance, and 50dB(A) as the onset of moderate annoyance. The Government's 57dB(A) L_{eq} level was chosen following a 1980s study which showed that this was a good indicator of the onset of 'significant community annoyance[82]. This figure also equates to advice from the World Health Organisation from that date. However, the nature of aircraft noise has changed since the 1980s.

Although individual planes are quieter, the number of flights has increased dramatically at most airports. Some argue that it is now the continuity of noise, rather than the loudness of particular planes, which is the principal contributor to annoyance. It is also possible that rising living standards have led to higher expectations among the general public about their local environment.

The DfT has commissioned a new research study which will, among other things, re-examine the relationship between measured aircraft noise levels and annoyance. Although preliminary results from the project are due before publication of the White Paper on the future of air transport later this year, final results will not be available until 2004. The recent consultation on options for airport capacity expansion in the UK used the indicator from the 1980s study for assessing noise impacts. Were the results of the current study to suggest that this measure is no longer valid or should be improved, the basis of any decisions on locations of airport capacity to be announced in the White Paper may be open to criticism.

Given the variety in, and subjectivity of, responses to noise, no single level can provide a cut-off between those who are affected and those who are not. Environmental and community groups argue that using the 57dB(A) L_{eq} contour underestimates the actual numbers annoyed by aircraft noise, as well as exacerbating annoyance for those affected outside the contour who feel that their problem is unacknowledged.

In Sydney in 1998, 90% of complaints about aircraft noise came from outside a contour broadly equivalent to the 55dB(A) L_{eq}[83], while at Gatwick around two-thirds of complaints come from outside the 57dB(A) L_{eq} contour[84]. Although the relation between actual levels of annoyance and complaints is not clear cut, with disproportionate numbers of complaints being received from affluent areas, these figures indicate that there is considerable community noise annoyance outside the 57dB(A) L_{eq} area.

[81] World Health Organisation, *Guidelines for Community Noise,* 1999.

[82] Brooker et al., *United Kingdom Aircraft Noise Index Study (ANIS)*: *main report – DR Report 8402*, report for the Civil Aviation Authority on behalf of the Department of Transport, January 1985.

[83] Australian Department of Transport and Regional Services, *Expanding ways to describe and assess aircraft noise*, 2000.

[84] BAA Gatwick, *Flight Evaluation Report 2001/2*.

Noise mapping and airport expansion: the Sydney experience

A third runway opened at Sydney's Kingsford-Smith airport in November 1994. Prior to the expansion, Australian Noise Exposure Forecast (ANEF) contours were presented to give residents an indication of noise impacts of the proposal. The ANEF contours are similar to the UK's L_{eq} measurement and measure average sound energy over a period of time. During planning, noise outside the 20ANEF contour, approximately equal to 55dB(A) L_{eq}, was, to all intents and purposes, treated as being 'insignificant'. After opening of the new runway aircraft movements over the city's northern suburbs rose from around 160 to around 370 per day. There was an immediate outcry from residents in the northern suburbs of Sydney living under the new flight paths who found themselves significantly disturbed by noise despite living outside the contours presented during planning. This became a high profile political controversy, including creation of a single issue 'No Aircraft Noise Party', and led to establishment of a Senate Select Committee on Aircraft Noise in Sydney.

The Senate Committee Report *Falling on Deaf Ears* concluded that opening of the third runway had "*scarred a city*" and "*irretrievably complicated the future of airport development in Australia*", as well as being an "*environmental and social tragedy*". It also commented that the policy in Sydney at the time of concentrating noise pollution in one area was "*a form of discrimination*". The Committee was also highly critical of use of ANEF contours in informing the public about aircraft noise impacts. One local authority, in evidence to the Committee, viewed indicators of average levels of aircraft noise as "meaningless", both due to the significant variation in noise exposure throughout a year and because it was typically the peak noise levels which caused the greatest disturbance. The Committee also recommended that it was "*essential*" that information on noise impacts outside the 20ANEF contour was provided to residents.

In response to the issues raised by the committee, the Australian Department of Transport and Regional Services (DOTARS) has proposed an alternative approach to conveying information on aircraft noise. The approach is intended to supplement the use of ANEF contours by providing a means of describing aircraft noise to non-experts. Diagrams of flight paths to and from an airport are overlaid on a local map. For each flight path, information can be provided on:

- Aircraft altitude at different points along the flight path
- The average daily number of aircraft on the flight path concerned
- The range of aircraft numbers between the quietest and busiest days
- The proportion of days with no aircraft movements on that flight path
- The proportion of total aircraft movements using the flight path concerned (to make residents aware to what extent noise is 'shared' between different areas)
- 'Respite hours' – what percentage of the day, evening and night are typically free of overflights.

Information can be provided on a seasonal basis, or for a particularly sensitive time such as weekends or nights. The figure opposite shows such a diagram for Sydney airport, compared with the 20 ANEF contour. It is clear that information is provided on noise exposure of areas considerably beyond the contour. These more intuitive approaches to representing aircraft noise have been welcomed by the community around Sydney airport and similar methods are likely to be a part of the environmental impact assessment of any further airport developments in Australia.

DOTARS also proposed providing information on the number of aircraft noise events in particular areas exceeding a certain noise threshold, usually 70 dB(A), in a day. These maps provide another way of describing aircraft noise in terms easy to understand. For instance, adding up the total number of individual exposures to a threshold noise level (say 70 dB(A)) and dividing by the population exposed gives a measure of average individual exposure. When the third runway at Sydney was opened, such measures increased significantly despite the fact that the number of people within the 20 ANEF contour fell by around 30%. In other words, although average noise exposure levels decreased, the number of times individuals were exposed to noisy overflights increased, and this noise burden was concentrated on a smaller number of individuals.

Lessons for the UK

- Sydney residents felt that they had been misled by use of noise contours to give an indication of likely noise impacts of the 3rd runway. Given that the UK's recent consultation on aircraft expansion also uses noise contours, it is possible that aircraft communities in the UK will have similar reactions.
- DOTARS proposed measuring noise exposure by the number of events above a given threshold, implying that once noise reaches a level high enough to be intrusive, the level of noise beyond this is irrelevant. This conclusion accords with the subjective experience of some UK airport communities, who report that it is the frequency of noise events rather than the loudness of individual events which leads to annoyance.
- The Sydney experience also demonstrated that residents are most likely to be annoyed by and complain about aircraft noise if they feel they have been misled about it. Those provided with information about aircraft movements before moving in to an area would be less likely to find them annoying, as they would have been given the opportunity to factor them into their decisions on whether to take up residence in that area. This suggests that providing user-friendly information about aircraft noise to prospective house buyers and tenants near major flight paths could reduce complaints about aircraft noise.

Sources: *'Falling on Deaf Ears,* Report of the Senate Select Committee on Aircraft Noise in Sydney, November 1995 and *Expanding Ways to Describe and Assess Aircraft Noise,* Department of Transport and Regional Services, Australia, March 2000.

Informing communities

Environmental and community groups argue that use of L_{eq} contours in discussing options for airport expansion or changes in airport use is unhelpful. Contour maps may mistakenly lead people to believe they will be unaffected by noise. In addition, communities often find it difficult to interpret contour maps measured in decibels; rather they want to know where and how often aircraft will be overflying, how loud this will be in comparison with the neighbour's lawnmower, what the worst and best days will be like, whether there will be quiet periods and, if so, at what time of day. The uncertainty arising from feeling that they do not know what the actual consequences of any proposal will be is a major source of anxiety for airport communities. These points are discussed further in the box below, which describes the system of noise mapping developed at Sydney airport in response to protests that noise contours produced for construction of a new runway had misled residents as to the likely noise impacts.

Is there an alternative?

Some environmental groups argue that the L_{den} index would be a more appropriate index of noise around airports. L_{den} attaches higher weight to evening noise than daytime noise and still higher weight to night noise. A recent EU Directive, discussed in more detail in the next section, will require member states to perform noise mapping around major airports using the L_{den} index from 2007. But L_{den}, like L_{eq}, shares the disadvantage that it is difficult to interpret for those affected. In response some airports have developed more intuitive ways of presenting aircraft noise. The Australian approach described in the box on the previous page involves, among other things, providing maps of flight paths with indications of the number of movements and times of those movements on the flight paths, aircraft heights at different points on the flight path, and details of typical daily or yearly quiet periods. In the UK Gatwick Airport provides maps of flight paths in its Flight Evaluation Report, together with details of the percentage of flights using each path. However, UK airports do not regularly provide information on use of flight paths, respite periods or variation between 'quiet' and 'noisy' days, and only the designated airports regularly publish flight path information.

Qualitative methods such as those described in the box are clearly not a universal solution to the problem of measuring aircraft noise. For example, they cannot be used to determine possible health effects, since the vast majority of research in this area uses L_{eq} or L_{den} to measure noise (health effects of aircraft noise are discussed further in section 3.2 in the main text). However, these qualitative methods do provide a much more intuitive picture of noise levels to local residents and could play an important role both in the planning process and in informing aiport communities. There is clearly scope for the UK to develop a framework or best practice guidance on provision of information on aircraft noise to local communities.

Overall, the question is not whether L_{den} is better or worse than L_{eq} as a noise measure, but whether one is more effective in explaining to the public what they can expect in terms of the noise that could affect them. Thus, other ways of communicating might be to report the density of flight paths, or the numbers of aircraft movements exceeding particular noise levels. DfT is examining these issues, and is willing to consider introducing new means to communicate aircraft noise if these prove suitable.

Annex to Chapter 7: Environmental assessment

In planning, the main use of environmental data and modelling is for the environmental assessment of projects, programmes, plans and policies. Environmental assessment is the method that is used to evaluate the effects that are likely to arise from a project, programme, plan or policy that significantly affects the natural and artificial environment. The environmental assessment of a project is referred to as environmental impact assessment and that of plans, programmes and policies is called strategic environmental assessment. A more limited assessment of the environmental impacts of the most potentially polluting industrial installations is also required for projects that require a permit under the integrated pollution prevention and control regime (IPPC). An IPPC environmental assessment covers emissions to air, water and ground and sets targets for fuel efficiency and noise level.

Project Level Environmental Impact Assessment

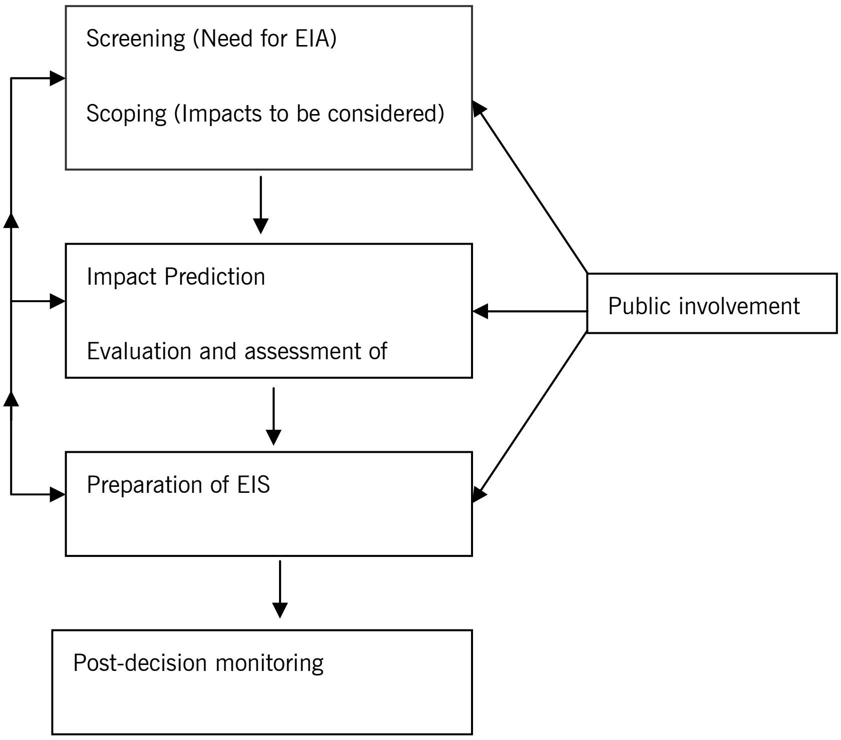
Environmental impact assessment (EIA) is a systematic participatory process for identifying and evaluating the probable environmental impacts of a proposed development. It helps to ensure that the importance of the predicted effects, and the scope for reducing them, are properly understood by the public and the relevant planning authority when it makes a decision as to whether a project should be allowed to proceed.

EIA was introduced on an EU wide level in 1988 through the EU EIA Directive 85/337/EEC. This was the first piece of EU legislation to require EIA to be carried out in the UK for development projects that had the potential to cause large scale environmental disruption. This Directive was later amended by Directive 97/11/EC which came into force in March 1997.

The EIA Directive identifies projects that always require EIA, which include airports (as well as power stations, chemical plants, railways, major roads) and lists them in Annex I. Annex II identifies projects that require EIA to be conducted if they are likely to have significant environmental impacts, such as intensive agriculture, land reclamation, extractive mining etc. (Circular 02/99). Annex II projects must be subjected to a preliminary environmental screening process, and during the planning process the planning authority must make a decision on whether a proposal that is listed as an Annex II development requires EIA.

The EIA process consists of a series of iterative steps and ideally is cyclical, with feedback and interaction between the various stages. The figure on the next page shows the stages often involved in EIA. This is a rather idealised and simplistic view, and in practice, the process can vary; with stages operating in a different order or sometimes missed out altogether. The findings of the EIA are contained within an environmental impact statement which, according to the EIA Directive, must contain a description of the development, a description of the mitigation measures, the data necessary to identify and assess the main effects, an outline of the main alternatives considered and a non-technical summary.

Main steps in the environmental assessment process



EIA in the UK is integrated into the planning consent procedure, and the EIA Directive is implemented through over 40 different secondary regulations. Different regulations apply to England and Wales, Scotland and Northern Ireland, and are supplemented by guidance documents. The Town and Country Planning (Environmental Impact Assessment) (England and Wales]) (Amendment) Regulations 1999 account for 70% of EIAs conducted in the UK (Wood, 1995). Other Regulations are necessary for projects listed in Annex I and Annex II of the EU Directive that are authorised outside of the English and Welsh planning system. Such developments include motorways and trunk roads, certain types of power station, afforestation projects and work conducted on water courses.

The EIA Regulations require EIA to be conducted for two categories of project, given in Schedules 1 and 2 of the Regulations. Schedule 1 projects always require EIA and Schedule 2 projects require EIA if their potential environmental impacts are considered likely to be significant. The selection criteria provided in schedule 3 helps to determine whether a schedule 2 development needs EIA (Circular). The developer has three options when deciding whether or not to conduct EIA:

- developer decides that a project requires EIA under the Regulations, or wishes to conduct one anyway.
- developer is uncertain about whether EIA is required and requests a 'screening opinion' from the Local Planning Authority (LPA).
- developer decides that EIA is not required and when the planning application is submitted, the LPA must determine whether EIA is required, and if so, request it.

In the UK there is no requirement for the local planning authority to be consulted before the environmental statement is submitted, nor is there a requirement for a formal scoping stage in which the information to be included in the environmental statement is determined. However, guidance documents stress the benefits of early consultation on the scope of the EIA and the developer can ask the LPA for a 'scoping opinion', and if the LPA fails to provide one, then a scoping direction can be provided from the Minister.

Neither the EIA Directive nor the UK Regulations expressly require the developer to study alternatives, but if alternatives are considered, they must be recorded in the environmental statement, and developers are encouraged to consider strategic alternatives early in the development process to enable them to be considered as feasible options.

The information that should be included in the environmental statement (ES) is split into two sections in Schedule 4 of the EIA Regulations. The first section outlines the information that may be necessary for the assessment but is not mandatory, and the second section states the minimum legal requirements. Schedule 4 identifies the environmental aspects that might be significantly affected and indicates that consideration should be given to the likely significant effects resulting from the use of natural resources, pollutant emissions, creation of nuisance and elimination of waste. EIA should cover direct, indirect, secondary and cumulative effects, short, medium and long term effects, permanent and temporary effects and positive and negative effects (Circular 02/99). According to the EIA Regulations, a number of statutory consultees must be involved in the EIA process, but unless the LPA has adopted a screening opinion there is no requirement for consultation with these bodies before submission of the ES. There is also no formal requirement for the public to be involved in the EIA process or even informed that it is taking place until the ES has been completed, when it must be publicised and made available for public inspection and comment.

The LPA must make a decision within sixteen weeks of receiving the planning application and ES. A planning application cannot be dismissed as invalid because the ES is considered inadequate, but the LPA can request more information, which must be supplied and publicised by the developer. When the LPA makes its decision, the ES and any comments submitted by members of the public or statutory consultees must be taken into consideration.

Neither the EIA Directive nor UK Regulations require monitoring of the actual effects of a development by the developer or the planning authority, and in general, environmental statements contain only limited undertakings to monitor environmental impacts, and monitoring is rarely part of planning conditions. The fact that environmental statements are produced for the planning decision and do not form the basis for monitoring or enforcement is considered a major weakness of EIA. There is also no specific reference to the need for EIA to consider health impacts, so environmental statements rarely contain a discussion of human health issues, despite the fact that the environmental effects such as emissions to air, water and soil can have significant health implications.

If there are plans to makes changes to an existing or approved development, EIA is only required if the changes are likely to have significant environmental effects. It is necessary to consider the proposal in the context of its use, for example small extensions to a runway may allow larger aircraft to land which in turn will result in significant increases in emissions and noise, therefore significant environmental impacts and the need for an EIA.

Schedule 1 of the regulations uses the term airport to mean an airport that complies with the definition in the 1994 Chicago Convention and requires EIA for the construction of airports with a basic runway length of 2,100m or more. Schedule 2 includes the construction of airfields not included in Schedule 1 and extensions to a runway or if the area of works at an airport exceeds 1ha. In deciding whether a schedule 2 development actually requires EIA, it is necessary to think about the characteristics of the development such as the size, cumulative impacts, natural resource use, waste production, nuisance caused and risk of accidents. Consideration should also be given to the location including existing land use, natural resources in the area, absorption capacity of the area especially if it is in a wetland, coastal zone, mountain/forest area, nature reserves/parks, protected areas, areas where the environmental quality standards are already exceeded, densely populated areas, historical, cultural or archaeologically significant landscapes, and the characteristics of the potential impacts, such as the extent of the impact, transfrontier nature, magnitude, complexity, probability of the impact, duration, frequency and reversibility of the impact.

Strategic Environmental Assessment

Although the assessment of individual projects helps to identify and mitigate environmental damage there are many drawbacks. For example it is generally limited to the direct impacts on a small site and cannot consider cumulative effects of small projects that do not require EIA. It also does not consider induced impacts such as occur when a project stimulates further development. There are also difficulties in dealing with synergistic effects and global impacts. It also occurs after strategic decisions have already been made and therefore only considers a limited range of alternatives (23rd report). Environmental impact assessment for large transport infrastructure is carried out routinely but has severe limitations, mainly related to the fact that it is linked to the last step in the decision-making process, when it is often too late to consider more strategic alternatives such as modal and route choices. As a result, there is growing consensus that SEA of national/regional/local transport policies, plans and programmes is essential to ensure that environmental considerations are taken into account at all levels of decision making, and ensure that feasible alternatives are properly considered and that the public and environmental authorities are fully involved in the decision making process. SEA is conducted earlier in the decision-making process and encompasses all the projects of a certain type in a certain area. Thus, it can ensure that alternatives are adequately assessed, cumulative impacts considered, the public is fully consulted and decisions concerning individual projects are made in a proactive rather than reactive manner.

Strategic environmental assessment is the extension of the EIA principles to policies, plans and programmes, i.e. more strategic decisions. The EU Strategic Environmental Assessment (SEA) Directive has now come into force and member states have until 21st July 2004 to implement this Directive into their own legislation. The SEA Directive does not require assessment of policies, but does require a formal environmental assessment of plans and programmes with significant environmental effects by the UK central, regional and local authorities. SEA will be mandatory for all plans and programmes that:

- set the framework for development consents of individual project in Annex 1 and 2 of the EIA Directive
- are in the fields of agriculture, forestry, fisheries, energy, transport, waste, water management, telecommunications, town and country planning or land use
- require assessment under the habitats Directive (92/93) in view of likely effects on Natura 2000 sites

For other plans and programmes SEA will only be required if they are likely to have significant environmental effects. In the UK context, this means that development plans (structure plans, local plans and unitary plans) and regional planning guidance would definitely be subject to SEA.

The SEA Directive is modelled closely on the EIA Directive. The assessment required is broad, including secondary and cumulative effects, and that the analysis is available for public consultation and inspection. This Directive does not apply to policies, and there is no requirement for scoping or to establish indicators, although ideally it will be applied throughout the multiple stages of plans and programme development. SEA is a central step in the achievement of sustainable development. SEA practice is mostly an expansion of SEA techniques and principles to more strategic actions. The Directive requires the lead agency that is responsible for the plan or programme to assess its impact on human beings, flora, fauna, soil, water, air, climate, landscape, material assets and the cultural heritage. The SEA will also have to include a discussion of the contents and objectives of the plan or programme, the environmental characteristics of any area likely to be significantly affected by the plan or programme, the existing environmental problems, relevant environmental protection objectives and how they were considered, the significant environmental effects of the plan or programme, alternative methods of achieving the objectives of the plan or programme that were considered, mitigation measures and difficulties encountered in compiling the information. The environmental authorities, the public and affected Member States will then be given the opportunity to comment on the SEA and these comments will be taken into consideration before the plan or programme is adopted.

However, there are problems associated with SEA which can be technical or procedural in nature. One problem is that many potential future developments spread over a large area can lead to substantial analytical complexity. Information about existing and projected environmental conditions and about the nature, scale and location of future development proposals is usually very limited so the impacts of these developments cannot be predicted precisely. The requirements for public participation, as well as the large number of alternatives also complicate the process.

Abbreviations

ACARE	Advisory Council for Aeronautics Research in Europe
ANMAC	Aircraft Noise Monitoring Advisory Committee
APD	air passenger duty
AQMA	Air Quality Management Area
ATC	air traffic control
ATM	air traffic management
BATA	British Air Transport Association
CAA	Civil Aviation Authority
CAEP	Committee on Aviation Environmental Protection
CBI	Confederation of British Industry
CDA	continuous descent approach
CO	carbon monoxide
CO_2	carbon dioxide
dB	decibel
dB(A)	A-weighted sound level measurement (to replicate response of the human ear)
DETR	(former) Department of the Environment, Transport and the Regions
DfT	Department for Transport
DTI	Department of Trade and Industry
ECAC	European Civil Aviation Conference
EEA	European Economic Area
EIA	Environmental Impact Assessment
GDP	gross domestic product
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICCA/A	International Coordinating Committee of Aviation Industry Associations
ICSA	International Coalition for Sustainable Aviation
IPCC	Intergovernmental Panel on Climate Change
L_{eq}	measure of noise indicating equivalent continuous noise level
L_{den}	measure of noise for day and evening sound levels
L_{max}	measure of noise indicating the maximum sound level from a single noise event
LTO	landing and takeoff
mppa	million passengers per annum
MtC	million tonnes of Carbon
NATS	National Air Traffic Services Limited
NO_2	nitrogen dioxide
NOx	oxides of nitrogen
NPR	noise preferential route
NTK	noise and track keeping
ODPM	Office of the Deputy Prime Minister
OEF	Oxford Economic Forecasting
PM_{10}	particulate matter with diameter smaller than 10 millionths of a metre
RCEP	Royal Commission on Environmental Pollution
SEA	Strategic Environmental Assessment
VOCs	volatile organic compounds
WHO	World Health Organisation

Acknowledgements

Primary Authors (in alphabetical order)

Liz Anastasi*, Dr Helen Dickinson*, Gary Kass^ , Karen Smith*, Claudia Stein*

* these people were on temporary placements at POST during 2002. POST is grateful for their assistance in preparing this report.
^ Gary Kass is Environment and Energy Adviser at POST, and can be contacted on 020 7219 2161; kassg@parliament.uk

Acknowledgements

The Parliamentary Office of Science and Technology and the authors would like to acknowledge the following organisations for providing invaluable information and expert comment:

Organisation	Name
AEA Technology	Dr Brian Underwood
Airport Operators Association	Andrew McCall
Aviation Environment Federation	**Tim Johnson**, Jeff Gazzard
BAA plc	Phil Dunn, Stephen Hardwick, Graham Earl, Rick Norman
Boeing	Herbert Lust
Cambridge University	Dr Helen Rogers
Civil Aviation Authority	**Peter Havelock**
CPRE	Brendon Sewill
Department for Environment, Food and Rural Affairs	Rupert Furness
Department for Transport	**Graham Pendlebury**, Philip Grindrod, Roger Gardner, Mike Crompton, Jeff Thompson, Roberta McWatt
Department of Transport and Regional Services, Australia	David Southgate
Greener by Design	Charles Miller
HACAN Clearskies	John Stewart
Hounslow Borough Council	Rob Gibson
Manchester Airport	Jon Bottomley
Manchester Metropolitan University	**Prof Callum Thomas**, Dr Paul Upham
National Society for Clean Air	**Tim Williamson**, Mary Stevens
National Air Traffic Services plc	Carole MacMahon
Newcastle Airport	Graeme Mason
PA Consulting	Liz Orme
Queen Mary, University of London	Prof Stephen Stansfeld
Retired Head of Environment, British Airways	**Dr Hugh Somerville**
RollsRoyce	Dr Colin Beesley
Royal Commission on Environmental Pollution	Anna Bradbury
SASIG, Local Authority aviation group	**Jim Bailey**
Scottish Executive	David Doxford
Society of British Aerospace Companies	**Dr Mike Steeden**
Zurich Airport	Emaunel Fleuti

Those signified in **bold** text were members of an advisory group set up for this project. POST is extremely grateful for their continued input during this study. It must be noted however, that this report is that of POST itself, and not that of the advisory group.

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