Department for Transport

UK Air Passenger Demand and CO_2 Forecasts

November 2007

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1. Introduction and key results

Introduction

1.1 In December 2003, the Government set out a sustainable long-term strategy for the development of air travel to 2030 in *The Future of Air Transport*[1]. This was supported by forecasts of demand for air travel at UK airports which were reported in *Air Traffic Forecasts for the United Kingdom*[2] in 2000. Further supporting analysis of demand and carbon emissions forecasts from UK aviation were set out in *Passenger Forecasts: Additional Analysis*[3] and *Aviation and Global Warming*[4] in 2004.

1.2 These forecasts are used to inform and monitor long term strategic aviation policy, and wider Government policy on tackling climate change. They are also inputs to the appraisal of airport developments supported by the Air Transport White Paper, the results of which were set out in *Passenger Forecasts: Additional Analysis*.

1.3 The 2006 *Progress Report* reported updated passenger demand forecasts, and committed the Government to publish in 2007:

- a technical note on our passenger demand forecast methods and results; and,
- revised UK aviation emissions forecasts.

This report meets these commitments. It sets out our latest demand, CO_2 forecasting, and appraisal methods; gives updated passenger demand and CO_2 forecasts; and updates our economic appraisal results.

1.4 Since 2004, there have been a number of developments relevant to our forecasts of passenger demand and CO_2 emissions, and appraisal results:

- In 2006 the Government published the *Stern Review on the Economics of Climate Change* and the Eddington study. Following the recommendations in these reports, the Department for Transport has revised its Transport Appraisal Guidance to include a requirement that economic appraisal of transport schemes should include quantification and monetisation of impacts on carbon emissions.
- BERR has revised its projections of oil prices, while HMT and the IMF have updated their forecasts of UK and international economic growth.

[1] *The Future of Air Transport*, Department for Transport, Dec 2003.
[2] *Air Traffic Forecasts for the United Kingdom 2000,* DETR, May 2000.
[3] *Passenger Forecasts: Additional Analysis,* Department for Transport, Dec 2003.
[4] *Aviation and Global Warming,* Department for Transport, Jan 2004.

- DEFRA has revised its guidance on the shadow price of carbon dioxide.

We have also updated our airport capacity assumptions in line with the latest plans indicated by airport operators, and our process of continual development has delivered a number of incremental improvements to our forecasting methodology.

Key results

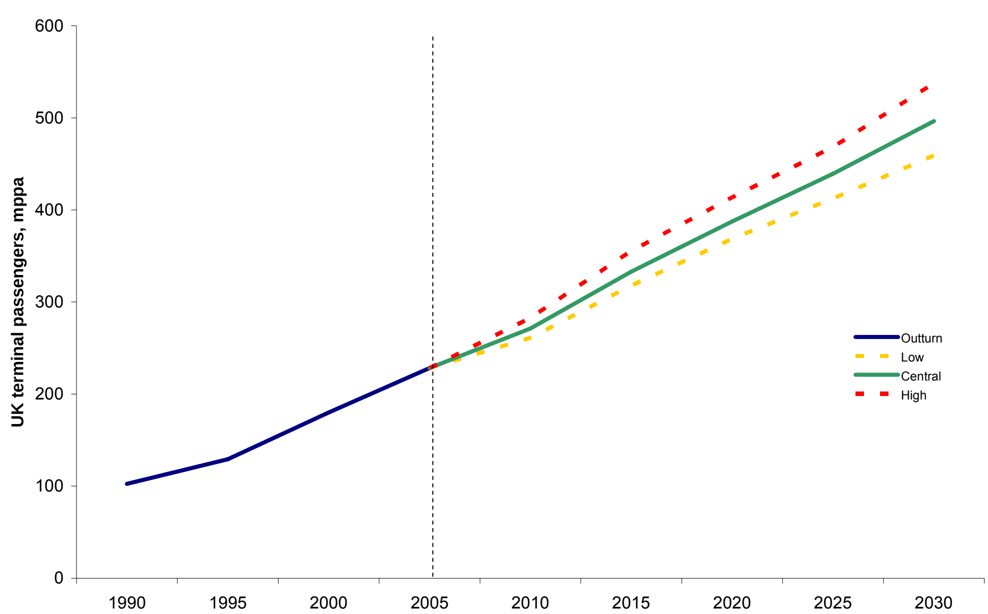
Passenger demand

1.5 Our passenger demand forecasting methodology remains essentially the same as that used for *The Future of Air Transport.* The forecasts have been updated to incorporate:

- the most recent demand data;
- new DEFRA guidance on the shadow price of carbon dioxide;
- new HMT GDP projections;
- new BERR oil price projections; and,
- improvements to elements of the modelling.

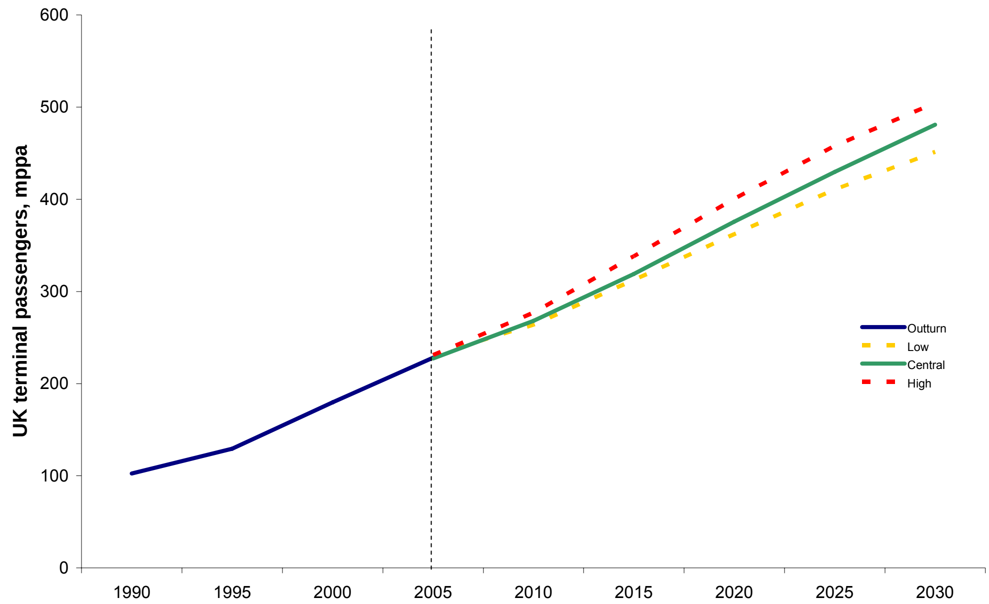
1.6 Figure 1.1 shows that, if not constrained by airport capacity, air travel demand at UK airports is forecast to grow strongly under the central case, from 228 million passengers per annum (mppa) in 2005 to 495mppa in 2030 (within the range 460-540mppa).

Figure 1.1: Unconstrained demand forecast



1.7 However, continued demand growth would eventually become constrained by airport capacity. Figure 2 shows that, even with the additional capacity supported in the White Paper, capacity constraints limit the 2030 central demand forecast to 480mppa (within the range 450mppa to 505mppa).

Figure 1.2: Constrained demand forecast



Carbon dioxide emissions

1.8 We have developed a new methodology for forecasting UK aviation carbon dioxide emissions which is a significant improvement over the method used at the time of the Air Transport White Paper (reported in *Aviation & Global Warming*).

1.9 For forecasts to 2030, the new method combines:

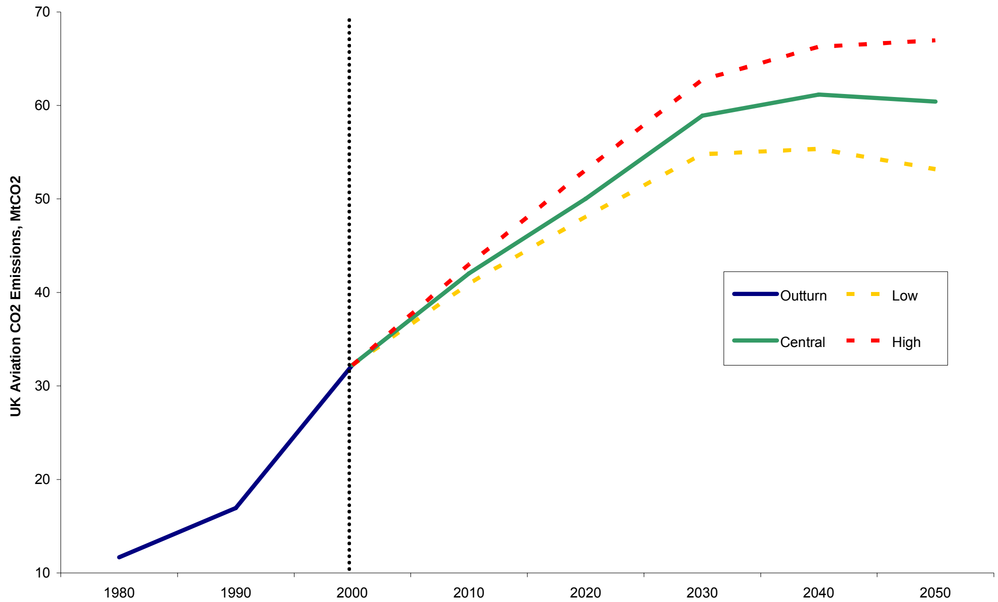
- detailed forecasts of ATMs and trip length from UK airports from our demand forecasts;
- the European Environment Agency's CORINAIR methodology for estimating aviation fuel burn by specific aircraft types; and,
- a newly developed detailed fleet turnover model, which improves our projections of aviation fuel efficiency.

1.10 Beyond 2030, we use simpler, yet still robust, methods to project aviation carbon dioxide emissions:

- to 2050, to inform analysis of the UK's target to reduce CO_2 emissions by 60% over 1990 levels, and
- to 2080, to inform our updated appraisal of the airport developments supported in the Air Transport White Paper.

1.11 As illustrated in figure 1.3, UK aviation CO_2 emissions are forecast to grow from 37.5MtCO_2 in 2005 to 59MtCO_2 in 2030, within the range 55MtCO_2 to 63MtCO_2. After 2030, the growth in emissions is projected to slow, partly due to capacity constraints slowing demand growth. By 2050 emissions are projected to flatten and reach 60MtCO_2, within the range 53MtCO_2 to 67MtCO_2.

Figure 1.3: UK Aviation CO_2 forecasts 2005-2050



Economic benefits of additional capacity in the South East

1.12 The economic appraisal of key development scenarios in the South East reported in *Passenger Forecasts: Additional Analysis* in 2004 has been updated in light of the developments outlined above.

1.13 We have updated our appraisal of airport development scenarios in the South East, following: the Eddington and Stern reports; our process of continual improvement; new economic and oil price projections; and revised DEFRA's latest guidance on the shadow price of carbon.

1.14 Key changes are the inclusion of the cost of CO_2 emissions from additional capacity; the benefits of reduced delays and air noise costs from additional Heathrow capacity. We have also extended the appraisal period to comply with the DfT Transport Appraisal Guidance (WebTAG).

1.15 The capital cost estimates for adding a new runway and associated infrastructure at Stansted and Heathrow have been updated to account for changes in construction costs and the evolution of airport operators' development plans since the 2003 White Paper.

1.16 The updated analysis shows that the development of a new runway at Stansted, and at Heathrow (subject to noise and air quality conditions), supported in the Air Transport White Paper would deliver a net economic benefit of £21-22bn (net present value, 2006 prices). The development would have a strong Benefit-Cost Ratio in the range 2.8-3.0.

1.17 Given the uncertainties inherent in forecasting, these results have been subjected to sensitivity tests. Table 1.1 below shows that the economic case for the ATWP-supported development at Stansted and Heathrow remains sound, even at the low end of the demand range, and at the high end of the shadow price of carbon dioxide and radiative forcing factor ranges.

Table 1.1: Sensitivity of ATWP economic case to forecast demand, shadow price of carbon dioxide, and radiative forcing factor ranges

Sensitivity test	NPV (£bn)	BCR
Central case	£22	3.0
Low end of demand range	£15	2.4
High end of demand range	£31	3.8
Lower Shadow Price of Carbon Dioxide	£33	4.0
Higher Shadow Price of Carbon Dioxide	£19	2.7
Lower Radiative Forcing Factor	£37	4.3
Higher Radiative Forcing Factor	£12	2.1

Notes:
1. 2006 prices, NPVs discounted to 2006
2. Shows results for lower Heathrow infrastructure costs, where applicable
3. 'Benefits' equals transport user benefits net of climate change disbenefits, including the effect of delay reductions at Heathrow on users and carbon emissions, where applicable.
4. Figures in parentheses refer to the opening date and annual ATM capacity of the developed airport
5. 'Benefit-cost ratio' is here defined as (benefits-disbenefits)/(infrastructure costs). This represents the value per pound of society's resources the development would deliver. This cannot be compared with the NATA BCRs reported for road and rail schemes, which divide the net benefits by the net effect on government spending.

2. Air Passenger Demand Forecasts

- Air passenger demand at UK airports has grown strongly for several decades.
- Future demand is forecast in two stages. National demand is forecast, unconstrained by airport capacities, with the econometric National Air Passenger Demand Model. The likely impact of future airport capacity constraints and split of passengers between airports is then forecast using the National Air Passenger Allocation Model.
- The national demand forecasts incorporate the latest economic growth forecasts from HMT and IMF, the latest oil price projections from BERR, the 2007 rise in Air Passenger Duty, and assume that aviation will in future meet its climate change costs.
- National demand, unconstrained by airport capacities, is forecast to rise from 228mppa in 2005 to 495mppa in 2030 (within a range of 460mppa to 540 mppa). Accounting for capacity constraints remaining after delivery of the ATWP-supported airport developments reduces 2030 demand to 480mppa (within a range of 450mppa to 505mppa).

2.1 This chapter is formed of three sections that set out:

- in Section 2A, an overview, including a review of the performance of recent forecasts;
- in Section 2B, the methodology and assumptions and validation of the forecasting models; and
- in Section 2C, the forecasts.

SECTION 2A: OVERVIEW

2.2 In December 2003, the Government set out a sustainable long-term strategy for the development of air travel to 2030 in *The Future of Air Transport*[5]. This was supported by forecasts of demand for air travel at UK airports which were reported in *Air Traffic Forecasts for the United Kingdom*[6] in 2000. Further supporting analysis of demand forecasts, and carbon emissions forecasts from UK aviation, were set out in *Passenger Forecasts: Additional Analysis*[7], *Aviation and the*

[5] *The Future of Air Transport*, Department for Transport, Dec 2003.
[6] *Air Traffic Forecasts for the United Kingdom 2000,* DETR, May 2000.
[7] *Passenger Forecasts: Additional Analysis,* Department for Transport, Dec 2003.

Environment: Using Economic Instruments[8], and *Aviation and Global Warming*[9] in 2004.

2.3 The 2006 *Progress Report* reported updated passenger demand forecasts, and committed the Government to publish in 2007:

- a technical note on our passenger demand forecast methods and results; and,
- revised UK aviation emissions forecasts.

2.4 This chapter sets out:

- the nature, purpose and interpretation of the forecasts;
- the performance of previous forecasts; and,
- our methodology, assumptions and results.

Nature and purpose of forecasts

2.5 We forecast the number of passengers passing through UK airports ('terminal passengers') each year. This covers UK and foreign residents travelling to, from or within the UK. As part of the process to account for the impacts of airport capacity on passenger demand, we also forecast the number of air transport movements. Box 2.1 explains the definition of terminal passengers and air transport movements that we use.

2.6 These forecasts are used to inform and monitor long term strategic aviation policy. They are inputs to the forecasts of UK aviation CO_2 emissions, which inform analysis of the UK's target to reduce CO_2 emissions to 60% below 1990 levels. Also, they are inputs to the appraisal of airport developments supported by the Air Transport White Paper.

2.7 We forecast demand in detail to 2030, using sophisticated statistical and other modelling techniques. For the purposes of the CO_2 forecasts and airport development appraisal, we further project demand to 2050 and 2080 (respectively) using simpler, yet robust, methods.

2.8 The rest of this chapter sets out the interpretation of our forecasts and projections, the methodology underpinning them, and the latest results.

[8] *Aviation and the Environment: Using Economic Instruments,* HM Treasury and Department for Transport, Mar 2003.
[9] *Aviation and Global Warming,* Department for Transport, Jan 2004.

Box 2.1: Terminal passengers and air transport movements

The Civil Aviation Authority (CAA) records the number of passengers, and the number of aircraft take-offs and landings, at UK airports each year.

The CAA defines a 'terminal passenger' as a person joining or leaving an aircraft at a reporting airport, as part of an air transport movement. This includes passengers 'interlining' (transferring between connecting services), but excludes those 'transiting' (arriving and departing on the same aircraft without entering the terminal) at a reporting UK airport.

The CAA further defines an air transport movement as a landing or take-off of an aircraft engaged on the transport of passengers, cargo or mail on commercial terms (excluding 'air taxi' movements, and empty positioning flights). As it does not include non-commercial movements, it also excludes private, aero-club, and military movements.

The number of terminal passengers is related to, but not the same as, the number of trips by air to and from the UK. For example, a passenger making:

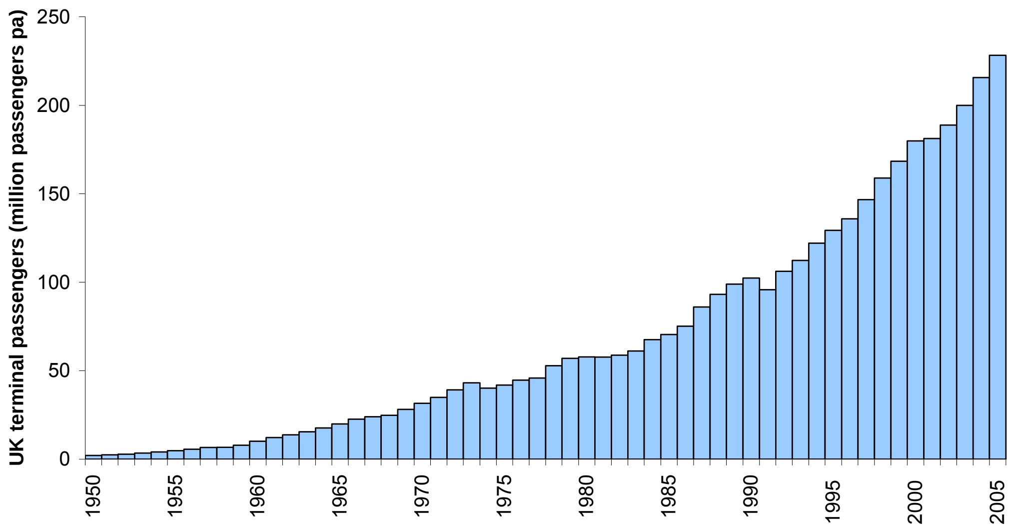
- A direct, one way trip from the UK to an overseas destination would count as one terminal passenger;
- A domestic, direct, one way trip would count as two terminal passengers;
- A one way trip from the UK to an overseas destination, via a UK connection (or transfer) would count as three terminal passengers; and,
- A one way trip between two overseas countries via a connection in the UK would count as two terminal passengers.

A round trip would involve double the terminal passengers of a one-way trip. The full definitions of terminal passengers and air transport movements is available on the CAA website at:

http://www.caa.co.uk/docs/80/airport_data/2006Annual/Foreward.pdf

2.9 Figure 2.1 shows the growth of UK air passenger travel since 1950. The frequent deviations from the long term trend have been driven by economic factors, such as recessions or oil price shocks, or by wider conditions, like military conflicts, terrorism, or fears of global pandemic. It is reasonable to expect that future forecasts will continue to be affected by such less predictable short term fluctuations.

Figure 2.1: UK terminal passengers 1950-2005



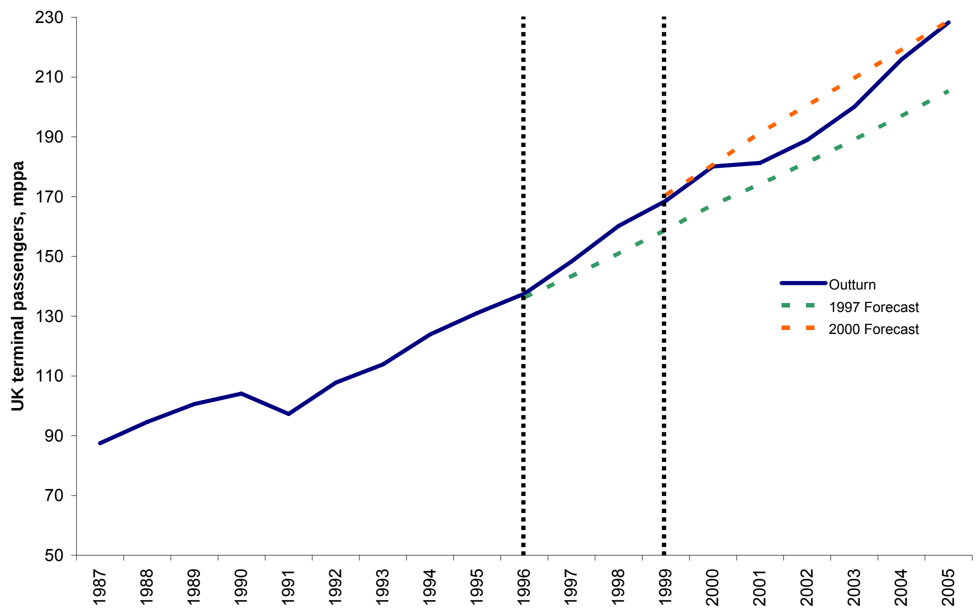
2.10 While some driving forces can be captured within the forecasting models (e.g. trend economic growth and oil prices), these forecasts do not seek to predict when recessions, booms, conflicts, etc. might occur. The purposes to which these forecasts are put require that it is more important to forecast accurately the trend in demand growth over a longer time scale.

Performance of previous forecasts

2.11 The previous detailed set of unconstrained UK air passenger demand forecasts was reported in *UK Air Passenger Demand Forecasts 2000*. This replaced the forecast issued in 1997, and was reviewed for the ATWP in 2003, then refreshed at the national level in the ATWP Progress Report in 2006. When considering the performance of previous forecasts, it would be useful to be able to examine the effects of improvements to the modelling and the evolution of the air travel market over time, but it is necessary to allow sufficient time since the forecasts were produced to observe the trend in outturn. We therefore consider the performance of the 1997 and 2000 forecasts.

2.12 Figure 2.2 below compares these two forecasts of unconstrained demand against outturn. It shows that the trend in demand growth exceeded the 1997 forecast. Assessing the 2000 forecast is not straightforward due to the disruption to the air travel markets resulting from conflicts, terrorist attacks, and fears of pandemic, which suppressed air travel demand between 2001 and 2003. However, it appears that demand has recovered from the very slow growth in 2001, and returned to the trend forecast in 2005.

Figure 2.2: 1997 and 2000 unconstrained demand forecasts versus outturn



SECTION 2B: METHODOLOGY, ASSUMPTIONS AND VALIDATION

Methodology & Assumptions

2.13 In broad terms, we generate our forecasts in two steps:

1. Forecast 'unconstrained' national air travel demand with the National Air Passenger Demand Model. This combines time-series econometric models and projections of key driving variables with 'market maturity' assumptions, to forecast national air travel demand assuming no UK airport capacity constraints.

2. Account for the likely impact of future UK airport capacity constraints on demand, while allocating forecast passengers to airports and translating passenger demand into air transport

movement demands, with the DfT National Air Passenger Allocation Model. This also provides key inputs to the CO_2 Forecasting Model and Transport User Benefits Model, and can be used for other detailed environmental assessments.

2.14 The unconstrained demand forecasts are therefore only an intermediate step in the forecasting process, showing how demand would grow if there were no UK airport capacity constraints.

2.15 Figure 2.3 illustrates the overall process for forecasting UK air travel demand to 2030, showing inputs, models, intermediate outputs, and final results. The methodology and assumptions behind these broad steps are set out in more detail below.

Unconstrained demand forecasts to 2030

Methodology

2.16 The National Air Passenger Demand Model is used to forecast national passenger air travel demand assuming no UK airport capacity constraints. It does this by combining a set of time-series econometric models of past UK air travel demand with projections of key driving variables and assumptions about market maturity.

2.17 A time-series econometric model is a statistically estimated equation which quantifies how key driving factors have caused the variable of interest (in this case air passenger demand) to move over time.

2.18 The demand for passenger air travel through UK airports has been split into separate markets reflecting the likelihood of different trends, strength of driving forces, and availability of data. We expect that the demand for leisure trips should be driven by income or consumer spending, and to some extent affected by air fares; while travel for business purposes should be more driven by international trade, and may not be significantly affected by air fares at the aggregate, national level. Similarly, we would expect the strength of the causal factors to vary between global regions, reflecting different stages in economic development. We therefore split demand according to:

- the global region the passenger is travelling to or from (see figure 2.3a);
- whether the passenger is a UK or overseas resident;
- the passenger's journey purpose (leisure or business);
- whether the passenger is on an international scheduled, international charter, or domestic flight; and
- whether the passenger is making an international to international connection at a UK airport (as part of a journey between two other nations).

Figure 2.3: Overview of UK Air Passenger Demand and CO_2 Forecasting

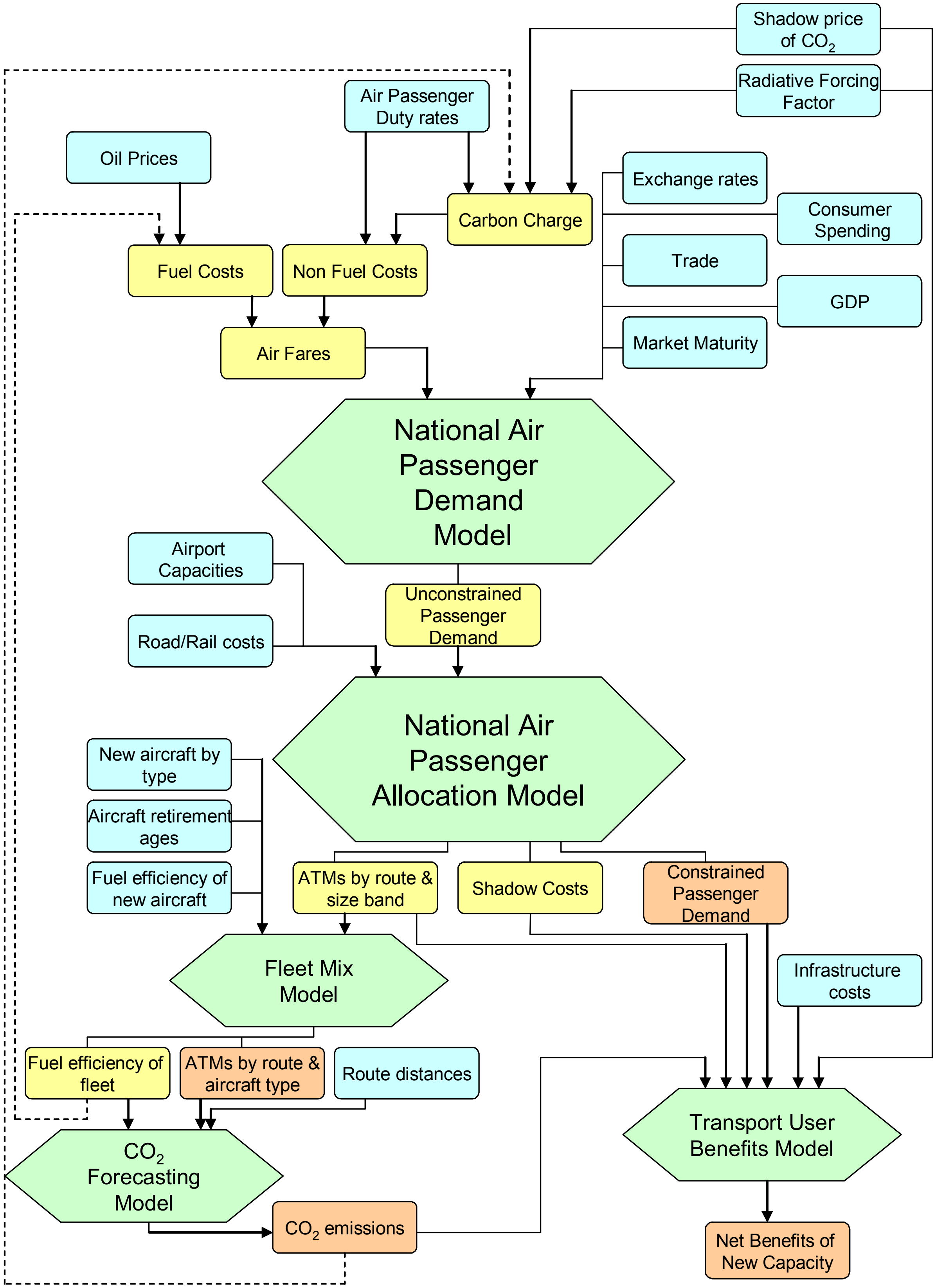
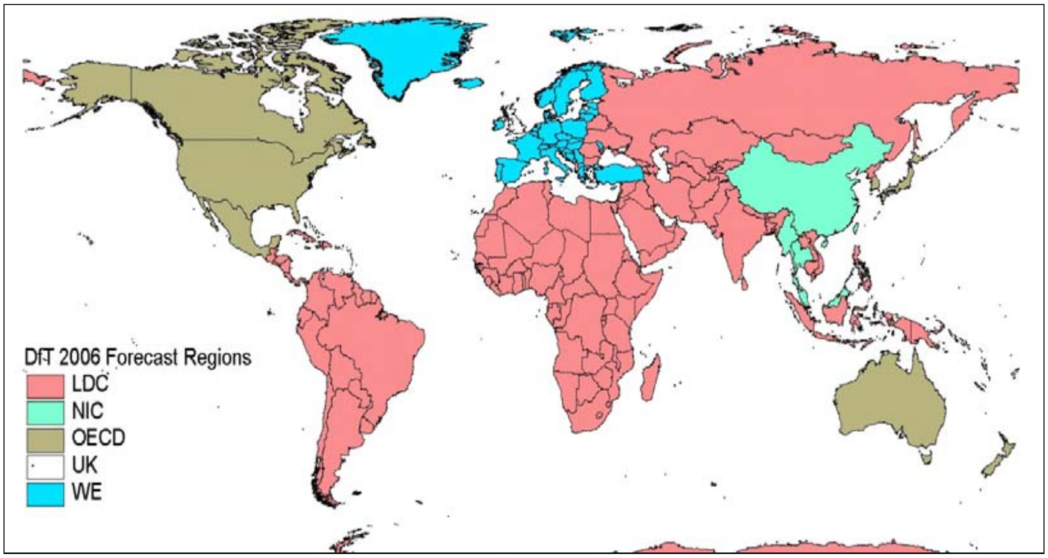


Figure 2.3a: Global regions used in the unconstrained demand forecasting models



2.19 Overall, this gives twenty one markets for which separate econometric models are estimated and used to forecast demand. Box 2.2 sets out some detail of our econometric modelling approach, and Annex A gives more detail on our econometric models.

2.20 The estimation confirmed that the key variables determining air travel demand varied by market segment, but in general included measures of economic activity (e.g. consumer spending, GDP, or international trade), air fares, and exchange rates. In the leisure sectors consumer spending, GDP, air fares, and exchange rates were identified as drivers. In the business sectors, a mixture of GDP, international trade, and exchange rate variables were shown to be the main drivers, with only limited price effects identified.

2.21 Table 2.1 below summarises the central estimates for the long run price elasticities[10]. This shows that income is a strong driver in the scheduled markets, with the estimated income elasticity of demand ranging from 1.4 to 2.1. This falls to 0.4 for the charter market, but the overall average income elasticity is strong at 1.5. Air fare effects are more variable. The UK leisure sector showed a strong price elasticity of -1.0, but no air fare effect could be identified for the UK business sector. Charter and domestic travel showed some fare effects (-0.4 and -0.3 respectively), but the limitations of the fare data for foreign-based travel prevented a price elasticity being found for this sector.

[10] The elasticity of demand with respect to another variable shows the percentage change in demand that would result from a 1% increase in the other variable.

Box 2.2: National aviation demand econometric modelling

The purpose of our time series modelling of air passenger demand is to quantify the relationship between demand and the variables which cause it to change. Economic theory and our analysis of data from earlier years suggests that income, consumer spending, international trade, exchange rates and air fares are likely to be causal variables.

The strong upward trend in air passenger demand means that simply estimating the relationship between these variables could suffer from the problem of 'spurious regression', where the statistical significance of the estimated relationship appears stronger than it really is. However, if there exists a relationship to which the variables tend to revert in the long run, the variables are 'co-integrated' and this problem can be overcome.

For most of our models we have therefore applied the single-step approach to testing for, and estimating a co-integrated relationship, and estimated regressions of the form:

$$\Delta Q_{it} = \alpha_i + \beta_i \Delta Z_{it} + \delta_i Q_{it-1} + \gamma_i Z_{it-1} + \varepsilon_{it}$$

where

Q_{it}	=	log of passenger demand in market i at time t
Z_{it}	=	log of explanatory variables in market i at time t
ε_{it}	=	error in prediction in market i at time t
$\alpha_i, \beta_i, \gamma_i, \delta_i$	=	parameters to be estimated
Δ	=	change between period t and period t-1

The models were estimated over different time periods, depending on the availability of data. The earliest sample period began in 1984, but all models used data up to 2004. This ensures that our models reflect the most recent trends in market structure, such as the rise of the 'low cost' airline model, and the response of competitors.

The results show a good fit to the data in most markets with statistically significant parameters of the expected sign and magnitude. The R^2 values (which show the proportion of the past variation in the dependent variable the models explain) for most of the market models are in the region of 0.7-0.9. This indicates that the models are successful in explaining past movements in demand, and gives us confidence in using them to project future demand.

Table 2.1: Long run price and income elasticities of UK terminal passenger demand

Sector	Share of passenger demand 2005	Elasticity of demand with respect to: Income	Air Fares
UK Business	8%	1.5	0.0
UK Leisure	29%	1.6	-1.0
UK Charter	16%	0.4	-0.4
Foreign	18%	1.5	-
Itol	11%	0.8	-0.4
Domestic	17%	2.3	-0.3
Overall	100%	1.5	-0.4

Notes:
No significant price elasticity found for UK business
Limited air fare data available for foreign business or leisure
Income variable depends on sector
Price elasticities are point estimates, income elasticities are arc estimates.

2.22 The resulting overall air fare elasticity is -0.44. It is intuitive that this is some way below unity, given that passengers may have options for responding to (e.g.) an increase in price which reduces the cost of their trip without preventing it, such as travelling to a less expensive destination, or by a less expensive class of travel or airline. It is also in keeping with findings for other modes that UK transport demand is relatively price inelastic. Furthermore, box 2.3 explains that these results are broadly in line with other relevant published studies.

2.23 The potential impact of the limited air fare data for foreign-based travel on the overall price elasticity can be examined by assuming for illustrative purposes that UK elasticity results apply to foreign-based travel. The impact of this is minimal, raising the overall average elasticity from -0.44 to -0.56. However, if the necessary air fare data could be obtained to allow estimation of foreign fare effects, it would be unlikely to impact significantly on the trends projected by the models. This is because, for the econometric model to continue to fit the past data, any change to its fitted values (and thus forecast) due to including a different price elasticity is likely to be broadly offset by changes to the estimates of other parameters.

Central case assumptions

2.24 The previous section outlined the econometric models used in our unconstrained demand forecasts. As discussed above, we feed projections of the relevant driving variables from 2005 to 2030 into the econometric model for each market sector to produce the unconstrained demand forecasts. The discussion below outlines the assumptions we make when projecting each driving variable under the central case. Annex B gives more detailed information.

Box 2.3: National aviation demand price and income elasticities comparisons

In assessing the results of our econometric modelling, we have compared our price and income elasticities with those found by others. In choosing elasticities for comparison, it is essential to focus on studies which are relevant to the UK national passenger demand. For example, it would not be accurate to compare a national level price elasticity to that of a sub-national market, or an individual airline. As shown by CAA (2005), price effects at the sub-national level could be stronger, reflecting greater substitution possibilities, but substitution between routes or airlines would not affect the total market size. Also, comparisons with markets in other countries or regions of the world are complicated by their different population distribution, geography and transport systems, and market structures.

Our literature review revealed that while there is a large number of studies of aviation price and income elasticities, relatively few are relevant to UK national demand. Key studies which are directly comparable are CAA (2005), Dargay & Hanley (2001), the literature review and modelling for CfIT by Dargay, Menaz & Cairns (2006), and Toner, Wardman & Whelan (1995). None of these covers all the market sectors we model and use for forecasting, but where they coincide they find price elasticities broadly comparable to ours.

For example, the price elasticity of UK national leisure travel is found to be in the range -0.7 to -0.8 (outbound) by CAA, -0.6 by Dargay & Hanley, and -0.8 (-1.0 short haul, -0.4 long haul) by Dargay, Menaz & Cairns. These results lie within the 90% confidence range around our finding of -1.0 +/-0.5. Both studies conclude that they cannot find significant fare effects for UK business travel, although Dargay & Hanley find a small price effect for Foreign Leisure and Business travel of -0.3. Similarly, Toner, Wardman & Whelan find domestic air travel to have a short-run price elasticity in the range -0.1 to -0.3, which compares well with our long run estimate of -0.3.

It is generally accepted that the income elasticity of air travel demand exceeds unity. The income elasticity of UK leisure travel is found to be 1.5-1.8 (outbound) by CAA, 1.1 by Dargay & Hanley, and 1.5 (1.0 short haul, 2.9 long haul) by Dargay, Menaz & Cairns. These results match well with our estimate of 1.5. UK business travel's income (trade) elasticity is found to be 1.1 by Dargay & Hanley, and 3.5 by Dargay, Menaz & Cairns. Our estimate of 1.4 is more comparable to the Dargay & Hanley result.

Macroeconomic factors

2.25 UK and foreign GDP, and UK consumer spending, growth assumptions are based on DfT WebTAG guidance[11], the HMT 2007 Budget and 2006 and 2007 Pre-Budget Reports[12] and the IMF World Economic Outlook[13]. The growth rates vary between regions and time periods, but generally show continued growth in incomes around the world, with much stronger growth in newly industrialising and less developed countries.

2.26 UK international trade assumptions are derived from the established relationship with UK and overseas GDP. These project continued steady growth in trade with Europe and OECD nations, and stronger growth for newly industrialising and less developed countries.

2.27 Exchange rates are particularly challenging to project over many years, being subject to both long term trends and short term movements. We therefore use a neutral assumption that they will remain constant.

Air fares

2.28 Air fares are assumed to move in line with airline costs. These are split into fuel costs, and non-fuel costs (including tax or charge elements).

2.29 Fuel costs are driven by fuel price and fuel efficiency. We project fuel prices by assuming that the strong historical relationship between aviation fuel and oil prices continues. Oil prices are assumed to move in line with the DTI's central oil price projection, which falls from about $65 per barrel in 2006 to $53 per barrel in 2030, with most of the decline occurring by 2012[14]. Fuel efficiency growth assumptions are derived from our fleet mix model, which is explained in chapter 3.

2.30 Analysis of airline cost data shows that non-fuel costs have trended downwards in the last decade, for both short- and long-haul operations. In the last five years, they have declined by around 5% per annum (pa). This has been driven by increasing airline competition, convergence of lower cost and full service airline business models, and the continuing evolution of non-fare revenue streams by airlines. We project this trend to continue, but at a slowing rate. Short haul and domestic non fuel costs are projected to fall (in real terms) by 4%-5% pa to 2010, 2.4% pa 2010-2015, and 1.9% pa 2015-2020, after which

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[11] *Webtag,* Unit 3.5.6 Values of Time and Operating Costs, Table 3, http://www.webtag.org.uk/webdocuments/3_Expert/5_Economy_Objective/3.5.6.htm.

[12] *Budget 2007 Report*, HM Treasury, March 2007, HC342; *2007 Pre-Budget Report and Comprehensive Spending Review*, HM Treasury, October 2007, Cm 7227; *2006 Pre-Budget Report*, HM Treasury, December 2006, Cm 6984.

[13] *World Economic Outlook, Statistical Appendix*, IMF, April 2007

[14] *Meeting the Energy Challenge: A White Paper on Energy*, BERR, Cm 7124, see Annex B, Table B5 for central assumptions. Oil prices shown in 2004 prices.

they are held constant. Similarly, long haul non fuel costs are projected to fall by about 3% pa to 2010, 1.6% pa 2010-2015, and 1.1% pa 2015-2020, after which they are held constant.

2.31 The Air Transport White Paper included a commitment to work to ensure that aviation meets its external costs. The forecasts supporting the White Paper therefore assumed that after 2010 passengers would face an additional cost reflecting their climate change emissions (both carbon and the warming effects of non-carbon emissions), phased in gradually over ten years.

2.32 The 2006 Air Transport White Paper Progress Report committed the Government to consult on the development of a new 'emissions cost assessment' to inform its decisions on major increases in aviation capacity. The Emissions Cost Assessment Consultation[15] proposed that revenues from Air Passenger Duty (APD) should count as part of the aviation industry's contribution to meeting its climate change costs.

2.33 Hence in these forecasts passengers are assumed to face charges to cover their climate change costs comprising APD (which was doubled in February 2007) and an additional cost equal to the difference between APD and aviation's climate change costs per passenger journey (if positive) from 2007.

2.34 APD rates are assumed to remain constant in real terms. Climate change costs are estimated at the route level to account for differing emission profiles by distance, aircraft type and load factor. In the central case scenario this is based on:

- CO_2 emissions per passenger kilometre by route from the CO_2 Forecasting Model (set out in chapter 3), and passenger kilometres by route, in each future year under a 'no additional carbon charge' scenario;
- the DEFRA central value for the shadow price of carbon dioxide emissions, which rises from £19/tCO_2 in 2000 (2000 prices) by 2% per annum in real terms; and,
- a 'radiative forcing factor' of 1.9, by which in-flight carbon emissions are multiplied to account for the warming effect of non-carbon emissions.

Market maturity

2.35 Air travel demand has shown very strong growth for several decades. While it is important to use models capable of capturing the relationship between air travel demand and its key drivers in the past, we must also ensure that we account for the likely future maturity of the air travel market. As with most markets, we would expect there to be some product cycle in aviation demand, with rapid early demand growth

[15] *Consultations on the Emissions Cost Assessment*, Department for Transport, August 2007.

giving way to steadier growth in later years. 'Market maturity' refers to the declining income elasticity we would expect to characterise this slowing of growth.

2.36 Our econometric models are estimated from data covering the more recent period of aviation demand growth, and so should reflect the most recent form of the relationship of demand with its drivers. However, market maturity is not inherent in them, and so (as with previous forecasts) it is necessary to overlay assumptions about maturity. Annex B provides more detail on the method for applying these assumptions.

Box 2.4: Shadow price of carbon dioxide emissions

Following the Stern Review, the government has updated its guidance on the social cost of carbon. DEFRA's previous guidance set the 2000 social cost of carbon at £70/tC in 2000 prices, rising by £1/tC pa in real terms. Its new guidance recommends a 2000 shadow price of carbon dioxide emissions of £19/tCO_2 (in 2000 prices), rising by 2% pa in real terms. DEFRA's guidance is available at:

http://www.defra.gov.uk/environment/climatechange/research/carboncost/index.htm

The guidance recommends that all appraisals using the shadow price of carbon dioxide emissions should include a sensitivity test varying the 2000 shadow price by [at least] [+/-5%] to check for policy conclusions which depend critically on this value. DEFRA have since recommended that it would be prudent to test a wider range of -10% to +20%, or £17/tCO_2 to £23/tCO_2. This wider range has therefore been adopted in our sensitivity

Sensitivity test assumptions

2.37 As with any forecasting exercise looking twenty five years ahead, there is uncertainty over the future path of the driving variables. We therefore produce for each variable a pair of sensitivity tests around the central case projection. These tests examine the impact on forecast demand of varying the projections of the driving factors within reasonable bounds. The nature of each sensitivity test depends on the uncertainty surrounding the projected variable. The assumptions used in each test are summarised below, and Annex B provides more detail.

Economic activity

2.38 The economic activity test allows growth in each variable reflecting economic activity (GDP, consumer spending and trade) to vary by +/-0.25% per annum from 2005 to 2030.

Oil prices

2.39 The oil price test varies the projection of oil prices within the BERR oil price projection range ($25 per barrel to $80 per barrel by 2030) at (base year) 2004 prices.

Non-fuel costs

2.40 For the period over which non-fuel costs are assumed to decline (up to 2020), this test varies the projection of non-fuel costs by +/-½% pa around the central projection.

Shadow price of carbon dioxide emissions

2.41 Box 2.4 explains that in line with DEFRA guidance and advice, we vary the 2000 shadow price of carbon dioxide emissions by -10% to +20%, i.e. between £17/tCO_2 and £23/tCO_2.

Radiative forcing factor

2.42 The radiative forcing factor test varies the amount by which in-flight carbon emissions are multiplied to account for non-carbon climate change emissions released at altitude between 1 and 4.

Fuel efficiency of new aircraft

2.43 Chapter 3 explains the sensitivity test performed on the fuel efficiency of aircraft entering service.

Forecast range

2.44 The overall range of forecast demand summarises all these uncertainties. The range is found by taking the outer limit of all the sensitivity tests combined in each year.

Constrained demand forecasts to 2030

2.45 The unconstrained demand forecasts, as discussed above, provide an input to the DfT National Air Passenger Allocation Model which produces 'constrained' demand forecasts taking into account the effect of airport capacity constraints.

2.46 The DfT National Air Passenger Allocation Model comprises several sub-models and routines. These are used in combination and iteratively:

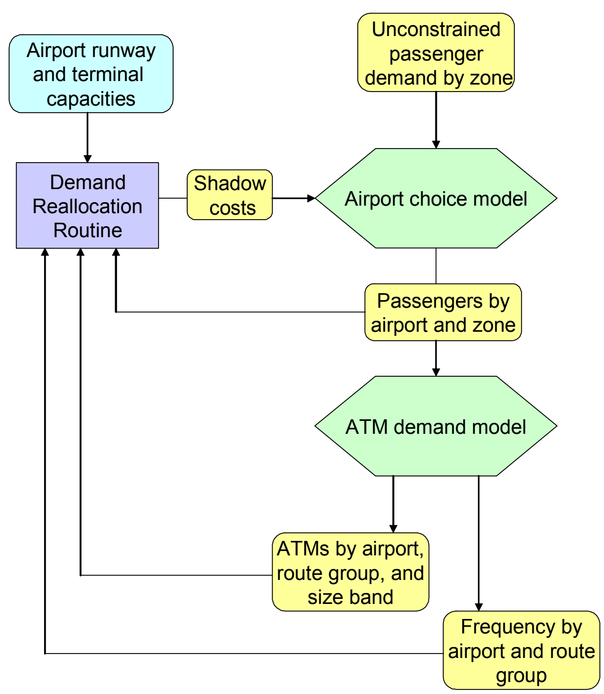
- the Passenger Airport Choice Model forecasts how passenger demand will split between UK airports;

- the ATM Demand Model translates the passenger demand forecasts for each airport into ATM forecasts; and,
- the Demand Allocation Routine accounts for the likely impact of future UK airport capacity constraints on air transport movements (and thus passengers) at UK airports.

2.47 Figure 2.4 below illustrates this structure and process. The discussion below outlines:

- what the sub models do;
- how they are estimated;
- their validation, by showing how well they reproduce the base year data; and,
- how they are used to forecast constrained passenger demand.

Figure 2.4: National Air Passenger Allocation Model



Passenger Airport Choice Model

2.48 The Passenger Airport Choice Model component of the National Air Passenger Allocation Model has been built to explain and reproduce passengers' current choice of airport, as recorded in CAA data. The forecasts of demand by airport are obtained by feeding projections of the variables which have been found to drive passengers' airport choice into the model.

2.49 Importantly, this means that our forecasts of airport choice (and thus the impact of capacity constraints on demand) are grounded in passengers' actual, observed behaviour. They are not based simply on (for example) assumptions about how excess demand spills between airports, nor simple extrapolations of recent trends at particular airports. We set out below how the model is estimated and used to forecast the split of demand between airports.

Model estimation

2.50 A passenger flight is usually one part of a journey, comprising several stages and modes, between different parts of the world. To understand how passengers choose between UK airports we therefore need to consider not just the airports they are flying between, but the initial origin or ultimate destination of their journey in the UK. For example, a passenger leaving Gatwick might have an initial origin at their home in Kent, and a passenger arriving at Leeds-Bradford might have a destination in York.

2.51 A traveller's choice of airport will therefore be determined by a number of factors, including:

- the initial origin (for outbound) or ultimate destination (for inbound) in the UK of their trip;
- the location of airports in the UK;
- the availability of flights (and their prices) offered at each airport;
- the possibilities of transferring and making onward connections at UK and overseas airports;
- the travel time and other costs for accessing each airport by road and public transport; and,
- the traveller's preference for services offered at each airport and their value of time.

2.52 The Passenger Airport Choice Model component of the DfT National Air Passenger Allocation Model quantifies the relationship between these factors and passengers' current airport choice, estimating the extent to which each of the driving factors influences airport choice.

2.53 To do this, the model splits the UK into 455 zones (see figure 2.4a), and assumes that the share of travellers originating in, or destined for, each zone potentially travelling via each of the 31 modelled airports depends on:

- the time and money costs of accessing that airport by road or public transport

    - the model follows the standard transport modelling approach of combining journey time, including waiting and interchanging, and money costs into a single 'generalised cost' measure, based on the network of road and rail services, as illustrated in Figure 2.4b
- flight duration and frequency;
- air fares;
- travellers’ preferences for particular airports; and,
- travellers’ value of time (which varies by journey purpose).

For example, the lower the time and money costs of accessing an airport, and the greater the range and depth of services offered, the greater will be the share of demand to/from a given zone the airport will attract.

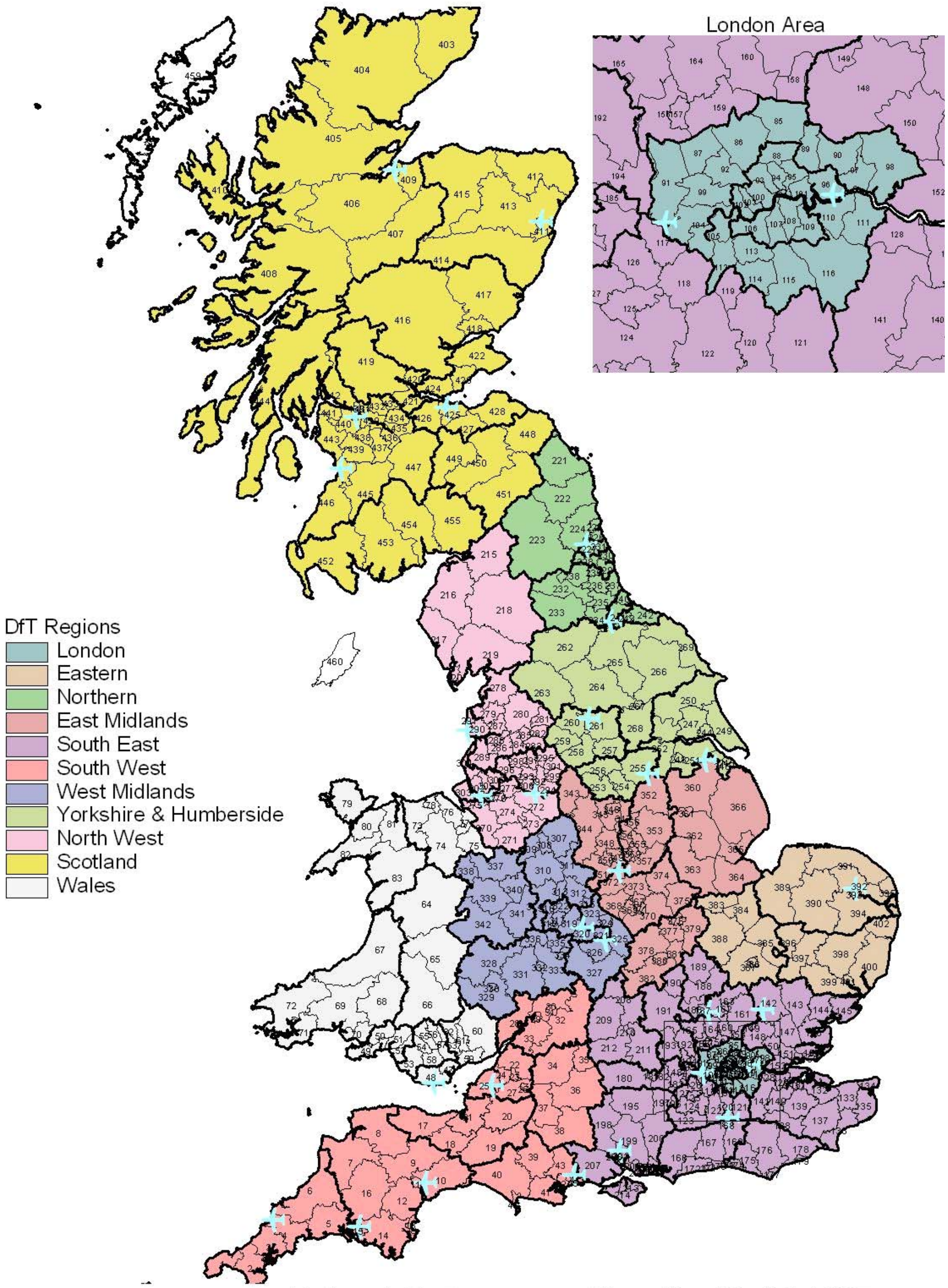
2.54 The strength of each factor in driving an airport’s share of demand is determined by calibrating the model to 2005 CAA airport choice data. Calibration is a statistical technique by which the weight to be placed on each factor is chosen so as to maximise the model’s accuracy in predicting current choices. This means that the model represents people’s actual, observed, airport choice behaviour. Annex C gives further detail on the model's functional form, and Annex D summarises improvements to the model since the ATWP generation.

Using the Passenger Airport Choice Model to forecast airport choice

2.55 The model of passengers' airport choice delivered by the estimation process outlined above is used to forecast passenger demand at each modelled UK airport. The first step is to use the unconstrained demand forecasts for each type of passenger journey purpose to project growth in demand to/from zones (the districts of ultimate origin or destination) in the UK. To forecast how this demand splits between airports, we also project:

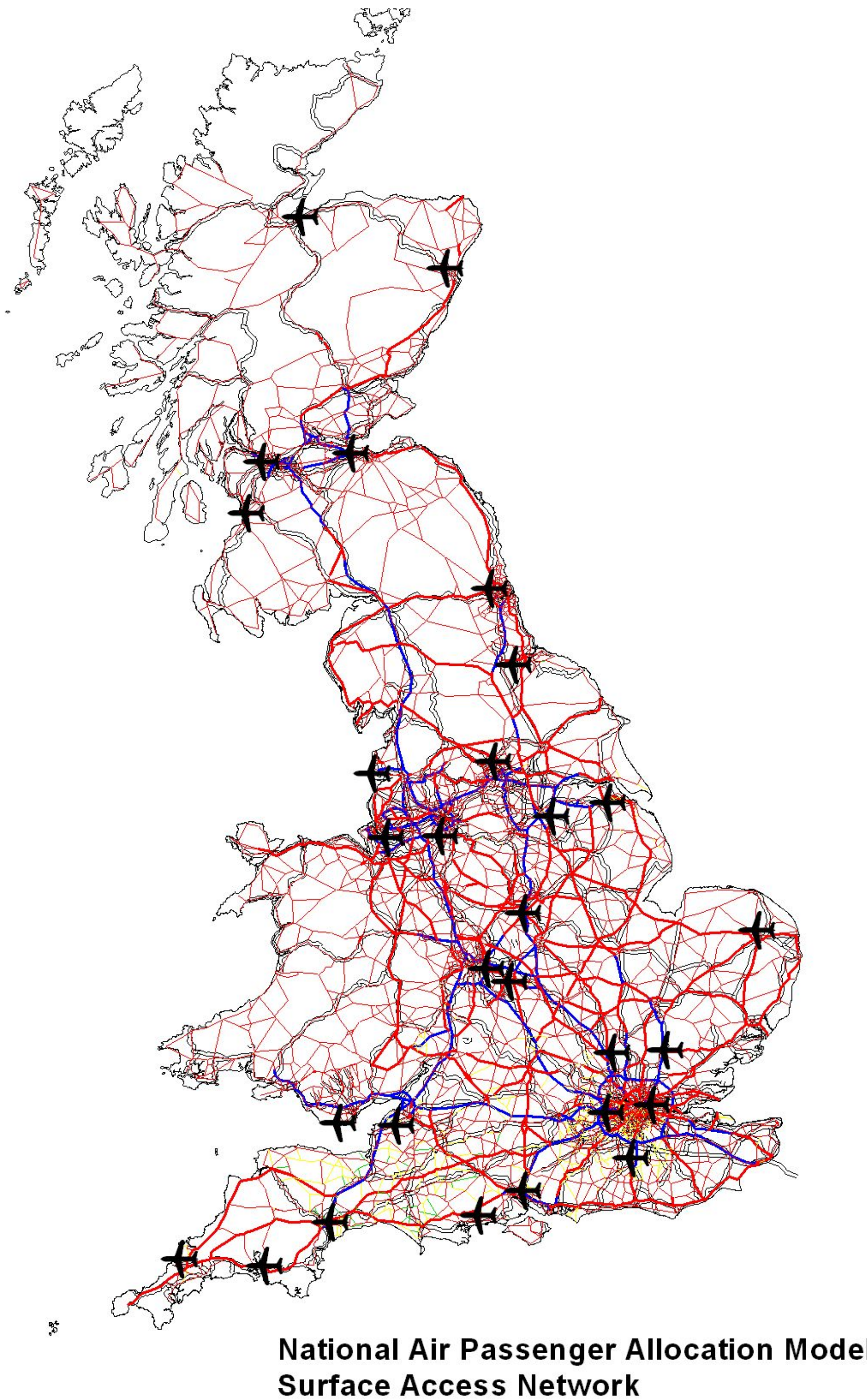
- travel time and costs between each zone and each airport, based on future road and rail network and conditions:
    - traffic growth extends road journey times but improvements implemented as part of the Governments Roads Programme deliver reductions;
    - rail journey times do not deteriorate, but schemes such as the West Coast Mainline Upgrade and Channel Tunnel domestic improvements deliver improvements.
- route availability and frequency at each airport;
- travellers’ value of time; and,
- for modelling domestic air travel, comparative road, rail and air travel time and other costs between all UK zones.

Figure 2.4a: Zones used in National Air Passenger Allocation Model



National Air Passenger Allocation Model: UK Zones

Figure 2.4b: Surface access network used in the National Air Passenger Allocation Model



2.56 These are fed into the Passenger Airport Choice Model, which applies the calibrated relationship between these driving factors of airport choice to forecast how much of the forecast demand to/from each zone will travel via each airport. Summing forecast demand for each airport across all the zones and passenger markets gives the total forecast demand for each airport, unconstrained by airport capacity.

2.57 These unconstrained demands for each airport are then, as shown in Figure 2.4, fed through to the ATM demand model and from there to the Demand Reallocation Routine to take account of capacity constraints. This routine feeds shadow costs into the Passenger Airport Choice Model and the process is repeated iteratively until demand is optimally distributed within the constraints of capacity.

Passenger Model Validation - airport level

2.58 An important factor determining the confidence which can be placed in a calibrated model is its ability to replicate the observed data, known as 'validation'. For airport modelling, this can be assessed both at the airport level, and in considerably more detail at the route level. The former involves comparing actual (base year) and predicted demands at each airport, while the latter compares actual and predicted demands on each route.

2.59 Table 2.2 below reports the accuracy of the model in predicting passenger demand at those airports which handled more than 3mppa in 2005 (these comprise 91% of modelled demand). It shows that the model is very successful in predicting the number of passengers travelling through each UK airport. Demand is predicted to within +/-1% at the three largest London area airports, and to within +/-3% at Luton and London City. The London area total fitted value is also highly accurate. Similarly, at most airports outside the London area the model is accurate to within +/-4%, with the accuracy widening in two cases (although these each account for 5mppa, 2% or less of the national modelled total).

Table 2.2: Actual and predicted passengers at modelled airports, mppa in 2005 base year

	Actual	Fitted	Difference	Difference (%)
Heathrow	67.7	68.1	-0.4	-1%
Gatwick	32.7	32.8	-0.2	0%
Stansted	22.0	22.3	-0.3	-1%
Luton	9.1	8.9	0.3	3%
London City	2.0	2.0	0.0	2%
London Subtotal	133.5	134.1	-0.6	0%
Manchester	22.1	21.6	0.5	2%
Birmingham	9.3	9.2	0.1	1%
Glasgow	8.8	9.1	-0.4	-4%
Edinburgh	8.4	8.5	-0.1	-1%
Bristol	5.2	5.6	-0.4	-7%
Newcastle	5.2	5.3	-0.1	-1%
Belfast International	4.8	4.9	-0.1	-1%
Liverpool	4.4	4.5	-0.1	-2%
East Midlands	4.2	3.8	0.4	10%
Other Airports in Model	20.1	20.7	-0.6	-3%
Total in Model	226.0	227.3	-1.3	-1%
Non-Model	2.3			
National Total	228.3			

2.60 At the airports with 3mppa or less in 2005 (comprising 9% of modelled total), the model predicts passenger demand to within 15% in 94% of cases. See annex E for more detailed analysis of the model's calibration and validation at all airports.

Passenger Model Validation - route level

2.61 Table 2.3 summarises the model's success in predicting passenger demand on individual routes. In the table we have presented the validation against data for the 742 modelled routes[16] which each carried more than 25,000 passengers per annum in 2005[17]. The results are weighted by the number of passengers on each route. The table shows that over half of the passengers are on routes where passenger numbers are predicted to within +/-10% of actual figures, rising to over three quarters within +/-20%.

2.62 Figure 2.6 illustrates the correlation between the actual and fitted passenger numbers in a scatter plot. The trend line has a slope very close to one, and the data are scattered very closely around the trend line. This indicates that the model is very successful in predicting route level demands in the base year. Annex E provides more detailed validation results.

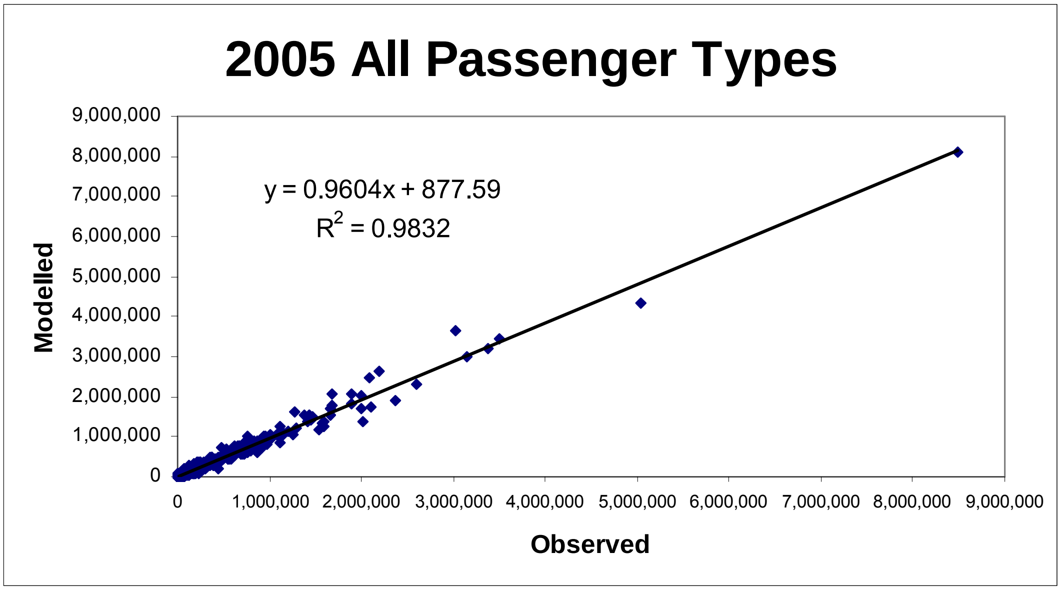
[16] The model has 59 specific airport destinations in the UK and Europe and 21 destinations which are geographical groupings of routes to smaller or more remote airports (a "route group"). Strictly the definition of route here is "route or route group".

[17] Validation in practice extended to all routes with more than 5,000 passengers in 2005, extending the total calibration exercise to include close to 1,000 separate routes.

Table 2.3: Route level passenger prediction, 2005, all flights (domestic and international)

Error band	Proportion of routes	Cumulative proportion
0%-5%	35%	35%
5%-10%	20%	55%
10%-20%	24%	80%
20%-30%	12%	91%
30%-40%	4%	95%
40%-50%	3%	98%
50%+	2%	100%

Figure 2.6: Scatter plot of actual and fitted passenger numbers by route, all flights (domestic and international), 2005



ATM Demand Model

2.63 The Passenger Airport Choice Model provides the forecast demand at each modelled UK airport. As demand is forecast to grow, forecast demand will exceed capacity at some airports. The limiting capacity could be the airport terminal, runway, or planning constraint. Runway capacity is measured not by passenger numbers, but by the number of air transport movements (ATMs). The ATM Demand Model translates passenger demand into air traffic movement (ATM) demand at each airport, to allow comparison of demand with both passenger and ATM capacity constraints.

2.64 The ATM Demand Model also projects the availability of routes from each modelled airport. We assume that, in line with mainstream economic theory, supply will respond to demand, subject to airport capacity, so long as the market is commercially viable. Hence we forecast the supply of flights on routes to grow with demand, provided markets satisfy a minimum viability threshold. The ATM Demand Model simulates the introduction of new routes by testing in each forecast year whether sufficient demand exists to make new routes viable from each airport. The test is two-way, so routes can be both opened and withdrawn. Also, airports are tested jointly for new routes, allowing them to compete with each other.

2.65 For each route from each airport, the ATM Demand Model then forecasts the size of aircraft, load factor, and frequency of operation used to meet forecast passenger demand, subject to demand, by applying relationships between passenger demand, aircraft size and load factors, and flight frequency derived statistically from historical data. These relationships indicate the stages of passenger demand growth that are likely to be accommodated by increases in frequency, and the points in the growth of demand at which a switch to operating larger aircraft can be expected. Box 2.5 provides further detail on the modelled relationship between capacity, demand, and aircraft size.

Box 2.5: Relationship between capacity, demand and aircraft size

The relationship between aircraft size and airport capacity is complex. The historical relationship between aircraft size and passenger demand at the route level shows a well established correlation between increasing aircraft size and rising passenger demand. When this relationship is extended into the future, adding new capacity increases route level demand and aircraft sizes can grow.

However, and conversely, it is also possible that a shortage of runway capacity should favour the use of larger aircraft, to maximise the passengers using scarce slots. The most prevalent effect in the ATM Demand Model is in line with the underlying historic data of aircraft loads tending to increase as demand rises. But the other effect is equally plausible, and in practice the response to capacity limits will vary between airlines depending on their differing business models and objectives.

2.66 This results in forecasts of the number of ATMs by aircraft size band and route, at each airport. Forecasts of CO_2 emissions and environmental assessments require more detailed assumptions to be made about the specific aircraft types that make up the stock of aircraft in each forecast year. These are generated in the Fleet Mix Model, which is explained in chapter 3.

ATM Model Validation - airport level

2.67 As with the model of passengers' airport choice, an important factor determining the confidence which can be placed in this calibrated model is its ability to replicate observed data on passenger aircraft movements, and their loadings. We have therefore examined how successfully the model predicts 2005 air transport movement demand, at both the airport and route level.

2.68 Table 2.4 below reports actual and predicted air traffic movements at individual airports with over 3mppa demand (these comprise 91% of passenger demand). It shows that the model predicts ATMs very accurately at London area airports. Heathrow, Gatwick, Stansted and Luton ATMs are predicted to within +/-1%. The tolerance widens to +/-6% at London City, but its relatively small throughput means total London area traffic is accurately forecast to within +/-1%.

2.69 The ATM predictions at the larger airports outside the London area are similarly accurate, with most being within +/-9% of actual figures.

2.70 At the airports with 3mppa demand or less (comprising 17% of total ATMs), the model predicts ATM demand to within 15% in 82% of cases (see annex E for the results for all modelled UK airports).

Table 2.4: Actual and predicted passenger ATMs at modelled airports, 000s pa in 2005 base year

	Actual	Fitted	Difference	Difference (%)
Heathrow	474	473	1	0%
Gatwick	253	252	1	1%
Stansted	180	180	0	0%
Luton	79	78	1	1%
London City	61	57	4	6%
London Subtotal	1,046	1,040	6	1%
Manchester	218	205	13	7%
Birmingham	114	114	0	0%
Glasgow	100	97	3	3%
Edinburgh	119	118	1	1%
Bristol	64	65	-1	-2%
Newcastle	57	54	3	5%
Belfast International	49	48	0	1%
Liverpool	50	48	2	4%
East Midlands	54	51	3	7%
Other Airports in Model	393	367	26	7%
Total in Model	2,264	2,207	57	3%
Other Non-Model	137			
National Total	2,401			

ATM Model Validation - route level

2.71 Table 2.5 shows the performance of the model in predicting aircraft movements on individual routes. As with the passenger demand predictions, the large number of routes means the results are summarised by accuracy band.

2.72 The validation of aircraft movements by route is a particularly stringent test of the model accuracy, being dependent on both the modelled passenger allocation to the route and the performance of ATM Demand Model in allocating appropriate aircraft sizes and types to each route. It also requires that the model satisfactorily models aircraft loads (passengers per ATM) at the route level.

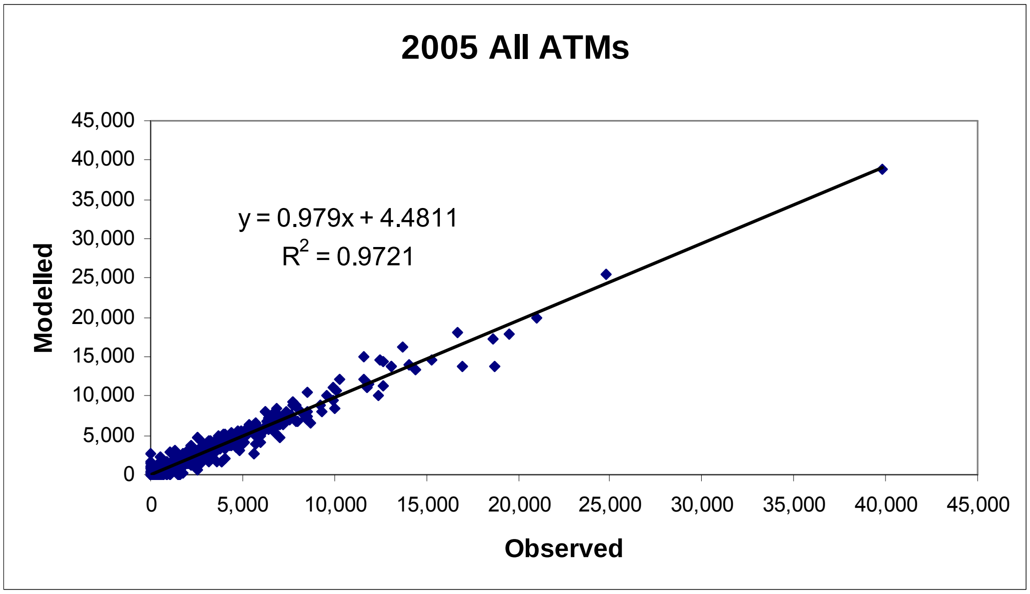
2.73 The table shows that 40% of passengers are on routes where ATMs are predicted to within +/-10% of actual and two thirds of passengers are on routes where ATMs are predicted to within +/-20%.

2.74 Figure 2.7 shows the correlation between actual and fitted ATMs, by route. The slope of the trend line being close to one, the low intercept, and the fairly tight fit of the data around the trend line indicate that the model is successful in predicting base year ATMs by route.

Table 2.5 Route level ATM prediction, 2005, all flights (domestic and international)

Error band	Proportion of routes	Cumulative proportion
0%-5%	23%	23%
5%-10%	17%	40%
10%-20%	26%	66%
20%-30%	14%	80%
30%-40%	7%	87%
40%-50%	4%	91%
50%+	9%	100%

Figure 2.7: Scatter plot of actual and fitted ATMs by route, all flights (domestic and international), 2005



Demand Reallocation Routine

2.75 As illustrated in Figure 2.4, the Passenger Airport Choice Model and the ATM Demand Model jointly forecast passenger and ATM demand at each airport. However, a successful forecast must account for the effect of capacity constraints on demand at every airport in a system-wide manner. The Demand Reallocation Routine component of the National Air Passenger Allocation Model therefore models the reduction in passenger demand, and re-allocation of passengers to alternative airports, that result from capacity constraints.

2.76 If unconstrained passenger demand at an airport exceeds capacity, the Demand Reallocation Routine estimates the extra cost of using the airport that would be necessary to reduce excess demand to zero. This is known as a 'shadow cost', or 'fare premium' and performs the mechanical function of limiting demand to capacity. It also represents the value a marginal passenger would place on flying to/from that airport, if extra capacity were available. It is therefore a key input to the appraisal of potential additional capacity, as explained in chapter 4.

2.77 The Demand Reallocation Routine adds the shadow cost to the other costs of using each over-capacity airport, then re-runs the Passenger Airport Choice and ATM Demand models to re-forecast passenger and ATM demand at each airport. This routine is iterated until an equilibrium solution is found in which capacity is not exceeded at any airport[18,19].

2.78 The Demand Reallocation Routine tests for breaches of both runway and terminal capacity. The effects of runway and terminal shadow costs tend to differ. As the shadow cost is ultimately added to the individual passenger's overall cost of travel, a runway constraint will stimulate the use of larger aircraft and higher passenger loads (to help airlines meet demand and because the charge levied on the use of the runway is lower on a per passenger basis for heavier loaded aircraft). Conversely a terminal shadow cost will not penalise the use of smaller aircraft. Runway capacity is generally a more finite or 'binding' limit than terminal capacity and the settings of the Demand Reallocation Routine encourage a runway shadow cost solution, particularly at the congested London airports

2.79 Importantly, this means that in our forecasts the effect of capacity constraints on airport demands takes into account capacities at all airports, and is based on passengers' observed airport choice behaviour.

Airport capacity assumptions

[18] *Rules and Modelling: A Users Guide to SPASM, Edition 2,* DfT/Scott Wilson, April 2004, see Chapter H.

[19] An equilibrium solution which satisfies capacity limits at all airports is computationally intensive and progressively more difficult to solve as demand mounts through the forecasting period. The solution is generally deemed to be found when over-capacity airports are within +/-3% of their input capacities. Runway capacity is regarded as a "harder" capacity than terminal capacity in the search for an equilibrium solution.

2.80 Modelling the impact of capacity constraints requires assumptions about both the terminal and runway capacities of each modelled airport. Box 2.6 summarises our approach to determining the capacity of airports.

Box 2.6: Runway capacity estimation

Runway capacity assumptions are a key input to our forecasts. The National Air Passenger Allocation Model works in annual passenger and aircraft units and uses annual estimates of runway capacity.

The annual runway capacity depends on physical, operational and demand characteristics. Physical characteristics include the runway length and the provision of parallel taxiways and rapid access and exit taxiways. Operational characteristics include the hours of operation, aircraft separation requirements, air traffic control restrictions and in some cases planning limits on ATMs. Demand characteristics include the prevailing daily and seasonal profiles, because airports with a high proportion of seasonal holiday traffic will have less effective capacity than airports that can make full use of their runways all year round, and airports which depend heavily on premium business traffic can make relatively less use of their off-peaks.

Our annual capacity inputs were originally developed during runway simulations and consultations with regional airport operators during the Regional Air Services Coordination Study (RASCO, 2002) and with BAA and others during the South East Regional Air Services Study (SERAS, 2002). Typical annual capacities input for forecasting are usually around 225,000 annual ATMs for single runways. This is a little higher than many airports might currently estimate, but allows for some piecemeal improvements to taxiways and aprons to achieve maximum use of existing runways. It also allows for an increase in off peak and out of season movements as national demand grows. Some airports which depend heavily on peak period traffic might consider themselves runway constrained at lower levels such as 190,000-200,000 annual ATMs.

The November 2007 consultation document *'Adding Capacity at Heathrow Airport'* reported the results of employing sophisticated noise and air quality modelling techniques to establish the operating capacity of a potential third runway and / or mixed mode operations at Heathrow that could meet the tests laid down in the ATWP which qualified Government support for such development. The results reported in that document are used as the Heathrow capacity input assumptions in our current forecasting.

2.81 The Air Transport White Paper (ATWP) of 2003 outlined where additional capacity would be supported, and this was reaffirmed in the ATWP Progress Report of December 2006. The strategy supports making better use of existing capacity at both regional and South East airports, alongside the construction of a further runway at Stansted, and at Heathrow if environmental tests can be met. Options for second runways at Birmingham and Edinburgh and a replacement of Luton's existing runway were also supported.

2.82 We consider seven future capacity scenarios, updated with latest information. These have evolved from the scenarios used in the White Paper analysis, and the convention of giving each a shorthand 'code' has been maintained, as shown in table 2.6 below.

Table 2.6: Capacity scenarios

Code	Description
s01	The 'planning case': no capacity beyond that already in the planning system
s02	Making 'maximum use' of existing airport infrastructure: the 'planning case' plus developments at Stansted (241k 2015), and Luton (135k 2015)
s05	Maximum use, plus Heathrow R3 (605k in 2020, rising to 702k in 2030)
s07	Maximum use, plus Stansted R2 (480k in 2015)
s12s2	Maximum use, plus Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)
s12s2mm1	Maximum use, plus Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)
s12s2mm2	Maximum use, plus Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)
s12s2	Maximum use, plus Stansted R2 (480k 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)

Note: Figures in parentheses refer to the opening date and annual ATM capacity of the developed airport. The 'maximum use' scenario involves terminal capacity increases, but no new runways.

2.83 The 'maximum use' scenario (code 's02') involves each airport developing as necessary to utilise fully its current runway capacity, if sufficient demand exists. This includes a terminal expansion and limited improvements to the taxiways at Luton, plus an increase in capacity (with a single runway) at Stansted to 35mppa.

2.84 Table 2.7 shows the 2030 South East runway capacities by development scenario.

Table 2.7: Runway capacity assumptions, k ATMs pa, 2030.

		s01	s02	s05	s07	s12s2	s12s2mm1
Airport	2005	Planning System in SE	Maximum Use	Heathrow R3 (605k in 2020, rising to 702k in 2030)	Stansted R2 (480k in 2015)	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)
Heathrow	480	480	480	702	480	702	702
Gatwick	260	260	260	260	260	260	260
Stansted	241	241	259	259	480	480	480
Luton	100	100	135	135	135	135	135
London City	73	73	73	73	73	73	73
South East Total	1,154	1,154	1,207	1,429	1,428	1,650	1,650

2.85 Table 2.8 shows our assumptions for terminal passenger capacity. This is the maximum number of passengers an airport's terminal and associated passenger handling infrastructure is assumed capable of serving.

Table 2.8: Terminal capacity assumptions, mppa

		s01	s02	s05	s07	s12s2	s12s2mm1
Airport	2005	Planning System in SE	Maximum Use	Heathrow R3 (605k in 2020, rising to 702k in 2030)	Stansted R2 (480k in 2015)	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)
Heathrow	72	86	86	135	86	135	135
Gatwick	40	40	47	47	47	47	47
Stansted	25	25	35	35	82	82	82
Luton	10	10	17	17	17	17	17
London City	5	5	5	5	5	5	5
South East Total	152	166	190	239	237	286	286

SECTION 2C: PASSENGER AND ATM FORECASTS

Passenger Demand Forecasts

2.86 This section summarises the resulting unconstrained and constrained forecasts of passenger and ATM demands derived using the methodology described in the previous sections. Constrained forecasts are also given at the airport level. Annex G provides more detailed results.

National unconstrained demand forecasts

2.87 As explained above, the 'unconstrained' demand forecast shows the demand for air travel that would be expected if there were no airport capacity constraints[20]. The unconstrained demand forecasts are therefore an intermediate step in the forecasting process, showing how demand would grow if there were no UK airport capacity constraints. Only the final, constrained demand forecasts take account of future airport capacities.

2.88 Table 2.9 shows that in the absence of capacity constraints the trend of strong growth in UK air travel demand is expected to continue, rising from 228 million passengers per annum (mppa) in 2005 to 495mppa in 2030 under the central case, within a range of 460 to 540 mppa. Figure 2.8 illustrates the central, low and high case unconstrained forecasts. Annex G provides more detailed results.

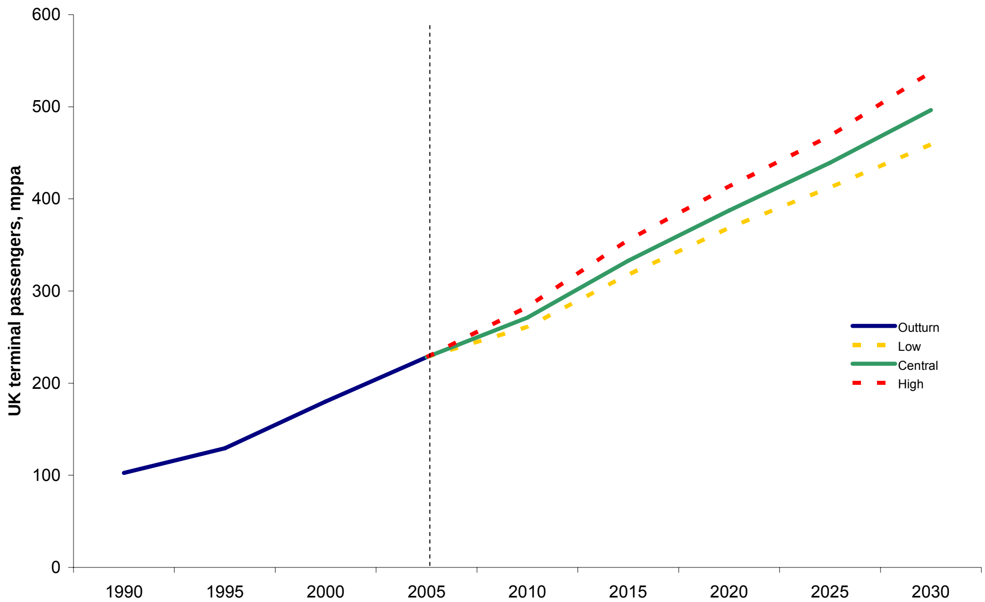
Table 2.9: UK terminal passengers forecast (unconstrained), mppa

	Low	Central	High
2005	228	228	228
2010	260	270	285
2015	320	335	355
2020	370	385	415
2025	410	440	470
2030	460	495	540

Note: Figures in forecast years rounded to 5mppa

[20] Air passenger demand is in practice also reduced by the use of Air Passenger Duty to ensure aviation meets its climate change costs. Without APD, our 2030 forecast of unconstrained air passenger would be 525mppa.

Figure 2.8: Unconstrained demand: historic with, central, low, and high forecasts



2.89 Chapter 2 explained that the range around the central unconstrained demand forecast is established through a set of sensitivity tests, which vary the projections of key driving variables within reasonable bounds. Table 2.10 shows the tests on 2030 unconstrained air passenger demand against sensitivity ranges of key input variables.

National constrained demand forecasts

Central case

2.90 Earlier sections explained that the impact of future airport capacity constraints (after incorporating the developments supported in the Air Transport White Paper) on demand growth is found by feeding the above unconstrained demand forecasts into the National Air Passenger Allocation Model. Table 2.11 shows that after accounting for airport capacity constraints, under the central 's12s2' scenario (i.e. an extra runway at Stansted in 2015, and at Heathrow in 2020 - see table 2.8), 2030 national demand is forecast to rise to 480mppa in the central case, within the range 450mppa to 505mppa. Annex G gives more detail, and Box 2.7 sets out how these forecasts can be interpreted in terms of future trip-making by air passengers.

Table 2.11: UK terminal passengers forecast, 's12s2' capacity, mppa[21]

	Low	Central	High
2005	228	228	228
2010	265	270	275
2015	310	320	340
2020	360	375	400
2025	410	430	460
2030	450	480	505

Note: Figures in forecast years rounded to 5mppa

2.91 Figure 2.9 further illustrates the central, high and low case results for the central 's12s2' capacity scenario. Comparing these results with the unconstrained forecasts in table 2.8 and figure 2.9 shows that the likely future capacity constraints reduce forecast throughput at UK airports, and that the impact varies over time. Under the central case, capacity constraints are forecast to reduce throughput by 15mppa in 2015. But in 2020 and 2025, when the extra capacity supported at Stansted and Heathrow is delivered, the capacity effect is reduced to 10mppa. By 2030 much of the new capacity is taken up, and the capacity effect rises again to 15mpppa.

Table 2.10: UK terminal passengers forecast (unconstrained), sensitivity tests, 2030

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[21] Terminal passengers include modelled domestic interliners counted as three terminal passengers (once at the final arrival/departure airport and twice at the hub airport). Domestic interliners are approximately estimated (using base proportions) in unconstrained forecasts (Table 2.09). Modelled volumes of domestic interliners will not exactly agree with the unconstrained estimate and occasionally where constrained and unconstrained demand is close, could marginally exceed the unconstrained estimate.

Scenario	Difference from central case assumptions	2030 demand (mppa)	Difference from central case (mppa)	Difference from central case (%)
Central case	-	495	-	0
Lower GDP growth	GDP grows ¼% pa slower	460	-35	-7%
Higher GDP growth	GDP grows ¼% pa faster	540	45	9%
Higher Carbon Cost	Shadow price of carbon dioxide raised by 20%	490	-5	-1%
Lower Carbon Cost	Shadow price of carbon dioxide lowered by 10%	500	5	1%
Higher Oil Price	2030 oil price raised to $80/barrel	475	-20	-4%
Lower Oil Price	2030 oil price lowered to $25/barrel	530	35	7%
Higher radiative forcing factor	Radiative forcing factor raised to 4	470	-25	-5%
Lower radiative forcing factor	Radiative forcing factor lowered to 1	505	10	2%
Higher Airline Non-Fuel Costs	Airline non-fuel costs lowered by ½% pa 2005-2020	490	-5	-1%
Lower Airline Non-Fuel Costs	Airline non-fuel costs raised by ½% pa 2005-2020	505	10	2%
Lower fuel efficiency	Share of ACARE-consistent aircraft entering service in 2030 reduced to 5%	495	neg	neg
Higher fuel efficiency	Share of ACARE-consistent aircraft entering service in 2030 raised to 50%	495	neg	neg

Notes:
All mppa figures rounded to nearest 5mppa
'neg' means a result which is non-zero, but rounds to zero

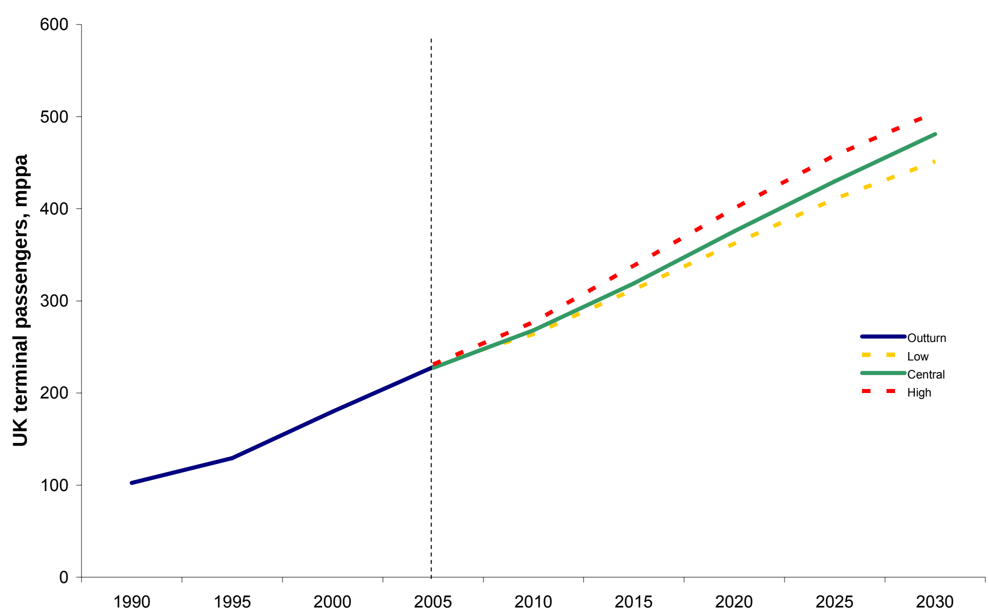
Box 2.7: Forecast terminal passengers and journeys

Interpreting the forecasts is aided by knowing what they imply for the average number of journeys by UK residents, and the total number of foreign visitors by air. To convert the 2030 constrained forecast of 480mppa into journeys requires a careful application of the definition of terminal passengers set out in Box 2.1 Applying this definition shows:

- excluding the connecting trips by foreign travellers at UK hub airports reduces the constrained 2030 forecast to 435m terminal passengers;
- 90m terminal passengers account for 22.5m internal domestic return journeys, leaving 345m terminal passengers (172.5m return journeys on international trips);
- of the remaining 345 terminal passengers about two thirds (230m) will be UK residents;
- Hence our forecast implies that there will be about 115m return international journeys made by UK residents and some 58m visits by foreign residents in 2030.

The UK population is projected to grow to around 70m by 2030, so 115m international and 23m domestic return journeys implies an average of just under two return air journeys per UK resident in 2030. This compares to just under one return journey per UK resident, and 21m visits by foreign residents, today.

Figure 2.9: Constrained demand: historic with, central, low, and high forecasts



Sensitivity tests

2.92 Table 2.12 shows the constrained demand forecasts for each sensitivity test, under the 's12s2' capacity scenario.

Table 2.12: Constrained demand sensitivity tests, 2030

Scenario	Difference from central case assumptions	2030 demand (mppa)	Difference from central case (mppa)	Difference from central case (%)
Central case	-	480		
Lower GDP growth	GDP grows ¼% pa slower	450	-30	-6%
Higher GDP growth	GDP grows ¼% pa faster	505	25	5%
Higher Carbon Cost	Shadow price of carbon dioxide raised by 20%	475	-5	-1%
Lower Carbon Cost	Shadow price of carbon dioxide lowered by 10%	480	neg	neg
Higher Oil Price	2030 oil price raised to $80/barrel	465	-15	-3%
Lower Oil Price	2030 oil price lowered to $25/barrel	500	20	4%
Higher radiative forcing factor	Radiative forcing factor raised to 4	460	-20	-4%
Lower radiative forcing factor	Radiative forcing factor lowered to 1.0	485	5	1%
Higher Airline Non-Fuel Costs	Airline non-fuel costs lowered by 0.5% pa 2005-2020	475	-5	-1%
Lower Airline Non-Fuel Costs	Airline non-fuel costs raised by 0.5% pa 2005-2020	485	5	1%
Lower fuel efficiency	Share of ACARE-consistent aircraft entering service in 2030 reduced to 5%	480	neg	neg
Higher fuel efficiency	Share of ACARE-consistent aircraft entering service in 2030 raised to 50%	480	neg	neg

Notes:
All mppa figures rounded to nearest 5mppa
'neg' means a result which is non-zero, but rounds to zero

Capacity scenarios

2.93 Table 2.13 shows the forecast of constrained demand by capacity scenario and year (assuming the central unconstrained demand case). It demonstrates that an extra runway at either Stansted or Heathrow accommodates a greater throughput. However, Stansted's earlier opening date and the assumed capacity limits at Heathrow (resulting from the noise and air quality conditions qualifying the ATWP's support[22]) mean that between 2015 and 2025 Stansted is able to deliver a greater contribution to serving growing demand. The table also shows that, while Heathrow and Stansted are different in the markets they serve, capacity increases at the two airports are to some extent substitutes. That is, the increase in throughput resulting from both airports adding a new runway is less than the sum of the increase in throughput resulting from each adding a new runway.

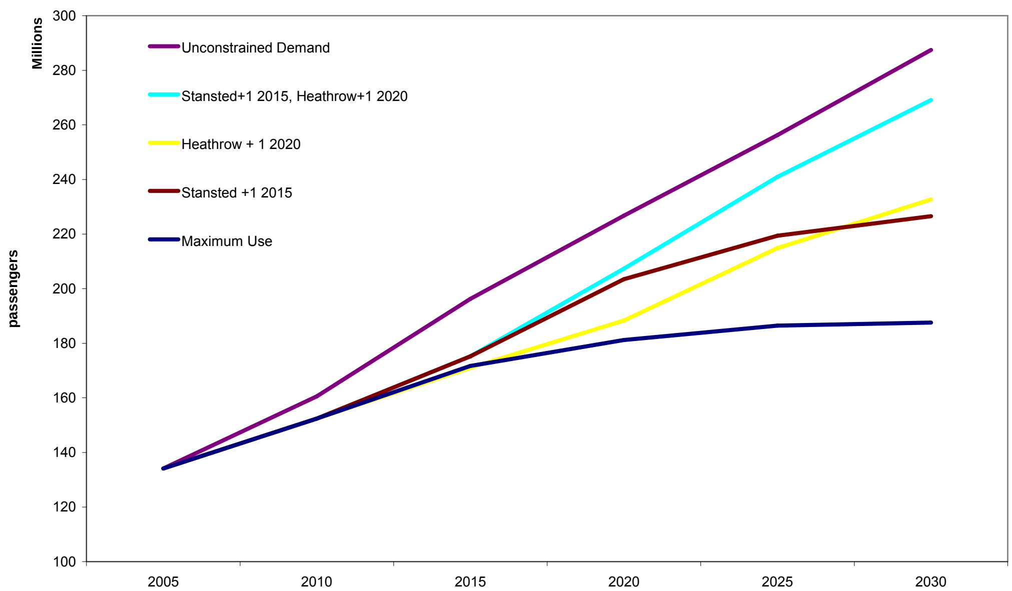
Table 2.13: Constrained terminal passenger demand forecasts, UK, mppa

		2010	2015	2020	2025	2030
s01	Planning System in SE	265	310	350	385	405
s02	Maximum Use	270	315	355	390	425
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	270	315	360	410	455
s07	Stansted R2 (480k in 2015)	270	320	375	415	445
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	270	320	375	430	480
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)	270	320	375	430	480
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)	270	325	375	430	480

[22] See 'Adding Capacity at Heathrow', DfT, November 2007

2.94 Figure 2.9a illustrates the position for the South East airports. It shows that additional capacity at Stansted or Heathrow would allow greater demand to be served. Stansted's earlier opening date and Heathrow's assumed gradual increase in capacity means additional capacity at Stansted would allow a greater throughput in 2020 and 2025. However, by 2030 both developments would provide a similar throughput. Additional capacity at both airports would permit the greatest increase in passenger traffic, but still would not meet all of the forecast unconstrained demand.

Figure 2.9a: Constrained terminal passenger demand forecasts at main South East airports, by capacity scenario



Airport Forecasts

2.95 The National Air Passenger Allocation Model forecasts how passenger demand will be distributed in a system-wide manner between airports around the UK, after accounting for likely airport capacity constraints. Table 2.14 below shows the airport forecasts for 2015 and 2030 for the South East airports, under the central demand and central 's12s2' capacity scenario. Annex F shows the results for each modelled UK airport.

2.96 The purpose of our forecasts is to inform strategic aviation policy. It is therefore necessary that the modelling accounts for the capacity and relative attractiveness of most of the airports offering commercial services. The Air Transport White Paper set out airport capacity developments that the government supports and these are incorporated in the modelling. However, the forecasts should not in isolation be interpreted as necessarily supporting particular levels of demand at individual airports.

Table 2.14: UK terminal passenger demand forecasts, South East airports, central 's12s2' scenario

Airport	2005	2015	2030
Heathrow	70	80	135
Gatwick	35	35	40
Stansted	20	40	70
Luton	9	15	15
London City	2	3	4
Others	95	145	210
Total	228	320	480

Notes:
Forecasts for airports with demand greater than 15mppa rounded to nearest 5mppa.
Rows may not sum to total due to rounding

2.97 The Air Transport White Paper of 2003 recommended that airport operators maintain a master plan document to inform the content of the local development framework. Nearly all airports have now made substantial progress on their master plans, and all include their own air passenger demand forecasts. Box 2.8 sets out how our airport forecasts tend to relate to airports' own forecasts.

Box 2.8: Airport Master Plan Forecasts

Following the ATWP recommendation, nearly all airport operators have produced their own demand forecasts. Several of these (including those of the largest London and regional airports) are broadly similar to our current and previous forecasts. Where local master plan forecasts differ from our forecasts, particularly at the medium or smaller sized airports, they usually exceed our forecasts. There are several possible reasons for this:

- Airport operator forecasts have often been prepared for business planning purposes, which while often presenting a range of possible outcomes, will by their nature tend towards a more positive view of their business prospects;

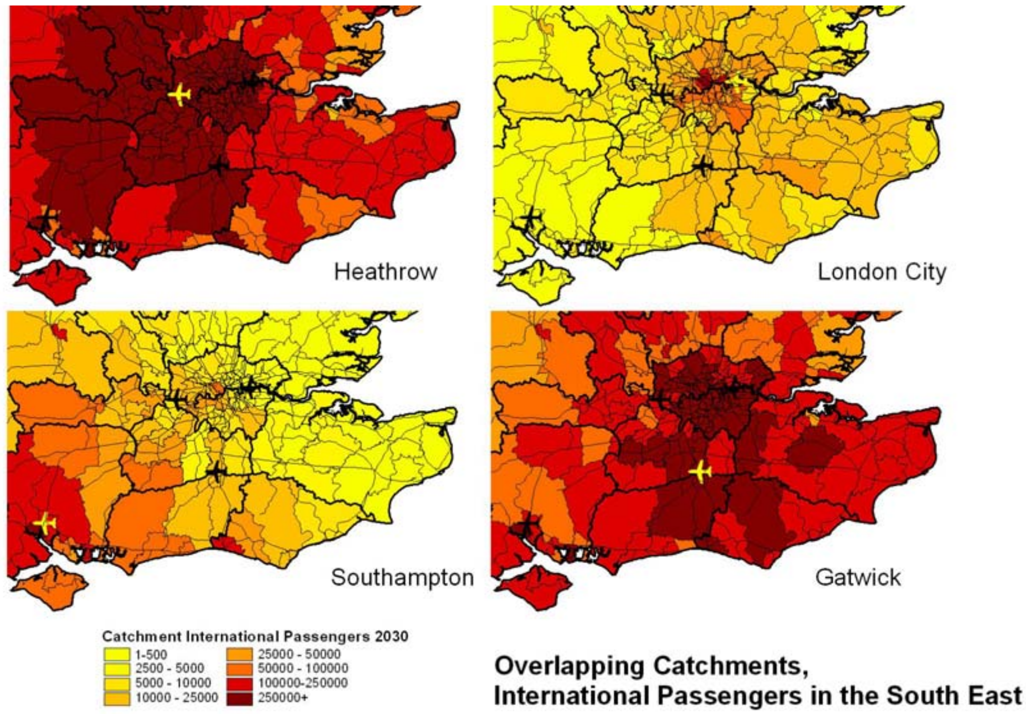
- With some exceptions, airport operator forecasts are produced in relative isolation and do not always take account of the degree to which their catchment is overlapped by competing airports; when totalled both nationally and regionally, master plan forecasts exceed our forecasts which are constrained to central national forecasts of demand and airport capacity; and,

- With the exception of the larger operators, the forecasts may be updated on a timetable different to ours.

Nevertheless, the airport operator forecasts have an important function. They are informed by knowledge of short term business developments and detailed knowledge of the local airport market. They can therefore provide a resource in the local planning process, such as where they include short term commercial initiatives which our longer term trend forecasts do not attempt to capture.

2.98 A key element of the constrained airport forecasts is that they are derived system-wide and allow airports to compete for demand for particular destinations. This demand originates at ground level and results in each airport having distinct catchment areas for its differing services. Figure 2.10 below illustrates how the National Air Passenger Allocation Model has produced overlapping catchments for four South East airports for the 2030 forecast year. It shows how the modelling allows passengers from individual catchments to travel to a range of airports. These catchments and potential airport choices can and do change over time as congestion in the system changes.

Figure 2.10: Projected overlapping catchments from four South East airports in 2030



2.99 Table 2.15 below shows for the main South East airports how demand is forecast to vary with the capacity scenarios. It shows that the extra runways supported at Stansted and Heathrow would permit a significant increase in the number of passengers served by 2030.

Table 2.15: Terminal passenger demand forecasts at main South East airports, by capacity scenario, 2030

		Heathrow	Gatwick	Stansted	Luton	London City	Total South East	Other	Total
s01	Planning System in SE	85	40	25	10	5	165	240	405
s02	Maximum Use	85	45	35	15	3	190	235	425
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	135	40	35	15	4	235	220	455
s07	Stansted R2 (480k in 2015)	90	45	75	15	4	225	220	445
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	135	40	70	15	4	270	210	480
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)	135	40	70	15	4	270	210	480
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)	135	40	70	15	4	270	215	480

Note: Forecasts for airports with demand greater than 15mppa rounded to nearest 5mppa.

Projections beyond 2030

2.100 The UK has a commitment to reduce its CO_2 emissions by 60% below 1990 levels by 2050, and HMT guidance requires appraisal of airport development to include the costs and benefits for 60 years after the scheme opening date. For the purposes of forecasting UK aviation CO_2 emissions and appraising airport developments, it is therefore necessary to project UK terminal passengers to 2080. In line with appraisal guidance this is achieved using simpler, though still robust, projection methods than the detailed modelling used to 2030 outlined above. These are summarised below for passenger demand and ATMs. The projections assume no further airport capacity expansion beyond the 's12s2' capacity scenario.

2.101 When projecting constrained passenger demand beyond 2030, it is necessary to capture the latest pre-2030 trends, and not the trend in earlier years. This is because the impacts of driving variables and capacity constraints will vary over the forecast period, tending to give lower growth rates in later years. However, it is also important to avoid creating instability in the post-2030 projections, which could result from projecting a trend taken from a short time period. We have therefore projected passenger demand by assuming that the trend in constrained demand in each market sector at each airport for the five years before 2030 continues until terminal capacity is reached, subject to the rate being positive, and less than double the national unconstrained demand projection.

2.102 The national unconstrained demand projection after 2030 is found by projecting the time trend in the unconstrained demand growth rate forecast to 2030 to continue. The preferred time trend is estimated using a power function, to ensure the projection reflects the rate of change at the end of the forecast period.

2.103 The ATM demand projection at each airport is derived from the projection of constrained passenger demand above, using a projection of average aircraft load, subject to runway capacity. It is assumed that the trend in average load at each airport, in each airline market sector, between 2020 and 2030 continues until a maximum average load (varying by market sector) is reached.

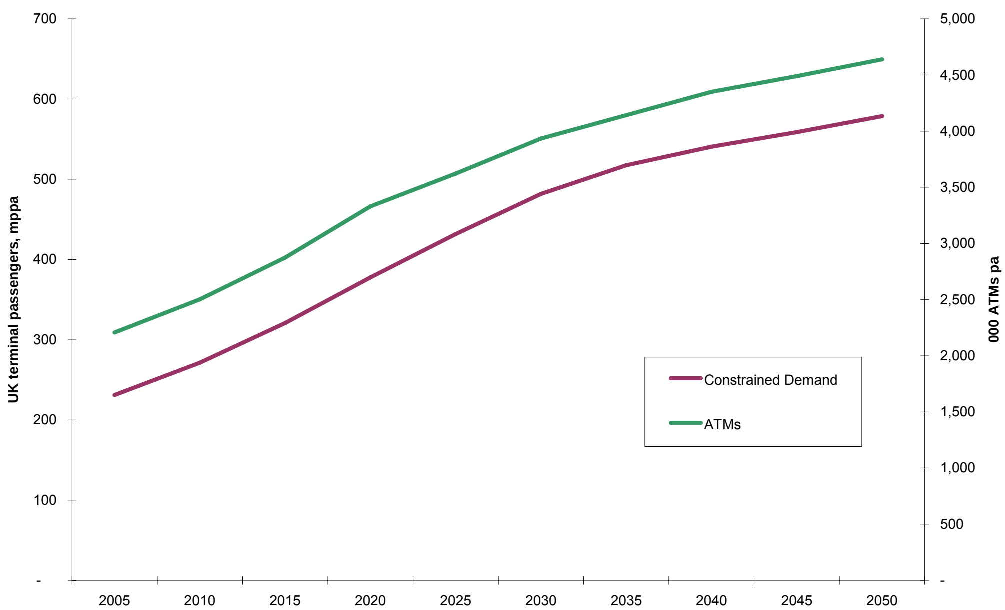
Results

2.104 Table 2.16 and Figure 2.11 below show the resulting national projections of unconstrained and constrained passenger demand, and ATM demand under the central 's12s2' capacity scenario. These reflect the fact that, even with the capacity developments supported in the ATWP, capacity constraints become significant around 2030, slowing the growth in passenger and ATM demand to 2050.

Table 2.16: Projected constrained passenger and ATM demand, to 2050

	mppa	k ATMs
2005	228	2205
2010	270	2505
2020	380	3330
2030	480	3935
2040	540	4350
2050	580	4640

Figure 2.11: Projected constrained passenger and ATM demand, to 2050



Sensitivity tests

2.105 The post-2030 projections of passenger and ATM demand at each airport respond to the pre-2030 demand forecasts. Hence the sensitivity tests used in the more detailed modelling outlined above flow through to the post 2030 projections to generate a demand forecast range to 2050 for use in the CO_2 forecast range, and to 2080 for use in airport development appraisal.

3. Aviation Carbon Dioxide Emissions Forecasts

- **International aviation accounted for 1.5% of global CO_2 emissions in 2004**
- **The UK's total CO_2 emissions were 2.0% of the global total in 2004**
- **UK domestic aviation accounted for 0.4% of the UK's carbon dioxide emissions in 2005**
- **If international emissions from shipping and aviation are added to the UK total for 2005, UK aviation (domestic and international) accounted for 6.3% of the UK's CO_2 emissions**
- **UK aviation's CO_2 emissions have grown strongly in past decades, rising from 12 $MtCO_2$ in 1985, to 21 $MtCO_2$ in 1995 and 37.5 $MtCO_2$ in 2005. This reflects demand growing faster than fuel efficiency**
- **Emissions are forecast to continue rising in the next two decades, as demand continues to grow faster than efficiency. By 2030, emissions are forecast to rise to 59 $MtCO_2$, within the range 55 $MtCO_2$ to 63 $MtCO_2$**
- **After 2030, the growth in emissions is projected to slow, as demand is constrained by airport capacity. By 2050, UK aviation CO_2 emissions are projected to flatten and reach 60 $MtCO_2$, within the range 53 $MtCO_2$ to 67 $MtCO_2$**

Introduction

3.1 The *Future of Air Transport* White Paper[23] set out the strategic framework for the development of airport capacity in the UK over the next 30 years. It also presented the central forecast of carbon dioxide emissions from UK aviation to 2050. A range around the central forecast, and the supporting analysis, was published in *Aviation and Global Warming*[24] in January 2004.

3.2 The forecasts in *Aviation and Global Warming* built on earlier forecasts produced in the joint report by DfT and HM Treasury: *Aviation and the Environment: Using Economic Instruments (2003).*

3.3 The 2006 *Future of Air Transport Progress Report* set out the Government's commitment to publishing revised CO_2 emissions

[23] *The Future of Air Transport*, Department for Transport, Dec 2003, Cm6406.
[24] See *Aviation and Global Warming,* Department for Transport, January 2004.

forecasts in 2007[25]. This chapter meets that commitment. It explains the nature and purpose, interpretation, and context of the forecasts, and reports revised forecasts to 2030 and projections to 2050.

Nature and purpose of the forecasts

3.4 We forecast carbon dioxide emissions produced by all flights departing UK airports to 2030[26]. The forecasts therefore include carbon dioxide emitted from all domestic flights within the UK, and all international flights which depart UK airports, irrespective of the nationality of passengers or carriers.

3.5 There is no internationally agreed methodology to allocate emissions to nations, so any approach taken to estimate UK aviation emissions can provide only an approximation. The approach adopted for the purposes of this analysis is consistent with the UNFCCC recommended approach for reporting on carbon dioxide emissions from international aviation[27].

3.6 These forecasts are used to help develop, monitor and inform long term strategic UK aviation and climate change policy. These emissions forecasts are used to:

- Inform the Government's approach to meeting its commitment to ensuring that aviation reflects the full costs of its climate change emissions[28];
- Develop and inform Government policy in the context of putting ourselves on a path to cutting total domestic CO_2 emissions by some 60% by about 2050[29]; and,
- Estimate the carbon impacts of airport developments supported in the Air Transport White Paper for the purposes of strategic appraisal.

3.7 The aviation CO_2 emission forecasts presented in this Chapter are used to inform Government policy both in relation to domestic climate change policy, and implicitly, the UK's role in EU policies in this area such as the proposed Emissions Trading Scheme, outlined in Box 3.1.

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[25] *The Future of Air Transport Progress Report*, Department for Transport, December 2006, Cm 6977, see Chapter 2.

[26] This covers the 31 largest airports in the UK. Emissions from the other minor airports are unlikely to be significant as they offer only short range services. This gives a close approximation to DEFRA's latest estimate of outturn aviation emissions in 2005 based on aviation bunker fuel use. For consistency, a small adjustment is made to our forecasts to convert them to a DEFRA-equivalent basis, and ensure an exact match in 2005.

[27] There, UK domestic aviation carbon dioxide emissions are reported in the UK total and international aviation emissions are reported as a memo item.

[28] See *The Future of Air Transport Progress Report*, Department for Transport, December 2006, page 7.

[29] See BERR *Meeting the Energy Challenge, A White Paper on Energy*, May 2007

3.8 Within an Emissions Trading Scheme, as currently proposed by the European Commission, growth in UK aviation CO_2 emissions above the 2004-2006 average would be offset by emissions reductions in other sectors.

1 **Box 3.1: UK Aviation CO_2 Emissions and Policy**

2 The Government has a comprehensive approach to reduce aviation's climate change impacts. This includes encouraging research and development into new technology and the development and adoption of better operating practices.

3 The Government is also working to bring international aviation within the European Union Emissions Trading Scheme (EU ETS). As currently proposed by the Commission, the Scheme would require airlines to have permits, or 'allowances', to cover their emissions of CO_2. Permits for the whole sector would be limited to the average level of emissions over the period 2004-2006; for emissions above that level, airlines would be required to buy permits from other sectors of the market.

4 Therefore, although aviation demand and emissions are expected to continue to grow for the UK (as explained in Chapters 2 and 3) and in other EU countries, this growth would not result in any overall growth in carbon emissions, because aviation would pay for reductions to be made elsewhere. The result would be that 'net' aviation emissions would effectively be capped.

5 For illustration, the table below sets out the targets in 2020 for the whole EU (20% below 1990 levels), and for aviation (illustratively 2005 levels, in line with the current Commission proposal which is the average of 2004-06). As shown, if aviation joins the EU ETS, under the current European Commission proposal emissions would be 'capped' at the average of 2004-06 levels. Any emissions above this level would be matched by reductions made elsewhere in the economy.

6 **EU25 Emissions (Bn tonnes of CO_2)**

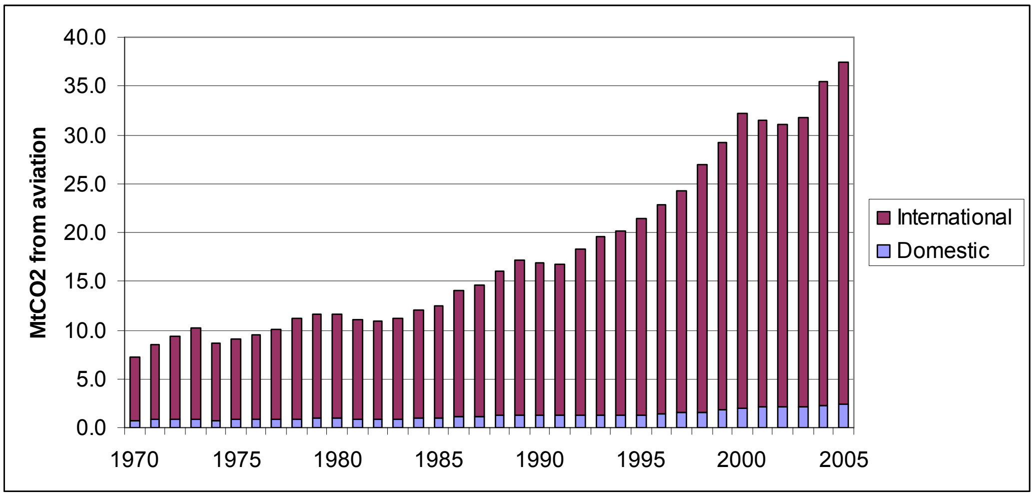
	1990	2005	2020 target
Total EU emissions	**5.8**	**5.0**	**4.7**
Aviation emissions (all arriving and departing flights)	**c. 0.1**	**0.2**	**0.2**
Total	**6.0**	**5.2**	**4.9**

Source: Table 2.1 "Towards a Sustainable Transport System: Supporting Economic Growth in a Low Carbon World, DfT October 2007

Context of aviation carbon dioxide emissions

3.9 Figure 3.1 shows UK aviation emissions since 1970. It demonstrates that in keeping with the global growth in demand for air travel discussed in Chapter 2, emissions have tended to grow strongly. Some deviations from the trend are evident, and these are explained by demand variations, such as those resulting from the oil price shocks in the 1970s, recessions, terrorism threats or fears of global pandemics. Figure 3.1 also shows that international travel from the UK, as opposed to internal domestic flights, has been the main source of emissions growth, consistently accounting for over 90% of emissions.

Figure 3.1: UK aviation emissions, $MtCO_2$



Source: Defra emissions statistics, www.defra.gov.uk

3.10 However, despite this strong growth, aviation is currently a relatively small contributor to total CO_2 emissions (both at the UK and global levels). Table 3.1 shows that globally, while transport as a whole accounts for 23% of total emissions, international aviation comprises only 1.5%.

Table 3.1: Global carbon dioxide emissions in 2004[30]

	Carbon dioxide ($MtCO_2$)	% of global total
Country level emissions		
Global (sectoral approach)	26,583	-
Europe (EU 25)	3,891	14.6%
UK	537	2.0%
Transport emissions		
World transport	6,214	23.4%
International aviation	400	1.5%

[30] Source: IEA World Energy Outlook 2006

3.11 At the UK level, table 3.2 shows that domestic aviation accounts for 0.4% of UK CO_2 emissions[31]. If international shipping and aviation emissions are added to the total, UK aviation (domestic and international) accounts for 6.3% of UK CO_2 emissions and total transport accounts for 28.5%.

Table 3.2: UK carbon dioxide emissions

	2005 (MtCO2)	% of total UK*
Total UK emissions excluding international shipping and aviation	554.2	-
Total UK emissions including international shipping and aviation	595.1	-
Total transport	169.9	28.5
Of which:		
- Road	*119.9*	*20.0*
- Rail	*2.0*	*0.3*
- Shipping	*10.1*	*1.7*
- Aviation	*37.5*	*6.3*
- domestic	*- 2.5*	*- 0.4*
- international	*- 35.0*	*- 5.9*

*** including international shipping and aviation in total, based on bunker fuel sales**

3.12 The strong growth in UK aviation CO_2 emissions, both absolutely and as a share of the UK total, means that the forecast of UK aviation's CO_2 emissions is important in formulating Government's transport and wider climate change policies.

Interpreting the forecasts

3.13 The definition of aviation CO_2 could cover many possible sources of emissions. For example, it might be argued that emissions from journeys to and from an airport are 'generated' by the existence of the airport and its services. However, this could cause double-counting of emissions in different parts of the inventory as journey purpose is not always identifiable. Hence for our forecasts we adopt a definition consistent with the way emissions are reported to the UNFCCC, including the relevant memo items. The sources of emissions covered in the forecasts in this chapter are set out in table 3.3 below.

[31] It is these domestic emissions, and not international aviation emissions, that count towards the current UK domestic CO_2 targets.

Table 3.3: Definition of CO_2 emissions in our forecasts

Emissions source	Included in the forecasts?
All domestic passenger flights within the UK	✓
All international passenger flights departing UK airports	✓
All passenger aircraft while on the ground in the UK e.g. taxiing	✓
All domestic freighter aircraft departing UK airports	✓
All international freighter aircraft departing UK airports[32]	✓
All freighter aircraft while on the ground in the UK e.g. taxiing	✓
Surface access, i.e. passenger and freight journeys to and from a UK airport	✗
Non-aircraft airport sources, e.g. terminal lighting and airfield vehicles	✗
UK registered aircraft flying from airports not in the UK	✗
International flights arriving in the UK	✗

3.14 DEFRA's estimates of outturn CO_2 emissions from aviation are based on the amount of aviation fuel uplifted from bunkers. While our definition is a close approximation to this, it is not exactly the same. Our 'forecast' for 2005 is about 1MtCO2 (3%) below the latest DEFRA estimate for that year. This reflects any difference in definition, including the absence from our modelling of the small number of flights of a volume too small to be modelled, or from very small airports. We have therefore made a small upward adjustment of around 1MtCO2 to our CO_2 forecast to ensure consistency with the DEFRA estimate.

3.15 As with the forecasts of air passenger demand, our aviation CO_2 forecasts are intended to capture the long term trend in emissions and the effect of changes in airport capacity on CO_2 emissions. They are not intended to predict short term deviations from the trend, as could be caused by a recession or other economic shock.

3.16 There are obviously uncertainties about the future path of the driving forces behind aviation CO_2 emissions. As with the demand forecasts, we therefore perform a variety of sensitivity tests, and present a range.

[32] Emissions from freight carried in the belly hold of aircraft are captured in the passenger aircraft emissions

The range in each year is found by taking the demand range, and applying a further sensitivity test on fuel efficiency.

3.17 The impact of aviation on climate change is not caused solely by carbon dioxide (CO_2) emissions. Other emissions arising from aircraft that can influence climate change include:

- Water vapour from engine exhausts, which leads to the formation at altitude of contrails and cirrus clouds;
- Nitric oxide and nitrogen dioxide (or NO_x), which contributes to the formation of ozone that acts at low altitudes as a greenhouse gas;
- Particulates (soot, nitrate and sulphate particles), some of which reduce and some of which increase aviation's total climate impacts; and,
- Other compounds including some hydrocarbons, carbon monoxide and radicals such as the hydroxyl radical, which affect the formation and removal of many of the above emissions.

3.18 The effects of emissions are usually calculated in terms of the climate metric 'radiative forcing'. Aviation was shown by the Intergovernmental Panel on Climate Change (IPCC) (1999)[33] to have a total radiative forcing of 2.7 times that of its CO_2 radiative forcing[34] - the so-called Radiative Forcing Index, or RFI. More recently, radiative forcing was evaluated by Sausen et al. (2005)[35]; the findings implied an RFI of 1.9, based upon better scientific understanding which mostly reduced the contrail radiative forcing.

3.19 Currently, there is no suitable climate metric to express the relationship between emissions and radiative effects from aviation in the same way that the global warming potential[36] does, but this is an active area of research. Nonetheless, it is clear that aviation imposes other effects on the climate which are greater than that implied from simply considering its CO_2 emissions alone and it is important that we take account of them.

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[33] *Aviation and the Global Atmosphere* (1999) Available at http://www.ipcc.ch/pub/av(E).pdf

[34] These findings (with a sensitivity range for RFI of 2 to 4) were based on the best evidence at the time using a 1992 fleet and excluded any effect from enhanced cirrus cloudiness which was too uncertain to be given a 'best estimate'.

[35] These findings were based on a 2000 fleet. *Aviation radiative forcing in 2000: An update on IPCC* (1999) Meteorologische Zeitschrift 14: 555-561 - available at http://www.ingentaconnect.com/content/schweiz/mz/2005/00000014/00000004/art00013

[36] Each greenhouse gas has a different capacity to cause global warming, depending on its radiative properties, its molecular weight and its lifetime in the atmosphere. Its so-called global warming potential (GWP) encapsulates these. The GWP is defined as the warming influence over a set time period of a gas relative to that of carbon dioxide.

3.20 The application of a 'multiplier' to reflect non-CO_2 effects is a possible way of illustratively taking account of the full climate impact of aviation. A multiplier is not a straight forward instrument. In particular it implies that other emissions are linked to production of CO_2, which is not the case. Nor does it reflect accurately the different relative contribution of emissions to climate change over time, or reflect the potential trade-offs between the warming and cooling effects of different emissions.

3.21 On the other hand, it would not be right to exclude consideration of the non-CO_2 climate change effects of aviation, and there is currently no better way of taking these effects into account.

3.22 In order to recognise the varying scientific views on radiative forcing and to demonstrate the potential magnitude of significance of these other effects, in line with the most recent evidence we propose to apply a multiplier value of 1.9 to the figure for carbon emitted as the central case, with sensitivity tests to define a range using a multiplier of 1 and 4.

3.23 Although these factors were derived from different sources and on the basis of different modelling, we believe that for the purposes of illustration, they reflect the best available evidence.

Methodology and assumptions

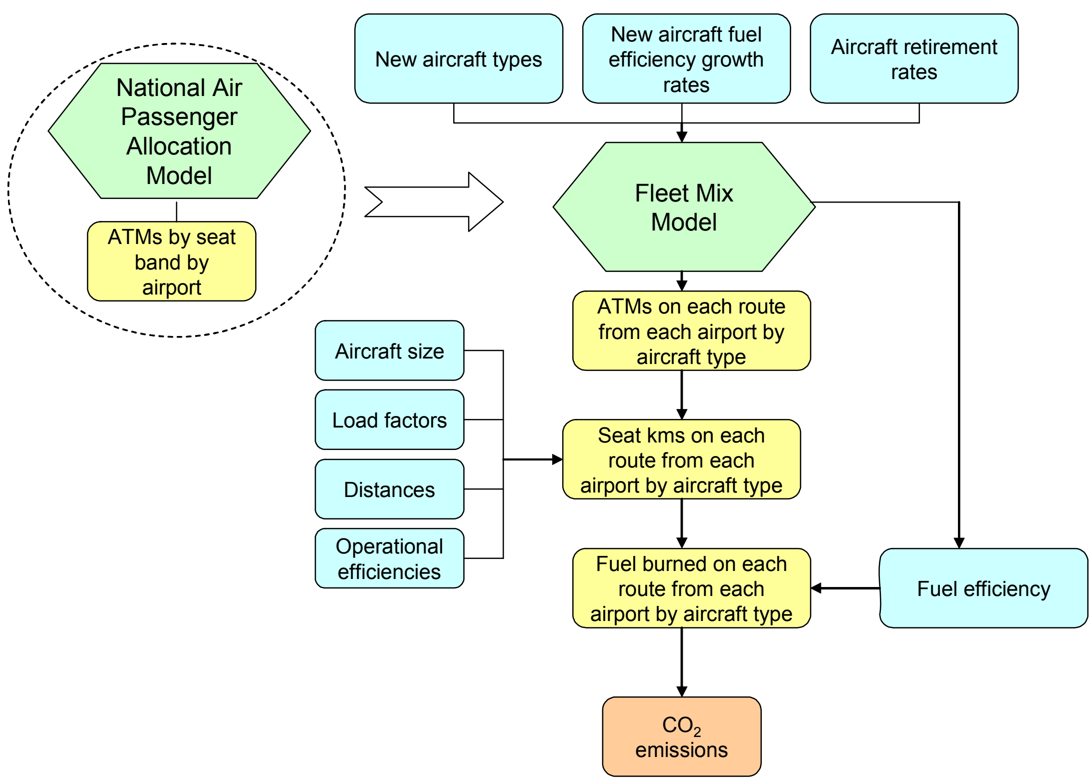
3.24 Aviation carbon dioxide emissions are, of course, directly related to the amount of aviation fuel consumed. There are therefore two key drivers of aviation carbon dioxide emissions:

i. **Total distance flown:** this comprises the volume and average distance of flights from the UK, which is driven by passenger and freight demand (after accounting for airport capacity constraints); and,

ii. **Fuel efficiency of aircraft**: the fuel required to fly a given total distance will fall as aircraft efficiency improves, driven by technological and operational improvements.

3.25 Chapter 2 explained how the passenger demand forecasts are obtained, and how they are converted into a forecast of air traffic movements (ATMs) from each airport in the UK to destinations around the world. This section sets out how the ATM demand forecasts are converted into CO_2 forecasts. Figure 3.2 provides an overview of the modelling components and key assumptions that together produce the forecast of carbon dioxide emissions to 2030. Below we explain each step in more detail. Annex I summarises the key improvements over the previous forecasts.

Figure 3.2: Forecasting aviation CO2 emissions



Passenger ATMs by aircraft type

3.26 The National Air Passenger Allocation Model forecasts ATMs for each airport and route by 'seat-band' of aircraft (i.e. the seating capacity of the aircraft, split into six bands). This feeds into the Fleet Mix Model (FMM) which forecasts the particular composition of the aircraft fleet for each airport and route by specific aircraft type and age. It achieves this by taking the base year distribution of ATMs by aircraft type and age operating at each UK airport, and projects it forward using the forecast of ATM demand by seat band at each airport from the National Air Passenger Allocation Model, with assumptions about:

- The retirement age of each aircraft type; and,
- The split of new aircraft entering the fleet each year between specific aircraft types (by seat band and class of airline)

3.27 The FMM retires aircraft from the UK stock as they reach the end of their serviceable life, typically 20-25 years, and replaces them with new aircraft. When an aircraft retires, it is assumed to be replaced by one of three types:

i. A new aircraft of the same type;

ii. A new aircraft of an existing but different type; or,

iii. A new aircraft of a new type

3.28 Reflecting the variation in business models in the aviation industry, different fleet replacement assumptions are used in different sectors of the market, i.e. scheduled, charter and low cost airlines.

Seat-kilometres

3.29 The forecast number of ATMs by specific aircraft types at each airport are then converted into forecasts of seat-kilometres at the same level of detail, by applying projections of aircraft size (i.e. the number of seats per ATM), and the distance flown on each airport route. The latter is based on 'great circle' distances, which is a common metric for aviation purposes, and represents the shortest air travel distance between two airports taking account of the curvature of the earth. The actual distance flown is likely to be longer than the great circle distance in reality due to sub-optimal routing and stacking at airports during periods of heavy congestion. We therefore apply an adjustment factor to uplift the distance flown by 9%[37].

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[37] IPCC *Aviation and the Global Environment,* 8.2.2.3 states that ATM routeing problem add an average of 9-10% to the distance of all European flights. Evidence to the Select Committee on Transport in July 2003, put the fuel consumption expended in stacking as high as 15%.

Freight ATM kilometres

3.30 The ATMs of passenger aircraft will account for the emissions from moving some freight as it is carried in the bellyhold of those aircraft. However, there are dedicated freight aircraft also operating which still must be accounted for. It is therefore necessary to forecast ATMs and emissions from freighter aircraft.

3.31 Forecasts of UK freight demand, split between bellyhold and freighters, were produced prior to the ATWP using MDS-Transmodal and Halcrow forecasts.[38] Using the relationship between freight demand and GDP, the strong demand seen over the 1990s was projected to continue.

3.32 Since the beginning of the decade, air freight demand growth has been subdued. Several reasons for this have been suggested, including: increased capacity and frequency of shipping services; aviation fuel prices rising faster than shipping fuel prices; disruption to air services (particularly on the North Atlantic routes) during 2001-2; and the increasing importance of the Far East market. While these appear to have held back air freight demand growth, it is unlikely that the underlying long run relationship between GDP and air freight demand has been completely eroded.

3.33 We have therefore assumed that to 2010 total air freight tonnage will remain broadly steady, after which the growth rates from the previous forecast (driven by GDP) will resume. The freighter share of this tonnage is assumed to rise in line with the MDS-T projection, and the average tonnage per freighter ATM is grown in line with the Halcrow projection. These are combined to obtain the national freighter demand forecast.

3.34 Unconstrained airport level freighter demand is forecast by growing base year freighter tonnage at each airport in line with the national tonnage demand forecast, and applying airport-specific payload projections. Future capacity constraints are accounted for by comparing unconstrained demand against freighter capacity at each airport, and iteratively redistributing unsatisfied demand to other airports which may have spare freighter capacity pro rata to the base year distribution of demand.

Fuel burn

3.35 The forecast of seat-kilometres by airport, route, and aircraft type is then combined with the projected fuel efficiency of each aircraft type (measured in seat-kilometres per tonne of fuel) to generate the forecast of fuel burned by flights departing each airport, on each route.

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[38] *UK Air Freight Study Stage 1*, MDS Transmodal, August 2000; *UK Air Freight Study Stage 2*, MDS Transmodal, August 2001; and, *SERAS Stage 2, Appraisal Findings Report – Supporting Documentation: Freight Forecasting*, Halcrow, May 2002.

3.36 For freighters, a similar approach is taken by forecasting at the national level using the resulting constrained demand. Emissions are projected to grow by combining the freighter ATMs, average trip length, and fuel efficiency projections. Trip length is projected to grow at a decreasing rate, and fuel efficiency is assumed to follow a similar path to that of other passenger aircraft.

3.37 Current fuel burn rates by aircraft type measured in kilograms of fuel per aircraft for different distance bands flown, and for different stages of the flight are taken from the European Environment Agency's 'CORINAIR' Emission Inventory Guidebook[39]. This is an established, authoritative source of data on aircraft fuel burn rates, giving separate values for the different stages of the flight such as landing and take off including taxiing and cruise emissions for different aircraft types[40]. It is used for general reference and for use by parties to the Convention on Long Range Transboundary Air Pollution (LRTAP) for reporting to the UNECE Secretariat in Geneva.

3.38 However, there has been a clear trend of improving fuel efficiency in the aircraft fleet for many years (see box 3.2), and the CORINAIR guidebook can provide only limited guidance on the efficiency of the future aircraft fleet. It is therefore necessary to use the CORINAIR information as the basis, but to project the likely fuel efficiency of the future fleet. Gains in the fuel efficiency of air travel on this metric can be split into two sources[41]:

- **Air traffic management and operational efficiencies:** By better co-ordinating and controlling air traffic movements, or eliminating non-essential weight, optimising aircraft speed, limiting the use of auxiliary power etc, less fuel will be needed for a given number of seat-kms flown.

- **Aircraft efficiency:** As new, more efficient aircraft replace older aircraft, the average efficiency of the fleet will rise. Improvements in new aircraft efficiency can be driven by better engine or airframe technology for example. These gains could take the form of new types of aircraft entering production (e.g. Boeing 787, the Airbus A380 and A350) or incremental improvements to existing types of aircraft in production. It is also possible for existing aircraft to become more efficient through retrofitting of the latest engine technology.

[39] EMEP/CORINAIR Emission Inventory Guidebook - 2006, European Environment Agency http://reports.eea.europa.eu/EMEPCORINAIR4/en/page002.html

[40] It is assumed that fuel burn on a 100% loaded jet aircraft will be 5% higher than on a 70% loaded aircraft, due to the increased weight. See Daggett, D. L., D. J. Sutkus Jr., D. P. DuPois, and S. L. Baughcum, 1999: *An evaluation of aircraft emissions inventory methodology by comparisons with reported airline data*. NASA/CR-1999-209480.

[41] Fuel efficiency is defined in our modelling as seat-km per tonne of fuel. It is therefore independent of load factors, which are accounted for elsewhere in our forecasting.

3.39 We assume that air traffic management and operational efficiency gains will meet the midpoint of the IPCC projection of a 6%-12% gain in fuel efficiency over the period 2006-2019[42].

3.40 We do not assume radical technological change before 2020. We also do not assume any fuel efficiency gains are delivered through retrofitting because these gains are likely to be relatively small.

3.41 The fuel efficiency assumptions we have made will impact on the whole fleet. As explained above, our fleet mix model forecasts the distribution of the future fleet by aircraft type, based on the retirement of old aircraft and the entry of new aircraft. To project gains in the fleet's efficiency due to the replacement of older aircraft with newer, more efficient models, we therefore need to project the efficiency of the aircraft that will enter service in the years to 2030, and feed that into the fleet mix model. Box 3.2 presents some of the available evidence on fuel efficiency improvements seen over recent years and what might be expected in the future. The following section sets out our method for projecting fuel efficiency improvements in the future.

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[42] *Aviation and the Global Atmosphere*, IPCC, 1999 suggested a range of 6-12% (page 278-9) so we have taken the mid-point.

Box 3.2: Trends in aircraft fuel efficiency

A range of estimates exist for the improvements in fuel efficiency in the aviation sector over recent years. Some studies have also set out their estimates of expected future improvements in efficiency.

To represent the range of evidence, the following sets out some illustrative examples to demonstrate the order of magnitudes. Despite the different metrics for assessing fuel efficiency, the results are indicative of the scale of change seen in the past and expected in the future.

<u>The IPCC (1999)</u>

Historically, improvements in fuel efficiency have averaged at 1-2% per annum (measured as fuel burn per seat km) for new production aircraft. This has been achieved through new engine and airframe technology. A similar trend is assumed when projecting forward to 2050.

IPCC draw on the research by Greene (1992) which looked at fuel efficiency (seat km per kg of fuel) to 2000 and extrapolated this forward to forecast annual fuel efficiency improvements over time:

	Annual fuel efficiency improvement
1990-2010	1.3%
2011-2020	1.0%
2021-2050	0.5%

IPCC, Aviation an the Global Atmosphere, 1999

Peeters et al (2005) took this work further to explore the impact of applying a fitted curve (instead of a linear trend) to the IPCC data and to that of Lee (2001) with the following fuel efficiency (all expressed in fuel used per available seat km) improvements per annum.

Fuel efficiency improvements per annum

	IPCC	Peeters et al (2005)
1960-1980	2.6%	2.2%
1980-2000	1.2%	0.9%
2000-2040	0.6%	0.5%

Peeters, P, Middel J and Hoolhorst A "Fuel efficiency of commercial aircraft. An overview of historical and future trends", 2005.

Box 3.2 (continued): Trends in aircraft fuel efficiency

Lee et al (2001)

This study looks at the efficiency changes in the US only and suggests that annual improvements in energy intensity (fuel use per seat km and per passenger km) were relatively strong in the past but are set to slow.

	Gain in efficiency per annum including load factor effects (fuel per passenger km)	Gain in efficiency per annum excluding load factor effects (fuel per seat km)
1971-1985	4.6	2.7
1985-1998	2.2	1.2
Present to 2025	1.3-2.5	0.7-1.3

Source: Formulated using Lee, J, Lukatchko S, Waitz I and Scafer A (2001) 'Historical and future trends in aircraft performance, cost and emissions. Annual Review of Energy and the Environment 17 p537-573

IATA (2007)

IATA suggest that fuel efficiency at the global level measured in terms of annual changes in fuel use per 100 revenue tonne kilometres (which includes load factor effects) and per available tonne kilometres (which excludes load factor effects) increased in recent years at a faster rate than is expected in the future:

	Gain in efficiency per annum including load factor effects (fuel per passenger km)	Gain in efficiency per annum excluding load factor effects (fuel per seat km)
1997-2006	2.3%	2.4%
2006-2020	1.9%	n/a

Source: IATA World Statistics 2007

On the basis of the evidence in these studies, there appears to be a consensus that fuel efficiency has improved over recent years due to both improvements in technology, and owing to higher load factors. Over time, fuel efficiency is expected to continue to improve, but at a slower rate of annual improvement than seen in the past.

Projecting fuel efficiency of new aircraft

3.42 It was noted above that aircraft entering service in a future year could be of an existing type, a known new type (i.e. aircraft not yet in service but are on order such as the Boeing 787, Airbus A350 and the Embraer 195) or a completely new type. The efficiency of new types of aircraft expected in the near future can be projected using manufacturers' specifications for their aircraft. Box 3.3 gives our specific assumptions.

Box 3.3: Efficiency of new aircraft types in the near future

Manufacturers' data is used to project the fuel efficiency of new aircraft types expected to enter service in the near future. For example, the Airbus A350 and Boeing B787 are assumed to be 20% more efficient than their nearest existing equivalent at the beginning of this decade, the Boeing B767. Similarly, the Airbus A380 is assumed to be 12% more efficient than a Boeing 747-400. These efficiency gains are applied to the CORINAIR efficiency data of the respective existing aircraft types to project the efficiency of the new types. We also make an adjustment to reflect the potential variation in seating configurations of the new aircraft.

With the smaller jets, known new models such as the Embraer 170/175 and 195 and Bombardier CRJ900 regional jets have been introduced to our modelled fleet mix and are assumed to have similar efficiency to the BAe146. However, in practice it is likely that the Embraer jets may be at least 7%, and the CRJ900 at least 10%, more fuel efficient than this type.

3.43 The development of new aircraft types tends to follow a product cycle over many years, and it is probable that a new set of aircraft types will enter production and the fleet before the end of our forecasting period. These aircraft are likely to be influenced to some degree by the Advisory Council for Aeronautics Research in Europe (ACARE) target for fuel efficiency[43].

3.44 This industry target is for aircraft manufacturers to deliver a 50% cut in new aircraft fuel consumption between 2000 and 2020. The terms of the commitment are set out in Sustainable Aviation's report: 'A Strategy Towards Development of UK Aviation'[44]:

"For CO_2, the target is a 50% cut in CO_2 emissions per seat kilometre, which means a 50% cut in fuel consumption in the new aircraft of 2020

[43] See *The Challenge of the Environment, Strategic Research Agenda*, Advisory Council for Aeronautics Research (ACARE), Volume 2, October 2002, (http://www.acare4europe.org/docs/es-volume1-2/volume2-03-environment.pdf)
[44] *A Strategy Towards the Development of Sustainable Aviation*, Sustainable Aviation, 2005

relative to new aircraft in 2000. The overall target of 50% reduction will be addressed through airframe, engine and air traffic management improvements. The role of an optimised air traffic management system is substantial with a target contribution of 5-10% lower fuel consumption through reductions in flight delays, route inefficiencies and taxiing times."

3.45 NASA independently has similar expectations for the future American aircraft fleet.

3.46 While the ACARE target sets an overall target for new aircraft efficiency, it could be consistent with a range of possible outcomes, so it remains necessary to project the number of aircraft types in service at any future year that will meet the ACARE target. This uncertainty is in part because fuel efficiency is not the sole determinant of airlines' fleet acquisition decisions. The cost of buying or leasing aircraft, the cost of their maintenance and operation, their operational performance, their suitability for airlines' business models and stock availability are all likely to influence the take-up of future aircraft types.

3.47 We therefore make the following cautious assumptions in our central case projection of new aircraft fuel efficiency:

- The ACARE target is assumed to be met in 2020 by some aircraft types entering service. Given the 9% gain in efficiency we assume from operational improvements (in keeping with ACARE's assumption of a 5-10% gain), the ACARE-consistent aircraft types have 40% lower fuel consumption than their equivalent in 2000[45]. None of the known new types are assumed to be ACARE compliant.

- The share of new aircraft entering service drawn from an ACARE-consistent aircraft type rises from 5% in 2020 to 25% in 2030.

3.48 Table 3.4 shows that these assumptions result in fleet fuel efficiency improving by 30% over 2005 to 2030, equivalent to 1.0% per annum. This is towards the lower end of the historic range quoted by the IPCC (1-2%), and is close to their assumption of 0.9% per annum over the same period. It is also close to the centre of the range forecast by Lee et al[46] of 0.7-1.3% per annum.

[45] The metric defined by ACARE for fuel efficiency refers to the inverse of that used in the modelling process. It has therefore been converted and applied in the modelling to ensure internal consistency.

[46] Lee et al: "Historical and Future Trends in Aircraft Performance, Cost and Emissions". Annual Review of Energy and Environment, 2001. 26: 167 -200. Lee, J. J, Lukachko, P., Waitz, I and Schafer, A.

Table 3.4: Annual average fuel efficiency to 2030

Year	Annual average improvement in fuel efficiency		
	DfT forecasts 2007	IPCC 1999	Historic average
2005-2010	0.8%	1.30%	1-2%
2010-2020	1.6%	1.00%	
2020-2030	0.6%	0.50%	
2005-2010	0.8%	1.30%	
2005-2030	1.0%	0.90%	
Aggregate 2005-2030	29.7%	33.00%	

Carbon dioxide

3.49 Once the above method has forecast the amount of fuel that is burned on flights departing each airport on each route by aircraft type, this is converted into carbon dioxide emissions on the basis that 1.00 kg of aviation fuel emits 3.15 kg of CO_2[47].

Sensitivity tests

3.50 There is of course uncertainty over the future path of the variables driving aviation carbon emissions, so we have developed a range around the central forecast. Chapter 2 explained how the demand range is derived from sensitivity tests which vary key demand driving variables within reasonable bounds. We have similarly developed a sensitivity test around the fuel efficiency of new aircraft, and hence the efficiency of the fleet.

3.51 The tests vary the speed at which the share of new aircraft entering service that are drawn from an ACARE-consistent aircraft type rises between 2020 and 2030, as shown in table 3.5. In the central case the share rises from 5% in 2020 to 25% in 2030. Under the 'lower efficiency' test, this remains at 5% between 2020 and 2030. Under the 'higher efficiency' test, this rises from 5% in 2020 to 50% in 2030.

[47] Each 1 kg of aviation fuel (kerosene) contains 858 g of carbon. Each 1kg of carbon is equivalent to 44/12 or 3.67 kg of CO_2.

Table 3.5: Proportion of aircraft entering service that is ACARE compliant

	2020	2030
Lower	5%	5%
Central	5%	25%
Higher	5%	50%

3.52 The carbon dioxide range is defined as follows:

- High case: high end of demand range, plus lower fuel efficiency case; and,
- Low case: low end of demand range, plus higher fuel efficiency case

Aviation CO_2 emissions forecasts to 2030

National Forecast

3.53 The above section set out the methodology and assumptions used to forecast carbon dioxide emissions to 2030. This section sets out the results of applying this method.

3.54 Table 3.6 reports our central forecast and range for CO_2 emissions from UK aviation (UK departures). The central case assumes:

- the central unconstrained demand forecast;
- that an extra runway is added at Stansted in 2015, and at Heathrow in 2020 (the 's12s2' scenario explained in chapter 2); and,
- the central fuel efficiency forecast.

3.55 As explained above, the range assumes the demand range (explained in chapter 2), and the fuel efficiency range (explained above).

3.56 The table shows that emissions are forecast to rise from 37.5 $MtCO_2$ in 2005 to 58.9 $MtCO_2$ by 2030 within a range of 54.8 $MtCO_2$ to 62.7 $MtCO_2$ in 2030.

Table 3.6: aviation carbon emission forecasts to 2030, $MtCO_2$

	Low	Central	High
2005	37.5	37.5	37.5
2010	40.9	42.0	43.0
2020	48.1	50.0	53.1
2030	54.8	58.9	62.7

Airport Forecasts

3.57 As explained above, the national forecast of UK aviation CO_2 emissions is based on detailed forecasts of passenger and ATM demand at the airport level. Chapter 2 explained that our airport forecasts should be interpreted as the forecasts resulting from a modelling process necessary to provide a full picture of capacity and demands for the purpose of informing strategic aviation policy. The Air Transport White Paper set out airport capacity developments that the government supports. The forecasts should not in isolation be interpreted as necessarily supporting particular levels of demand at individual airports. The CO_2 forecasts at each airport should be interpreted similarly.

3.58 Table 3.7 presents the central case CO_2 emissions forecast to 2030, for passenger ATMs, for the largest of the UK's airports.

Table 3.7: Carbon dioxide emissions from airports (central demand and efficiency)[48]

	Emissions million tonnes CO_2		Share of Total UK Departure CO_2	
	2005	2030	2005	2030
		Central		Central
Heathrow	18.2	24.9	49%	42%
Gatwick	4.8	5.4	13%	9%
Stansted	1.4	3.3	4%	6%
Luton	0.6	0.9	2%	2%
London City	0.2	0.3	0%	1%
London Total	25.2	34.9	67%	59%
Other UK Airports	9.1	18.2	24%	31%
Ground	1.4	2.2	4%	4%
Freight	0.6	2.4	2%	4%
Total	37.5	58.9	100%	100%

3.59 It shows that in 2005 London airports accounted for two thirds of total UK aviation carbon dioxide emissions. This is forecast to decline to 59% by 2030. Heathrow currently accounts for around half of the UK's aviation CO_2 emissions. This reflects its large share of traffic (around a fifth) and its larger proportion of long haul flights (64% of UK long haul ATMs are at Heathrow), which combine to give it a large share of seat-kilometres (just over a half).

Aviation CO_2 projections to 2050

3.60 The UK is committed to reducing carbon dioxide emissions by 60% below 1990 levels by 2050. The process of policy development and

[48] It should be noted that the emissions at the airport level represent emissions from passenger flights only and do not include additional emissions from congestion during taxiing, or the individual airport contribution to the freight total. The national total has been increased by around +1.2 $MtCO_2$ to ensure consistency with DEFRA 2005 outturn estimate.

monitoring progress against this commitment requires a longer term view of aviation carbon dioxide emissions.

Methodology and assumptions

3.61 Our CO_2 forecasts rely on our demand and fuel efficiency forecasts. These are available only to 2030, so we project CO_2 emissions to 2050 using simpler, yet still robust, methods.

3.62 Chapter 2 explained that passenger demand is projected beyond 2030 by assuming demand growth at each airport between 2026 and 2030 continues but with no further passenger or runway capacity added after 2030. Passenger demand is converted into ATM demand using projections of aircraft size and load factor trends. Growth at each airport continues, until either terminal or runway capacity is reached. By 2030 all the London area airports are forecast to be at capacity. There is no reallocation of demand away from constrained airports to unconstrained airports within these post-2030 projections.

3.63 The projections of ATM size are then combined with projections of average flight distance to obtain seat-kilometre projections by airport. These are then combined with a projection of the fleet fuel efficiency.

3.64 We are not aware of any projections of fuel efficiency beyond 2030. The IPCC assumed 0.5% per annum improvement for the fleet as a whole from 2021 onwards, and IATA and Lee et al project only to 2020 and 2025 respectively. We have therefore based our post-2030 projection on the IPCC long-term assumption of 0.5% improvement per annum, but allowed a slightly higher rate of 0.75% between 2030 and 2050. This reflects the continued propagation of ACARE-consistent aircraft through the fleet after 2030, and allows a smooth transition from our pre-2030 efficiency forecasts to our post 2030 projections. The resulting fleet efficiency gain from 2030 to 2050 remains below the forecasts to 2030 by Lee et al and IATA.

3.65 This results in a forecast fleet efficiency improvement of 29.7% 2005-2030 (1.0% pa), as shown in table 3.4, and 15.3% 2030-2050 (0.8% pa).

Sensitivity tests

3.66 To generate the CO_2 emissions projection range between 2030 and 2050, we have varied the fleet fuel efficiency assumptions by +/- 0.25% per annum. This produces a range to reflect the uncertainty around those factors that drive fuel efficiency that we are unable to capture in the modelling. This might include for example, alternative fuels or different technologies.

3.67 As with the demand forecast sensitivity tests, the projection range presented allows us to account for other unspecified uncertainties.

Aviation carbon dioxide emissions projections to 2050

3.68 Table 3.8 below combines the forecasts presented in table 3.6 with the results of applying the methodology outlined above under the central case to 2050.

Table 3.8: UK Aviation Carbon Dioxide Emissions to 2050 ($MtCO_2$)

	Low	Central	High
2005	37.5	37.5	37.5
2010	40.9	42.0	43.0
2020	48.1	50.0	53.1
2030	54.8	58.9	62.7
2040	55.3	61.1	66.3
2050	53.2	60.3	66.9

3.69 Table 3.8 shows that central case emissions are forecast to rise from 37.5 $MtCO_2$ in 2005 to 58.9 $MtCO_2$ in 2030, after which their growth is projected to slow and slightly decline between 2040 and 2050. We saw in Chapter 2 that post-2030, capacity constraints begin to bite again, so the growth in passenger demand slows. Fuel efficiency slows post-2030 as the scope for further improvements diminishes (without any step change technological developments), but post 2040 the balance of these two effects causes emissions to begin to decline.

3.70 Overall, aviation carbon dioxide emissions are projected to grow by some 1.8% per annum in aggregate over the period 2005-2030 slowing to an average of 1.1% per annum over the period 2005-2050 under the central case.

Further analysis

3.71 These CO_2 forecasts and projections have been used to update previous analysis showing:

- Improvements made to the modelling of aviation CO_2 emissions since *Aviation and Global Warming,* 2004 - see annex I
- The value of aviation's climate change impact - see annex J
- Aviation's share of UK climate change emissions - see annex K

4. Economic appraisal of airport development scenarios

- We have updated our appraisal of airport development scenarios in the South East, following the Eddington and Stern reports; our process of continual improvement; new economic and oil price projections; and revised DEFRA guidance on the shadow price of carbon dioxide emissions.

- Key changes are the inclusion of the cost of CO_2 emissions from additional capacity; the benefits of reduced delays and air noise costs from additional Heathrow capacity. We have also extended the appraisal period to comply with the DfT Transport Appraisal Guidance.

- The development of a new runway at Stansted, and at Heathrow (subject to noise and air quality conditions), supported in the Air Transport White Paper would deliver a net economic benefit of £21bn-£22bn (2006 prices).

Introduction

4.1 As outlined in chapter 2, we have also updated our modelling assumptions to account for recent developments. For example, we have adopted the latest forecasts of oil prices from BERR and economic growth from HMT and the IMF, and the revised shadow price of carbon dioxide values provided by DEFRA. We have also updated our airport capacity assumptions in line with the latest plans indicated by airport operators. We have also made a number of incremental improvements to our forecasting methodology. The base year has been updated. We now estimate delay reduction benefits at Heathrow from mixed mode operations, and have extended the appraisal period to bring it into line with the DfT Transport Appraisal Guidance . In light of these developments, we have refreshed our economic appraisal of key development options supported in the 2003 ATWP.

Appraisal Methodology

4.2 The Department's Guidance for appraisal of transport related projects and policy is set out in the New Approach To Appraisal, now published in *Web Transport Appraisal Guidance (www.webtag.org.uk)*. The methodology we use to appraise the costs and benefits of airport development is consistent with that Guidance.

4.3 The appraisal includes a cost-benefit analysis that compares the monetised costs and benefits of airport development. Benefits are defined as those to airport users and producers, net of the cost of extra carbon emissions. These net benefits are compared with capital and additional operating costs (including an appropriate share in necessary investment in road and rail infrastructure). Full details of the methodology are shown in **Annex H**, but the main points are summarised below.

Transport User and Producer Benefits

4.4 Our appraisal captures the following forms of economic benefits to air transport users and producers, from additional airport capacity:

- benefits to passengers who make aviation journeys that would otherwise face them with higher costs that they would have been willing to pay;
- reduction in travelling costs to passengers who otherwise would travel via less preferred airports;
- reduction in costs to passengers who enjoy higher frequencies;
- producer benefits to airport operators from additional air traffic;
- Benefits from additional air freight movements

Benefits from reduced delay

4.5 In addition to the transport user and producer benefits, , we have also estimated the benefits of reduced delay from additional capacity at Heathrow airport.

4.6 The current runway constraints at Heathrow have led to increasing delays and reduced resilience. Punctuality statistics show that average delay at Heathrow has increased by 15 per cent since 2002, from 16.3 minutes in 2002 to 18.8 minutes in 2006.

4.7 Introduction of mixed mode operations would help reduce airport delays. Airport delay imposes costs on society in terms of increased costs for airlines, passengers and wider communities. The airlines bear additional costs on the fleet as well as flying and ground personnel, since delays prevent them from operating in optimum conditions. This might also result in additional long-term costs from loss of competitiveness. The delay related costs for users are mostly airline passenger's opportunity cost, measured by the value of their time. Economic benefits therefore occur in terms of reduced travel time savings for passengers and lower operating costs.

Climate Change Disbenefits

4.8 The increase in carbon dioxide emissions under each airport development scenario has been assessed using the CO_2 forecasting model outlined in chapter 3.

4.9 For the purposes of valuing the climate change impacts of extra air travel resulting from additional airport capacity, these have been uplifted to account for the warming effects of non-carbon dioxide emissions at altitude by multiplying in-flight emissions by the central radiative forcing factor, equal to 1.9 (see chapter 3 for more detail on the radiative forcing factor). This is consistent with the approach taken in the Emissions Cost Assessment[49]. The resulting uplifted carbon dioxide emissions have then been valued using the new DEFRA guidance on the shadow price of carbon(see chapter 3).

Air noise disbenefits

4.10 Additional capacity would lead to an increase in the number of movements under both mixed mode and Heathrow third runway. This would lead to additional air and road noise. We have attempted to quantify the air noise impacts. No assessment has been made for the road noise since this would depend on the surface access strategy to accompany possible development options.

4.11 The quantification of air noise impacts has relied on noise modelling conducted by ERCD for the Project of Sustainable Development of Heathrow. The ERCD noise modelling results were for 2015 mixed mode within existing capacity (480k ATMs), 2015 mixed with additional capacity (540k ATMs) and 2030 for Heathrow third runway (702k ATMs). A number of assumptions are made:

- The quantification of air noise for Heathrow third runway relies on the 2030 noise modelling position. It assumes that the difference in the number of households affected between the base (480k ATMs in segregated mode) and third runway scenario(702k ATMs) is indicative for the period 2020 and 2080. We have assumed that technological improvements beyond 2030 would affect the base case and third runway option equally, and therefore the difference in the number of households over time and direction of noise changes in each of the years would remain broadly the same. For the period between 2020 and 2030 we have therefore slightly overestimated the noise impacts since capacity would be lower than the assumed 702k ATMs.

- In the absence of specific Government recommended values for airport noise, we have relied on values from Pearce and Pearce

[49] *Consultations on the Emissions Cost Assessment*, Department for Transport, August 2007.

(2000)[50] and the DfT WebTAG values for road and rail noise to provide an appropriate range of air noise costs. In line with WebTAG the noise values are assumed to grow in line with GDP from the current year to 2080.

4.12 Similar assumptions are made for quantifying the impact of mixed mode options. In particular, we have relied on the 2015 noise modelling positions to quantifying the impacts on noise changes before 2020.

Infrastructure costs

4.13 The infrastructure costs of airport development are estimated by assessing the likely infrastructure needed for each potential development, and applying standard engineering cost assumptions. This takes on board the latest information on likely infrastructure requirements from airport operators and engineering costs. The estimated infrastructure costs of development at Stansted and Heathrow are set out in table 4.1 below.

Table 4.1: Estimated infrastructure costs of Stansted and Heathrow development scenarios, £bn, 2006 prices

Scenario		Base case		Infrastructure costs
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	£6.8 to £7.6
s07	Stansted R2 (480k in 2015)	s02	Maximum Use	£4.3
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£6.8 to £7.6
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£7.4 to £8.2
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£7.4 to £8.3
s12s2	Stansted R2 (480k 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	£11.1 to £11.9

Notes:
Heathrow options include a range for surface access infrastructure costs.
Figures in parentheses refer to the opening date and annual ATM capacity of the developed airport

Non-monetised costs and benefits

[50] Setting Environmental Taxes for Aircraft : A Case Study of the UK (2000) - Brian Pearce and David Pearce.

4.14 The following potential benefits from additional capacity are not monetised:

- wider economic benefits, as identified in the Eddington Report, through raising productivity and improving competitiveness;
- benefits to international-to-international interliner passengers

4.15 The following costs from additional capacity are currently not monetised:

- additional local air quality emissions;
- impacts from additional road traffic congestion. These include climate change and air noise impacts;
- land use impacts in form of lost greenfield and agricultural land;
- impacts on heritage and any community severence effects;
- biodiversity and water related impacts;

Key Assumptions for Cost Benefit Analysis

Airport capacity development

4.16 The ATWP supported development of runway capacity at Stansted, Heathrow (if air quality and noise criteria could be met), Birmingham, Luton and Edinburgh. Birmingham International Airport has since announced that they currently do not intend to add a second runway before 2030, and Luton's operator has announced scaled-down plans for greater capacity. Chapter 2 explained how these revised plans have been included in our updated forecasts.

4.17 As in the forecasts supporting the ATWP, it has been assumed that sufficient capacity would be provided to meet local demand at airports outside the South East.

Appraisal period, discount rates, and optimism bias

4.18 In line with HMT and DfT guidance, costs and benefits are counted from the start of development to 60 years after scheme opening. Net present values are calculated using a real discount rate of 3.5% for the first 30 years, then 3.0% for the remaining years. Optimism bias is included, comprising a 44% uplift in capital cost assumptions.

Projections beyond 2030 for appraisal purposes

4.19 Fully detailed forecasts from the forecasting framework outlined in chapter 2 are available up to 2030. In line with DfT transport appraisal guidance, the costs and benefits are extended over the full appraisal period using simpler but robust methods.

4.20 Key drivers of the benefits of airport development are passenger and ATM demand. Our method for projecting passenger and ATM demand is set out in chapter 2. Shadow costs for South East airports exhibiting a shadow cost before 2030 are projected beyond 2030 by assuming that the relationship between excess demand and shadow costs before 2030 continues. This relationship has been established by estimating a regression equation using data on excess demand and shadow costs for multiple years during the modelled period from multiple model runs.

4.21 For airports without a shadow cost before 2030, shadow costs are applied from the year (after 2030) when runway or terminal capacity is reached, and increased at the same rate as the pre-2030 base case, in which there is no extra runway capacity at any airport. Hence the effect of new capacity in the system after 2030 is similar to that modelled formally pre-2030, in that it produces a delay in some airports reaching capacity, and a corresponding lag in their introduction of shadow costs.

4.22 As many airports outside the South East do not acquire shadow costs even in the base case, this leaves many non-South East airports without shadow costs. This implies some underestimate of the benefits from additional capacity beyond 2030.

4.23 The cost of extra climate change emissions from airport development is found by applying the methods outlined above to the projection of CO_2 emissions outlined in chapter 3.

Appraisal Results

Central case

4.24 The updated net economic benefits of the development options in the South East are summarised in Table 4.2 below. They show that the economic case for the airport development options supported in the ATWP remains strong.

Table 4.2: Net Benefits of South East Airport Development Scenarios, £bn, Net Present Value, 2006 prices

Scenario		Base case		Benefits	Infrastructure Costs	Net Benefit	Benefit-Cost Ratio
s02	Maximum Use	s01	Planning case	£3.9	£1.6	£2.3	2.4
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	£15.6	£6.8 to £7.6	£8 to £8.8	2 to 2.3
s07	Stansted R2 (480k in 2015)	s02	Maximum Use	£18.3	£4.3	£14.0	4.3
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£12.0	£6.8 to £7.6	£4.4 to £5.2	1.6 to 1.8
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£13.5	£7.4 to £8.2	£5.3 to £6.1	1.6 to 1.8
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£13.6	£7.4 to £8.3	£5.4 to £6.2	1.6 to 1.8
s12s2	Stansted R2 (480k 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	£30.2	£11.1 to £11.9	£18.3 to £19.1	2.5 to 2.7

Notes:
Heathrow options include a range for surface access infrastructure costs.
'Benefits' is equal to transport user benefits net of climate change disbenefits, including the effect of delay reductions at Heathrow on users and carbon emissions, where applicable.
Figures in parentheses refer to the opening date and annual ATM capacity of the developed airport
'Benefit-cost ratio' is here defined as (benefits-disbenefits)/(infrastructure costs). This represents the value per pound of society's resources the development would deliver. This cannot be compared with the NATA BCRs reported for road and rail schemes, which divide the net benefits by the net effect on government spending.

4.25 Table 4.3 provides a breakdown of the transport user benefits of the development scenarios.

Table4.3: Breakdown of transport user benefits, £bn, NPV, 2006 prices

Scenario		Base case		Generated Users	Existing Users	Freight	Producers	Government	Carbon disbenefits	Noise disbenefits	Delay Reduction Benefits		Total Benefits
											User Benefits	Carbon	
s02	Maximum Use	s01	Planning case	4	neg	neg	1	2	-3	-	-	-	4
s05	HeathrowR3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	14	neg	neg	5	3	-5	neg	-	-	16
s07	Stansted R2 (480k in 2015)	s02	Maximum Use	15	neg	neg	2	4	-3	-	-	-	18
s12s2	Stansted R2 (480k in 2015), HeathrowR3 (605k in 2020, rising to 702k in 2030)	s07	Stansted R2 2015	9	neg	neg	5	3	-5	neg	-	-	12
s12s2mm1	Stansted R2 (480k in 2015), HeathrowMixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	9	neg	neg	5	3	-5	neg	1	neg	13
s12s2mm2	Stansted R2 (480k in 2015), HeathrowMixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	9	neg	neg	5	3	-5	neg	2	neg	14
s12s2	Stansted R2 (480k 2015), HeathrowR3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	24	neg	neg	8	7	-8	neg	-	-	30

Notes:
'neg' means impact is estimated and non-zero, but rounds to zero at 0dp
'-' means that no impact is estimated

Sensitivity tests

4.26 Table 4.4 below shows that the economic case for the ATWP-supported development at Stansted and Heathrow remain robust, even at the low end of the demand range, and at the high end of the shadow price of carbon dioxide and radiative forcing factor ranges.

Table 4.4: Sensitivity tests on the net benefits of s12s2 scenario, £bn, Net Present Value, 2006 prices

Sensitivity test	NPV (£bn)	BCR
Central case	£22	3.0
Low end of demand range	£15	2.4
High end of demand range	£31	3.8
Lower Shadow Price of Carbon Dioxide	£33	4.0
Higher Shadow Price of Carbon Dioxide	£19	2.7
Lower Radiative Forcing Factor	£37	4.3
Higher Radiative Forcing Factor	£12	2.1

Annex A: Econometric models

Introduction

1.1 Chapter 2 explained that the unconstrained air passenger demand forecasts are produced using an econometric model of each of the 21 markets. This annex sets out the data and econometric approach on which these models are based, plus the resulting parameter estimates, diagnostic tests, and key long run elasticities.

Data sources

1.2 Our primary source of data for air passenger demand and fares paid is the ONS International Passenger Survey (IPS). This gives a continuous time series for traffic from 1984-2004, and for fares from 1987-2004. However, it collects fare data from only UK passengers, and does not include domestic air passengers. A total of 3.8m passenger interviews from the IPS have been analysed.

1.3 The passenger interview surveys conducted by the CAA provide an important supplementary source which has been used to supply time series for international-to-international interlining passengers, and to provide some data on domestic air fares and fares paid by foreign passengers. A total of 91 CAA airport passenger interview surveys comprising some 2.2m individual interviews have been used.

1.4 Elsewhere we have drawn on the ONS for data on UK GDP and consumer expenditure, UN statistics on foreign GDP, HM Revenue & Customs for trade data, Bank of England quarterly returns for dollar exchange rates, and UN local currency GDP statistics for other currency to dollar exchange rates.

Modelling approach

1.5 Most of the data series used for this modelling are trended, so using a simple OLS regression could result in biased standard errors on the estimated parameters, leading to incorrect conclusions on parameter significance. To avoid this, we have adopted a single step error-correction model[51], which allows us both to test for cointegration and efficiently to estimate the model's parameters while avoiding bias on the standard errors.

[51] The exception is international to international interliner traffic, where OLS in levels is used.

1.6 The general form in our modelling is:

$$\Delta Q_{it} = \alpha_i + \beta_i \Delta Z_{it} + \gamma_i Q_{it-1} + \delta_i Z_{it-1} + \varepsilon_{it}$$

where

Q_{it}	=	log of passenger demand in market i at time t
Z_{it}	=	log of explanatory variables in market i at time t
ε_{it}	=	error in prediction in market i at time t
$\alpha_i, \beta_i, \gamma_i, \delta_i$	=	parameters to be estimated.

1.7 The aim of the modelling was to estimate models which successfully explained past demand movements, had parameter estimates in line with economic theory, and passed the standard diagnostic tests. Particular emphasis was placed on establishing the relationship between demand and income variables, and searching for air fare effects where data permitted.

Parameter estimates and diagnostics

1.8 The resulting parameter estimates, standard errors, and diagnostic test for the 21 markets are reported in table A1 below. They show that:

- For most markets an R^2 value in the range 0.7 to 0.9 is obtained. The exceptions tend to be smaller, developing markets or those subject to considerable structural change, such as charter.
- The coefficients on GDP or consumption are positive in models where UK consumption, UK GDP or foreign GDP is included. Where both foreign and UK GDP are used, the net effect is positive. The income level variables are significant at the 5% level or higher in most models.
- Air fare level variables are significant at the 5% or 10% level, with two exceptions, where the variable is retained because the variables are jointly significant, and it aids model fit and explanatory power.
- There is no evidence of autocorrelation or heteroscedasticity at the 5% level.

Table A1: Parameter estimates

Sector	Const	D-Lnt-CON	D-Lnt-EXP	D-Lnt-EXR	D-Lnt-FGP	D-Lnt-GDP	D-Lnt-IMP	D-Lnt-IPS	D-Lnt-PFR	Lnt-Tra(-1)	Lnt-CON	Lnt-CON(-1	Lnt-EXP	Lnt-EXR	Lnt-EXR(-1)	Lnt-FGP	Lnt-FGP(-1)	Lnt-GDP	Lnt-GDP(-1)	Lnt-IMP	Lnt-IPS	Lnt-IPS(-1)	FGP	PFR	Dum
Charter Long Haul	-7.42			-0.15						-0.95				0.30				2.24							
Charter Short Haul	5.24									-0.74				-0.10							-0.29				
Domestic Business	-3.82							-0.06		-0.84								1.66							
Domestic Leisure	-1.82	1.37								-0.42		1.06										-0.24			
Foreign Business LDC	-0.48									-0.23						0.32				0.03					
Foreign Business NIC	0.00					4.10				-0.50						0.50									
Foreign Business OECD	2.90			0.53			0.34			-1.31			0.59			1.71		-1.62							
Foreign Business W. Europe	-1.03		-0.35	-0.35			0.37			-1.14			0.58					0.76							
Foreign Leisure LDC	0.00									-0.30							0.32								
Foreign Leisure NIC	0.00				-0.85				-0.06	-0.13						0.15									
Foreign Leisure OECD	1.17			0.36	1.82					-0.69						0.43									
Foreign Leisure W. Europe	-6.94			-0.63	-1.27					-0.93						2.40									
UK Business LDC	-0.93					4.32				-0.66									0.84						
UK Business NIC	1.27					1.15				-0.77						0.47									
UK Business OECD	0.00				1.55					-0.40						1.51		-1.11							
UK Business W. Europe	-1.99						0.54			-0.56			0.40					0.91		-0.32					
UK Leisure LDC	-3.88					1.85				-1.02								2.45			-0.62				
UK Leisure NIC	-5.48							0.27		-1.19	2.61			0.35							-0.58				
UK Leisure OECD	9.51			-0.72		1.15				-0.45					-1.09							-0.51			
UK Leisure W. Europe	3.40									-0.84		1.34			-0.33							-0.89			
Itol	0.55																						0.75	-0.33	-0.16

In defining the model form the following variable notation is used:

LNT Natural logarithm
D- Differenced variable
[-1] Offset one year
TRA Traffic
GDP UK GPP
CON UK Consumer Expenditure
FGP Foreign GDP
IPS UK Fares
PFR Foreign Fare
IMP Imports
EXP Exports
EXR Exchange Rate

Table A2: Parameter t-statistics

Sector	Const	D-Lnt-CON	D-Lnt-EXP	D-Lnt-EXR	D-Lnt-FGP	D-Lnt-GDP	D-Lnt-IMP	D-Lnt-IPS	D-Lnt-PFR	Lnt-Tra(-1)	Lnt-CON	Lnt-CON(-1)	Lnt-EXP	Lnt-EXR	Lnt-EXR(-1)	Lnt-FGP	Lnt-FGP(-1)	Lnt-GDP	Lnt-GDP(-1)	Lnt-IMP	Lnt-IPS	Lnt-IPS(-1)	FGP	PFR	Dum
Charter Long Haul	-4.32			-3.10						-5.66				5.34				4.55							
Charter Short Haul	2.25									-2.52				-1.46							-1.24				
Domestic Business	-4.32							-0.67		-3.80								4.13							
Domestic Leisure	-0.60	1.48								-1.49		1.40										-0.93			
Foreign Business LDC	-0.53									-1.06						3.02				0.23					
Foreign Business NIC	0.00					1.51				-2.56						2.58									
Foreign Business OECD	3.79			2.64			2.28			-7.52			4.16			3.01		-2.87							
Foreign Business W. Europe	-1.92		-2.12	-2.45			2.71			-6.89			5.40					3.79							
Foreign Leisure LDC	0.00									-2.23							2.25								
Foreign Leisure NIC	0.00				-0.96				-0.48	-0.70						0.80									
Foreign Leisure OECD	2.83			1.80	4.25					-3.43						2.30									
Foreign Leisure W. Europe	-4.14			-3.57	-2.35					-5.14						4.51									
UK Business LDC	-1.55					3.29				-5.34									3.56						
UK Business NIC	2.86					2.10				-4.04						4.20									
UK Business OECD	0.00				3.04					-4.94						3.13		-2.66							
UK Business W. Europe	-2.96						3.62			-4.02			4.80					3.28		-1.80					
UK Leisure LDC	-2.79					3.80				-5.52								4.92			-5.31				
UK Leisure NIC	-7.25							2.35		-9.72	10.77			4.95							-7.15				
UK Leisure OECD	4.45			-3.65		3.53				-3.09					-4.97							-2.35			
UK Leisure W. Europe	1.65									-5.58		5.01			-3.76							-3.24			
Itol	1.34																						2.34	-2.73	-4.53

Table A3: R^2, F statistics, F significance, Durbin-Watson d statistics, and RESET significance

Market sector	2005 share of modelled traffic	R2	F	F sig	Durbin Watson d	RESET sig
Charter Long Haul	2%	0.75	11.0	0.000	1.7	0.67
Charter Short Haul	14%	0.55	3.3	0.081	1.7	0.95
Domestic Business	9%	0.67	7.5	0.005	1.0	0.26
Domestic Leisure	8%	0.63	4.3	0.027	1.7	0.74
Foreign Business LDC	1%	0.83	12.8	0.002	3.0	0.35
Foreign Business NIC	0%	0.46	2.3	0.163	2.2	0.37
Foreign Business OECD	1%	0.86	13.3	0.000	2.7	0.11
Foreign Business W. Europe	4%	0.84	11.1	0.000	2.2	0.08
Foreign Leisure LDC	1%	0.22	2.5	0.111	2.3	0.39
Foreign Leisure NIC	0%	0.22	0.4	0.833	2.7	0.70
Foreign Leisure OECD	3%	0.71	9.3	0.001	2.5	0.20
Foreign Leisure W. Europe	7%	0.71	9.2	0.001	2.3	0.62
UK Business LDC	1%	0.83	14.7	0.001	1.5	0.97
UK Business NIC	0%	0.61	8.3	0.001	2.3	0.21
UK Business OECD	1%	0.84	20.9	0.000	2.2	0.97
UK Business W. Europe	6%	0.80	11.3	0.000	1.7	0.18
UK Leisure LDC	3%	0.84	18.0	0.000	1.6	0.15
UK Leisure NIC	1%	0.92	32.0	0.000	2.4	0.50
UK Leisure OECD	5%	0.78	10.1	0.000	1.5	0.41
UK Leisure W. Europe	21%	0.92	20.4	0.001	3.2	0.48
Itol	11%	0.91	17.2	0.005	2.3	0.93

1.9 The successful fit of the single-step error correction models in most markets itself indicates that the variables in each model chosen form a cointegrating relationship. We have not performed Dickey-Fuller tests to test this formally, given their low power and the relatively short data runs. We have instead examined plots of the residuals against time, and estimated the autocorrelation function (correlogram) of the residuals, for each model. The former suggests the residuals are untrended and mean-reverting, and the latter shows that for each market the autocorrelation function closes to zero rapidly, both of which confirm that the models comprise cointegrating relationships.

Long run air fare and income elasticities

1.10 The long run air fare elasticities are found by imposing the long run condition on the error correction model (change in each variable equals zero), solving for demand, and differentiating with respect to air fare. Due to the variety of income-related variables used in the modelling, an alternative approach is necessary to ensure that results are relevant to the forecasting context. The arc income elasticities have been estimated by increasing GDP in a one-off step change of 10% in 2010. This allows the effects of both GDP and the other income variables related to it to come through as they would in the actual forecasts.

1.11 Table A4 below summarises the resulting long run income and air fare elasticities. This shows that income is a strong driver in the scheduled markets, with the income elasticity of demand ranging from 1.5 to 2.1. This falls to 0.4 for the charter market, but the overall average income elasticity is strong at 1.5. Air fare effects are more variable. The UK leisure sector showed a strong price elasticity of -1.0, but no air fare effect could be identified for the UK business sector. Charter and domestic travel showed some fare effects (-0.4 and -0.3 respectively), but a lack of fare data for foreign-based travel prevented a price elasticity being sought for this sector. International to international interliner traffic was found to have a price elasticity of -0.4. The resulting overall air fare elasticity is -0.44.

Table A4: Long run price and income elasticities of UK terminal passenger demand

		Elasticity of demand with respect to	
Sector	Share of passenger demand 2005	Income	Air Fares
UK Business	8%	1.5	0.0
UK Leisure	29%	1.6	-1.0
UK Charter	16%	0.4	-0.4
Foreign	18%	1.5	-
Itol	11%	0.8	-0.4
Domestic	17%	2.3	-0.3
Overall	100%	1.5	-0.4

1.12 It is intuitive that the overall price elasticity is some way below unity, given that passengers may have options for responding to (e.g.) an increase in price which reduces the cost of their trip without preventing it, such as travelling to a less expensive destination, or by a less expensive class of travel or airline. It is also in keeping with findings for other modes that UK transport demand is relatively price inelastic. Furthermore, chapter 2 explains that these results are broadly in line with other relevant published studies.

1.13 The potential impact of the lack of air fare data for foreign-based travel on the overall price elasticity can be examined by assuming for illustrative purposes that UK elasticity results apply to foreign-based travel. The impact of this is minimal, raising the overall average elasticity from -0.44 to -0.56. However, if the necessary air fare data could be obtained to allow estimation of foreign fare effects, it would be unlikely to impact significantly on the trends projected by the models. This is because, for the econometric model to continue to fit the past data, any change to its fitted values (and thus forecast) due to including a different price elasticity is likely to be broadly offset by changes to the estimates of other parameters.

Annex B: Unconstrained demand forecasting assumptions

Introduction

1.1 Chapter 2 explained our method for forecasting air passenger demand, unconstrained by airport capacity constraints, using the 21 econometric models in the National Air Passenger Demand Model. This annex explains in more detail the projections of the key driving variables that are fed into the National Air Passenger Demand Model to generate the unconstrained forecasts.

1.2 The central case forecast requires central projections of economic growth, trade, exchange rates and fares, for the period 2005-2030. The sensitivity tests which are used to demonstrate the impact of varying key variables within reasonable bounds and form the basis of the forecast range further require a 'low' and 'high' projection of each variable.

Economic Growth

1.3 Variables related to income have historically been highly significant in explaining the long term demand for air travel, and have been found in all of the calibrated econometric models. These variables comprise UK GDP, UK consumer expenditure, and the GDPs of destination world areas.

1.4 The central assumptions for near term UK growth are based on the HM Treasury 2007 Pre-Budget Report[52]. The 2007 Budget Report includes long term fiscal projections beyond 2030.[53] In the long term consumer expenditure is assumed to 1/4 per cent lower than the GDP growth rate.

1.5 The Western Europe GDP assumptions to 2010 are taken from the 2007 HM Treasury Pre-Budget Report[54]. After 2010 the assumptions are based on the 2007 IMF World Economic Outlook (WEO) for the Euro area, but subject to the proviso that the rate of economic growth in this area will not exceed the UK rate. Other OECD rates of growth are taken from the IMF WEO with the average 1998-2007 rates being extended out to 2020. After 2020 this rate is reduced to halve the

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[52] 2007 Pre Budget Report, Annex A, Table A1.

[53] Budget Report 2007 Annex A, Table A.1. This gives long term "cautious" assumptions for GDP growth 2012-2037 and paragraph A.13 explains that the "neutral" view of productivity will be 1/4 per cent higher. The "medium range" central growth forecasts for 2007-2009 are given in Budget Report 2007, Chapter B, Table B4. Forecasts for the for 2010-2011 are interpolated between the HMT medium and long range forecasts.

[54] 2007 Pre Budget Report, Annex A, Table A1.

difference between the previous OECD rate and the prevailing European rate.

1.6 For newly industrialising countries (NIC) and the less developed countries (LDC) we have repeated the approach of the last forecasts which allowed for significantly higher economic growth rates from these areas which drop after 2015 but remain significantly above the rates for developed economies. The WEO now gives a higher average annual growth rate of 6.9% for developing Asia 2007-2010[55] which we have adopted for the newly industrialised countries (NIC), which is principally China. We have adopted this rate until 2015 when it is dropped to 3.5%. For the less developed countries we have adopted the latest WEO 2007-2010 forecast of 5.8% per annum out to 2015; thereafter it is reduced to 4% for the rest of the forecasting period.

1.7 Table B1 summarises the resulting central GDP and UK consumer spending projections for each geographical market.

Table B1: Real GDP and UK Consumer Spending Growth Assumptions, % pa

	UK	W Europe	OECD	NIC	LDC	UK Consumer Expenditure
2005-2012	1.93-3.00	1.5-3.0	2.6-3.0	6.9-7.4	5.80	2.03-3.04
2012-2017	2.25	2.00	2.85	3.5-6.9	4.0-5.8	2.00
2018-2020	2.00	2.00	2.85	3.50	4.00	1.75
2020-2030	2.00	2.00	2.43	3.50	4.00	1.75

1.8 For 'low GDP' sensitivity tests, central annual GDP and consumer spending growth rates are reduced by 0.25 percentage points. For 'high GDP' growth tests, central annual GDP and consumer spending growth rates are increased by 0.25 percentage points.

Trade

1.9 The growth rates for visible trade volumes have historically followed those of national output. The trade assumptions are therefore directly based on trade's relationship with GDP growth, and are thus derived from the HMT and IMF GDP forecasts described above. The same growth rates are assumed to apply to imports and exports so that we do not forecast any change from the base year balance of trade.

Table B2 : Visible Trade Growth Assumptions, % change pa

	W Europe	OECD	NIC	LDC
2005-2012	1.5-3.1	2.6-2.9	6.9-7.3	5.53
2012-2017	2.04	2.89	3.4-6.8	3.81-5.53
2018-2020	2.04	2.89	3.44	3.81
2020-2030	2.04	2.46	3.44	3.81

[55] IMF World Economic Outlook, April 2007, Statistical Appendix, Table 45.

Exchange Rates

1.10 We make the neutral assumption of no change to current exchange rates. This is consistent with applying growth rates equally to imports and exports, as outlined above.

Air Fares

1.11 The forecast annual growth rate in air fares is compiled from the assumptions about, fuel costs, non-fuel costs, taxation and other environmental charges.

Fuel Costs

1.12 Fuel costs are driven by fuel price and fuel efficiency. We project fuel prices by assuming that the strong historical relationship between aviation fuel and oil prices continues. Real oil prices are assumed to move in line with the DTI's central oil price projection, which falls from about $65 per barrel in 2006 to $53 per barrel in 2030, with most of the decline occurring by 2012[56]. This is illustrated in table B3. [57]

Table B3: Range of real oil price assumptions, $/barrel (2004 prices)

	Low	Central	High
2005	55	55	55
2010	25	57	70
2015	25	50	75
2020	25	53	80
2025	25	53	80
2030	25	53	80

1.13 Fuel efficiency growth assumptions are derived from our fleet mix model. Chapter 3 explains how the model works, what assumptions it is based on, and reports the resulting fuel efficiency growth rates for the fleet.

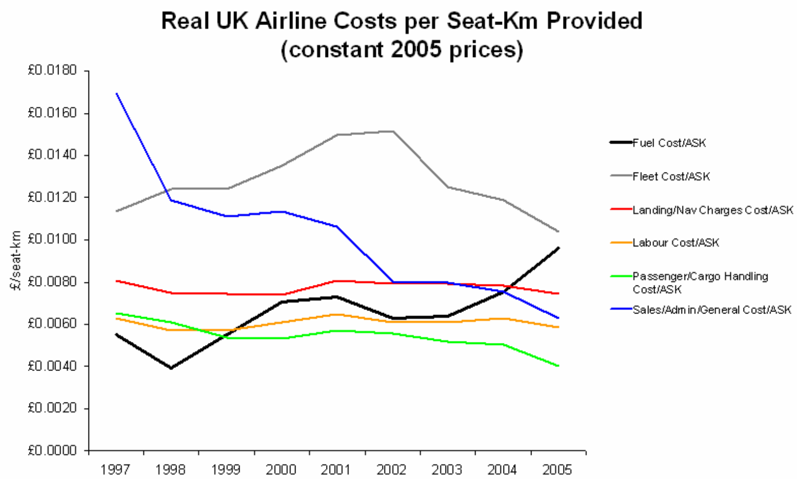
Airline Non-Fuel Costs

1.14 Figure B1 below shows the trend over the last decade in the real costs per seat-kilometre for the four largest UK registered airlines (British Airways, bmi, easyJet and Virgin Atlantic), derived from CAA data[58]. These costs exclude APD and have been converted to 2005 prices. It shows that most non-fuel cost elements have trended down, with the

[56] See *Meeting the Energy Challenge: A White Paper on Energy*, BERR, Cm 7124, Annex B, Table B5 for central assumptions.
[57] See Annex B *Updated Energy and Carbon and Emissions Projections*, (Energy White Paper Supporting Document) BERR, May 2007, URN 07/947.
[58] CAA ERG: UK Airline Financial Tables 1998-2006, *Table 2.6 Individual Airline Profit & Loss, Table 2.10 Operating and Traffic Statistics*.

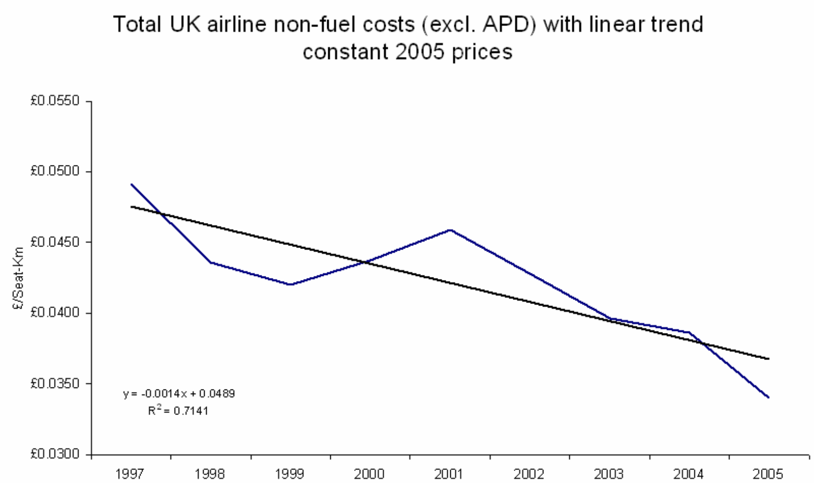
exception of fleet costs where costs have fallen in only the more recent years. Fuel costs have trended up, reflecting the rising price of oil.

Figure B1: UK airline costs per available seat kilometre, (exc. APD), 2005 prices, selected airlines



1.15 Figure B2 shows that summing the non-fuel cost elements reveals an overall downward trend in the last decade, for both short- and long-haul operations.

Figure B2: UK airline non-fuel costs (exc. APD), 2005 prices



1.16 This downward pressure on non-fuel airline costs is likely to have been driven by increasing competition, convergence of lower cost and full service business models, and development of non-fare revenue streams. We project this trend to continue, but at a slowing rate. The projected annual rates of reduction in airline non-fuel costs used in the central case are given in table B4. The sensitivity tests on non-fuel costs vary each growth rate by +/-0.5% pa to 2020.

Table B4: Airline non-fuel costs, % change pa

	W. Europe	OECD	NIC	LDC	Domestic Business	Domestic Leisure
2005-2008	-4.8%	-3.2%	-3.2%	-3.2%	-4.8%	-4.8%
2009-2010	-4.0%	-1.6%	-1.6%	-1.6%	-4.0%	-4.0%
2011-2015	-2.4%	-1.6%	-1.6%	-1.6%	-2.4%	-2.4%
2016-2020	-1.9%	-1.1%	-1.1%	-1.1%	-1.9%	-1.9%
2021-2030	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Air Passenger Duty (APD) and carbon charge

1.17 The Air Transport White Paper included a commitment to work to ensure that aviation meets its external costs. The forecasts supporting the White Paper therefore assumed that after 2010 passengers would face an additional cost reflecting their climate change emissions (both carbon and the warming effects of non-carbon emissions), phased in gradually over ten years.

1.18 The 2006 Air Transport White Paper Progress Report committed the Government to consult on the development of a new 'emissions cost assessment' to inform its decisions on major increases in aviation capacity. The Emissions Cost Assessment Consultation[59] proposed that revenues from Air Passenger Duty (APD) should count as part of the aviation industry's contribution to meeting its climate change costs.

1.19 Hence in these forecasts passengers are assumed to face charges to cover their climate change costs comprising APD (which was doubled in February 2007) and an additional cost equal to the difference between APD and aviation's climate change costs per passenger journey (if positive) from 2007.

1.20 APD rates are assumed to remain constant in real terms. Table B5 sets out the current rates.

[59] *Consultations on the Emissions Cost Assessment*, Department for Transport, August 2007.

Table B5: APD rates assumed 2007-2030

	In the lowest class of travel	Other than the lowest class of travel	Percentage of passengers in the lowest class[60]
Europe[61] and UK	£10	£20	97.4%
Other OECD	£40	£80	89.8%
NIC	£40	£80	85.3%
LDC	£40	£80	92.3%

1.21 Climate change costs are estimated at the route level to account for differing emission profiles by distance, aircraft type and load factor. In the central scenario this is based on:

- CO_2 emissions per passenger kilometre by route from the CO_2 Forecasting Model (set out in chapter 3), and passenger kilometres by route, in each future year under a 'no carbon charge' scenario.
- The DEFRA central value for the shadow price of carbon dioxide emissions (see chapter 3).
- A 'radiative forcing factor' of 1.9, by which in-flight carbon emissions are multiplied to account for the warming effect of non-carbon emissions released at altitude.

1.22 In the sensitivity tests, we follow DEFRA's guidance on the range around their new shadow price of carbon dioxide, varying the 2000 shadow price of carbon dioxide by -10% and +25%. The radiative forcing factor is varied between 1 and 4.

Typical Fares

1.23 Below we illustrate how the above assumptions combine to generate projections of how average single fares are expected to change over time[62] for two typical journeys: (1) to Western Europe, and (2) to the Far East. The projections show that fares are projected to continue to decline, driven by further reductions in non-fuel costs, and some reduction in fuel prices.

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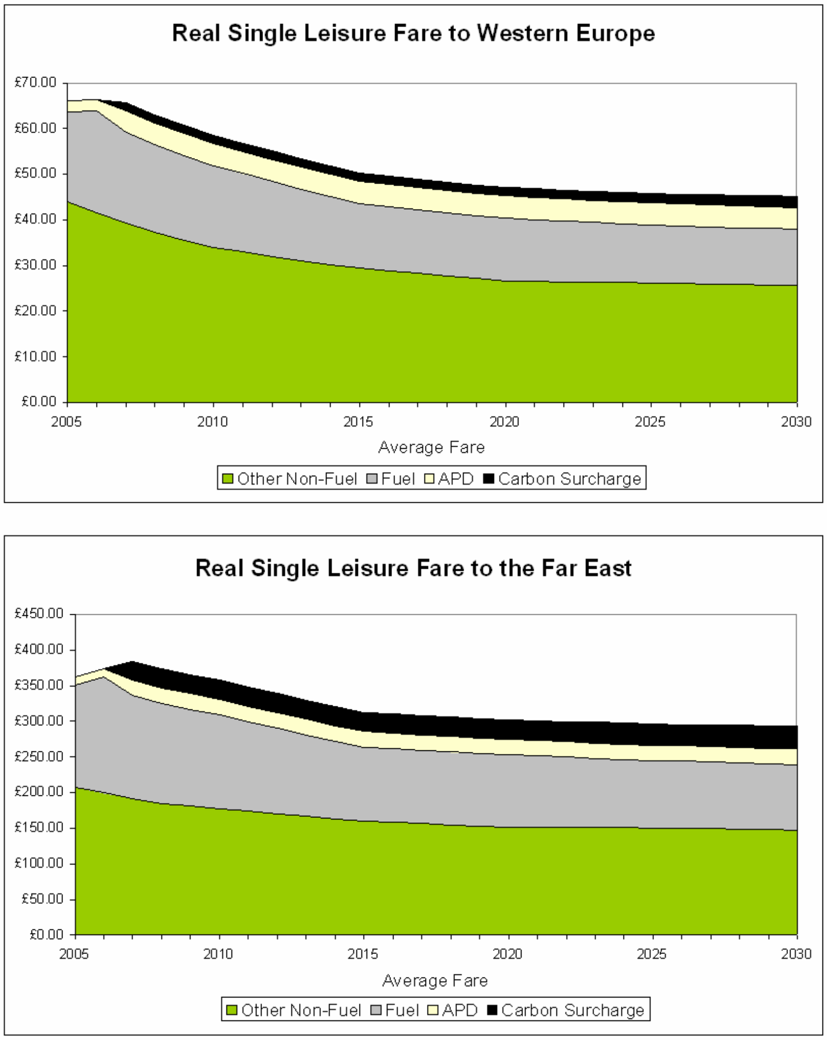
[60] Source: Analysis of CAA Passenger Interview surveys at major UK airports

[61] Defined by HM Customs and Revenue as passengers flying to destinations in the European Economic Area (EEA), the European Common Aviation Area, countries applying to join the EU and Switzerland.

[62] The graphs assume that the APD charge is effectively collected over both legs of a journey and therefore is illustrated at 50% of the prevailing rate on a single fare. Oil prices, carbon costs and radiative forcing all use central assumptions

Figure B1: Composition of two typical projected single fares 2005-2030



Market Maturity

1.24 Air travel demand has shown very strong growth for several decades. While it is important to use models capable of capturing the relationship between air travel demand and its key drivers in the past, we must also ensure that we account for the likely future maturity of the air travel market. As with most markets, we would expect there to be some product cycle in aviation demand, with rapid early demand growth giving way to steadier growth in later years. 'Market maturity' refers to the declining income elasticity we would expect to characterise this slowing of growth.

1.25 Our econometric models are estimated from data covering the more recent period of aviation demand growth, and so should reflect the most recent form of the relationship of demand with its drivers. However, market maturity is not inherent in them, and so (as with previous forecasts) it is necessary to overlay assumptions about maturity.

1.26 As in previous forecasts external maturity functions are applied in various markets starting in the period 2010-2020. The external maturity correction to give mature passengers (pax^*) for the year 't' takes the form:

$$Pax_t^* = \left(\frac{Pax_t}{Pax_{y0}} \right)^x \times Pax_t$$

Where Pax_t is the level of air travel demand in year *t* before maturity and y0 is the year from which maturity is applied. The values of the variable 'x' are shown in table B6 below.

Table B6: Market maturity inputs

Sector	x	Year applied from
Short Haul Business	-0.1	2020
Domestic Business	-0.2	2010
Long Haul Business	-0.1	2020
Short Haul Leisure	-0.3	2015
Domestic Leisure	-0.5	2010
Short Haul Charter	-0.7	2010
Long Haul Leisure	-0.2	2020
Long Haul Charter	-0.2	2020

1.27 The impact of these maturity exponents is to reduce the central national forecasts by 3 percent in 2015 and by 18 percent in 2030.

Annex C: Passenger Airport Choice Model - detailed methodology

Introduction

1.1 Chapter 2 explained that DfT's National Air Passenger Allocation Model is the mechanism for translating the national forecasts into passenger and aircraft demands at 31 individual airports operating as a national system. It projects how passengers might choose between airports given the differing amounts of capacity available in the future. It also projects air traffic movement (ATM) demand at each airport.

1.2 A key component of the model is the Passenger Airport Choice Model, which projects how a given level and pattern of demand is likely to split between airports. This annex gives further detail on how this model works.

Allocation Models

1.3 Modelling and forecasting how people choose between a set of discrete options is an established practice in statistics and transport modelling. The Passenger Airport Choice Model is an application of the standard multinomial logit formulation commonly used in this context. The model assumes the proportion of passengers with journey purpose *p* travelling to/from UK zone *i* to foreign destination *j,* that use airport *A,* P_{ijAp}, can be represented by the following very flexible functional form[63]:

$$P_{(i,j,A,p)} = \frac{e^{-\beta_1 \times Cost_{(i,j,A)}}}{\sum_{R \in all\ available\ Routes} e^{-\beta_1 \times Cost_{(i,j,R)}}}$$

where

i = zone of origin
j = zone of destination
p = journey purpose
A = airport
R = route
$Cost_{ijA}$ = generalised cost of travelling from zone i to zone j using airport A
β = unknown parameter to be estimated during calibration

[63] The form shown is the simplest of those used.

1.4 Model calibration involves analytically selecting the set of values for the unknown parameters which lead to the model's predictions best fitting the base year data.

1.5 The strength of different drivers of passengers' airport choice is likely to vary between passenger groups. For example, business passengers may be more affected by frequency of flights offered. We have therefore estimated separate allocation models for different types of passengers, some of which have more complicated functional forms than that shown above[64]:

- international scheduled[65] and charter (package holiday) passengers;
- domestic passengers beginning and ending their journeys in the UK;
- transfer passengers "interlining" by changing planes at a hub airport[66];
- UK and foreign passengers; and,
- business and leisure passengers.

1.6 Table C1 shows the 31 UK airports (by region) to which passengers can be allocated.

[64] A considerably more detailed description of the 2003 White Paper generation of the model is available in DfT/Scott Wilson *Rules and Modelling: A Users Guide to SPASM, Edition 2,* April 2004

[65] A further distinction is currently drawn between conventional scheduled and "No Frills" (NFC) airlines in the allocation as the calibration results showed a difference in parameter estimates. However, these markets have become less clearly differentiated over time, and this distinction is not made at all parts of the forecasting (e.g. the econometric models of unconstrained demand).

[66] These include passengers with UK origins or destinations changing at a UK hub airport ("domestic interliners"); passengers with UK origins or destinations changing at an overseas hub airport such as Amsterdam, Schiphol; or, passengers with no ground origin or destination within the UK but who use a UK hub airport to interchange ("international to international interliners").

Table C1 : UK Airports in National Air Passenger Allocation Model

London	**Midlands**	**Scotland**
Heathrow	Birmingham	Glasgow
Gatwick	Nottingham East Midlands	Edinburgh
Stansted	Coventry	Aberdeen
Luton		Prestwick
London City	**North**	Inverness
	Manchester	
Other East & SE	Newcastle	**Northern Ireland**
Southampton	Liverpool	Belfast International
Norwich	Leeds Bradford	Belfast City
	Durham Tees Valley	
SW and Wales	Doncaster-Sheffield	
Bristol	Humberside	
Cardiff Wales	Blackpool	
Bournemouth		
Exeter		
Newquay		
Plymouth		

ANNEX D: Updates to the National Air Passenger Allocation Model

Introduction

1.1 The National Air Passenger Allocation Model has evolved over a number of years. It was used in the SERAS and RASCO exercises, underpinned the 2003 *'Future of Air Transport: South East'* regional consultation document (and some others), and was used to inform the 2003 Air Transport White Paper.

1.2 The detailed working of an earlier version of the model is set out in *SPASM: Rules & Modelling* [67]. The updates to deliver the 2003 ATWP generation of the model were described in a White Paper supporting technical document[68]. Since then the model has remained under review both to keep pace with changes in the aviation market and to extend its ability to make detailed forecasts of aviation CO_2 and other emissions. This annex outlines these changes.

Aircraft Fleet Mix Modelling

1.3 The model's existing facilities to output aircraft forecasts in seat bands have been considerably enhanced so that we now forecast specific aircraft types year on year. The fleet mix model contains data on the age distribution of the existing fleet, the rate of fleet turnover and assumptions on the composition of the pool of potential replacement aircraft using UK airports in any particular year. The replacement pool data uses information from major airlines and draws on data of aircraft orders from manufacturers such as Boeing and Airbus.

1.4 The inclusion of integrated year on year aircraft fleet forecasts at a route level now allows us to forecast:

- CO_2 (and potentially other) emissions, taking account of changes to the routes and aircraft fleet in response to passenger demand at both national and local levels; and,
- changes in aircraft fuel efficiency over time.

1.5 It also provides the information that is needed for detailed forecasts of other environmental impacts of aviation. These include:

- noise impacts of operations at specific airports;

[67] See DfT/Scott Wilson *Rules and Modelling: A Users Guide to SPASM, Edition 2,* April 2004.
[68] See DfT, *Passenger Forecasts: Additional Analysis*, Dec 2003, especially Chapter 4.

- local air quality impact assessments; and
- independent checks on the environmental forecasts of airport operators and airlines.

New Input Data

1.6 Fresh data on passenger origins and destinations, journey purposes, airport choice and interlining patterns have been input from the most recent CAA interviews of air passengers. This includes data from the surveys at:

- Heathrow, Gatwick, Stansted, Luton and Manchester (2003, 2004 & 2005);
- London City, Birmingham, Bristol, Cardiff, Nottingham East Midlands, Exeter, and Liverpool (2003); and
- Bournemouth, Leeds Bradford, Newcastle, Durham Tees Valley, Aberdeen Edinburgh, Glasgow, Inverness and Prestwick (2005).

1.7 At some of the other regional airports we include the CAA have not recently conducted interviews. Here we have updated older surveys in line with recent route level passenger statistics.

An Updated Base Year

1.8 The model has been re-calibrated so that it produces forecasts of passengers, aircraft movements (ATMs) and aircraft loads (passengers per ATM) which match as accurately possible route level statistical returns. This is a complex "bottom-up" process involving matching up model forecasts with statistical returns on passengers, aircraft and aircraft loads on almost one thousand routes. High levels of accuracy have been achieved at all airports across the country for both 2004 and 2005. The results of this process of validating against actual returns for 2005 are presented in Annex E.

1.9 Three "new" regional airports which have opened or grown significantly in passenger traffic since 2003 (Blackpool, Coventry and Robin Hood Doncaster-Sheffield)[69] have been added to the model. These airports compete with their neighbours and their inclusion improves the modelling of passengers at all airports in their regions. The model retains a 32nd airport slot, which can be used to test the impact of another airport in the system.

Transfer Passengers

[69] But both Coventry and Robin Hood airports are constrained in the forecasts by their current planning caps in addition to competition from other regional airports.

1.10 Dubai has been introduced as an international hub to improve the passenger allocation reflecting its growing role as a staging post for trips to the middle and far east from the UK.

Regional Growth Adjustment

1.11 Earlier versions of the DfT model had built in assumptions that traffic outside the South East would grow by 1 percentage point per annum above the national growth rate until 2015. By 2003 much of this regional "catch-up" process had taken place, particularly in the No Frills and charter sectors, and the regional uplifts were scaled down as appropriate by market sector.[70]

1.12 Between 2003-2005 there is evidence that the process continued to the extent that regional traffic achieved the rise in propensity to fly originally envisaged to be achieved by 2015. More recently there has also been evidence of a slowing in the rate of increase of regional traffic. We therefore now no longer apply a regional uplift to the forecasts, but retain facilities in the model to locally vary demand growth in sensitivity tests.

1.13 Faster future growth in the regions is likely to reflect the impact of constraints at the south east airports biting, while regional airports remain relatively unconstrained. This is an effect captured in the main airport allocation modelling.

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[70] See DfT, *Passenger Forecasts: Additional Analysis*, Dec 2003, paragraphs 4.6-4.7.

Annex E: Detailed Validation Results

1.1 Chapter 2 set out some of the results of our model's airport- and route-level validation. This annex reports in more detail:

a) The airport level validation results, for both passengers and ATMs
b) The distribution of passengers by route error band, split between international and domestic flights; and,
c) Scatter plots of actual and fitted passengers, ATMs, and loads, split between international and domestic flights.

a) Airport level: actual vs fitted passengers and ATMs, 2005

	Passengers (mppa)			ATMs (000 pa)		
Airport	Actual 2005	Model Prediction	Model Difference	Actual 2005	Model Prediction	Model Difference
Heathrow	67.7	68.1	0.4	474	473	-0.6
Gatwick	32.7	32.8	0.2	253	252	-1.3
Manchester	22.1	21.6	-0.5	218	205	-13.4
Stansted	22.0	22.3	0.3	180	180	-0.3
Birmingham	9.3	9.2	-0.1	114	114	0.0
Luton	9.1	8.9	-0.3	79	78	-0.6
Glasgow	8.8	9.1	0.4	100	97	-2.9
Edinburgh	8.4	8.5	0.1	119	118	-0.6
Bristol	5.2	5.6	0.4	64	65	1.1
Newcastle	5.2	5.3	0.1	57	54	-2.8
Belfast International	4.8	4.9	0.1	49	48	-0.3
Liverpool	4.4	4.5	0.1	50	48	-1.7
East Midlands	4.2	3.8	-0.4	54	51	-3.4
Aberdeen	2.9	2.8	0.1	94	84	10.1
Leeds Bradford	2.6	2.9	-0.3	36	41	-5.1
Prestwick	2.4	2.3	0.1	21	19	1.2
Belfast City	2.2	2.2	0.1	39	36	2.9
London City	2.0	2.0	0.0	61	57	-3.5
Southampton	1.8	1.9	0.0	44	45	-0.7
Cardiff Wales	1.8	1.8	-0.1	21	21	0.0
Teesside	0.9	1.0	-0.1	12	22	-9.6
Exeter	0.8	0.9	0.0	13	13	0.0
Bournemouth	0.8	0.9	-0.1	12	11	1.1
Coventry	0.7	0.7	0.0	14	9	5.1
Robin Hood Doncaste	0.6	0.6	0.0	5	6	-0.3
Inverness	0.6	0.7	-0.1	20	14	6.6
Norwich	0.5	0.6	0.0	20	16	3.6
Humberside	0.5	0.4	0.0	12	11	0.3
Blackpool	0.4	0.4	0.0	14	3	11.3
Newquay	0.3	0.4	-0.1	8	10	-1.3
Plymouth	0.2	0.2	0.0	7	6	1.0

b) Route level distribution of passengers by route error band, 2005

All flights (domestic and international)

Error band	Proportion of routes	Cumulative proportion
0%-5%	35%	35%
5%-10%	20%	55%
10%-20%	24%	80%
20%-30%	12%	91%
30%-40%	4%	95%
40%-50%	3%	98%
50%+	2%	100%

International flights

Error margin	Proportion of routes	Cumulative proportion
0%-5%	26%	26%
5%-10%	20%	46%
10%-20%	30%	76%
20%-30%	13%	89%
30%-40%	5%	94%
40%-50%	3%	97%
50%+	3%	100%

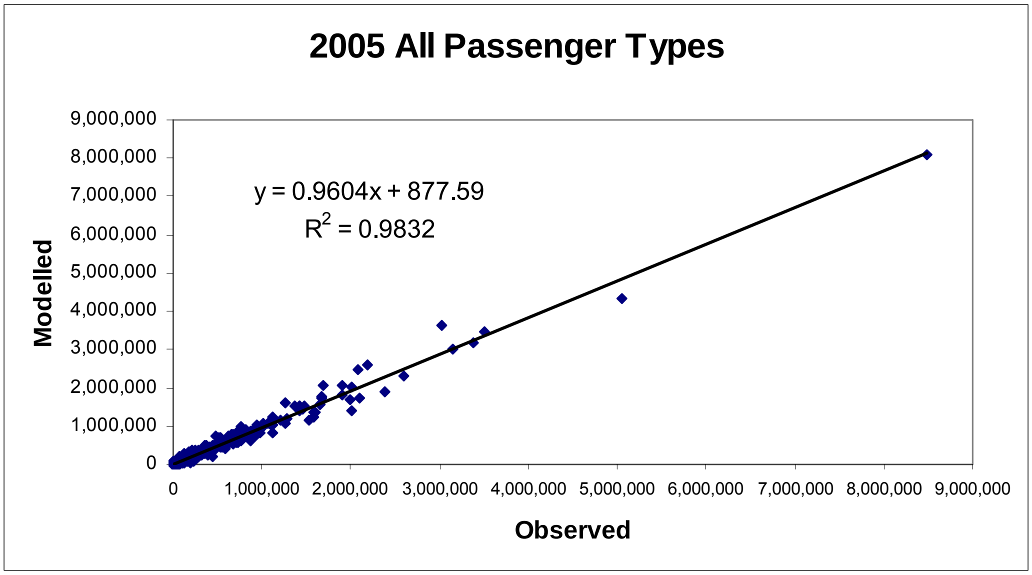
Domestic Flights

Error margin	Cumulative proportion of routes
0% to 5%	56%
5% to 10%	75%
10% to 20%	85%
20% to 30%	95%
30% to 40%	96%
40% to 50%	98%
>50%	100%

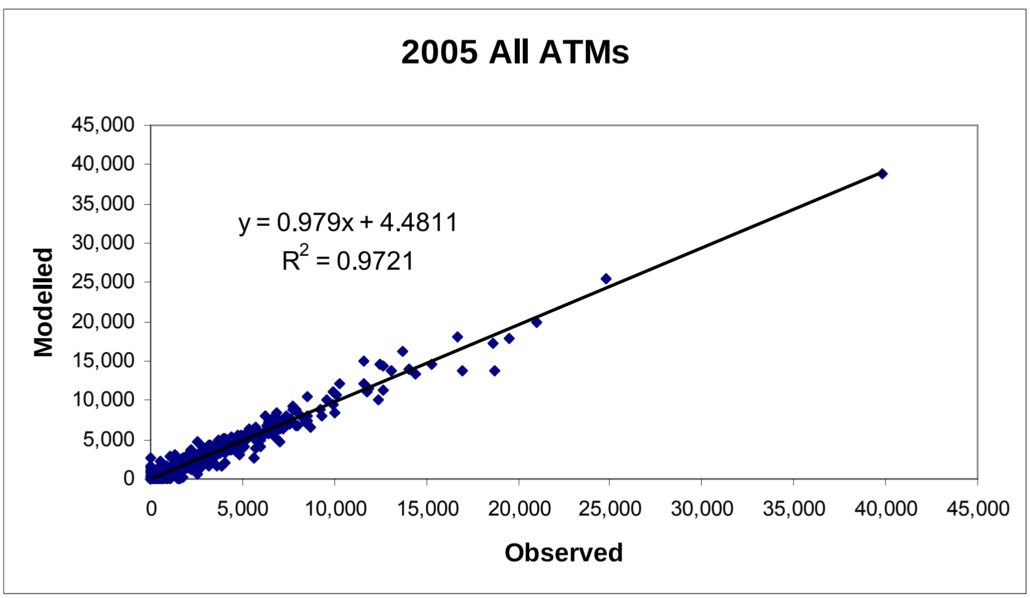
c) Route level scatter plots

All Flights (domestic and international)

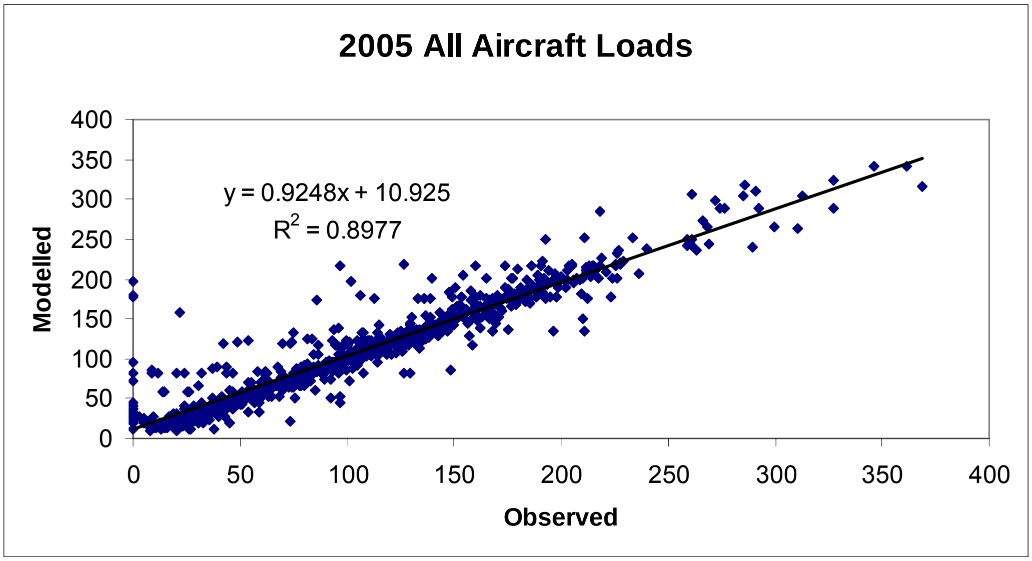
Passengers



ATMs

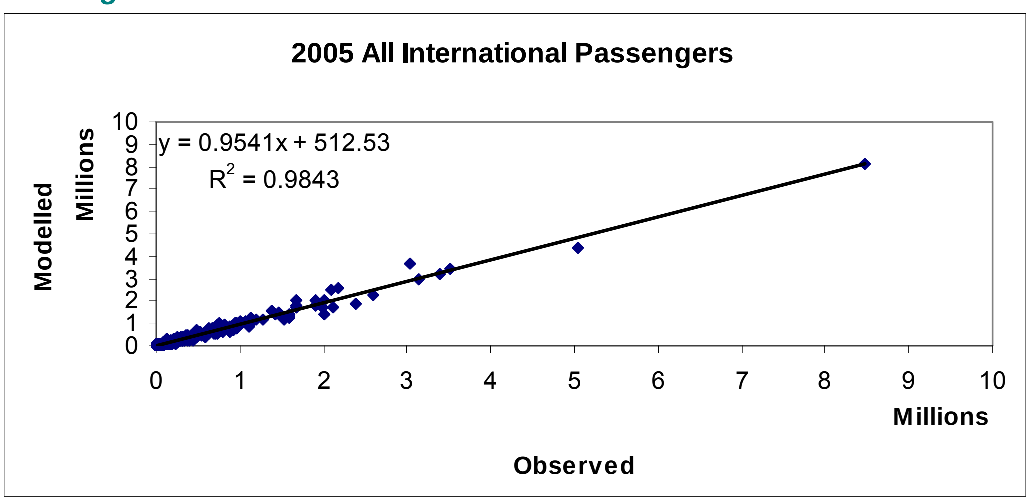


Loads

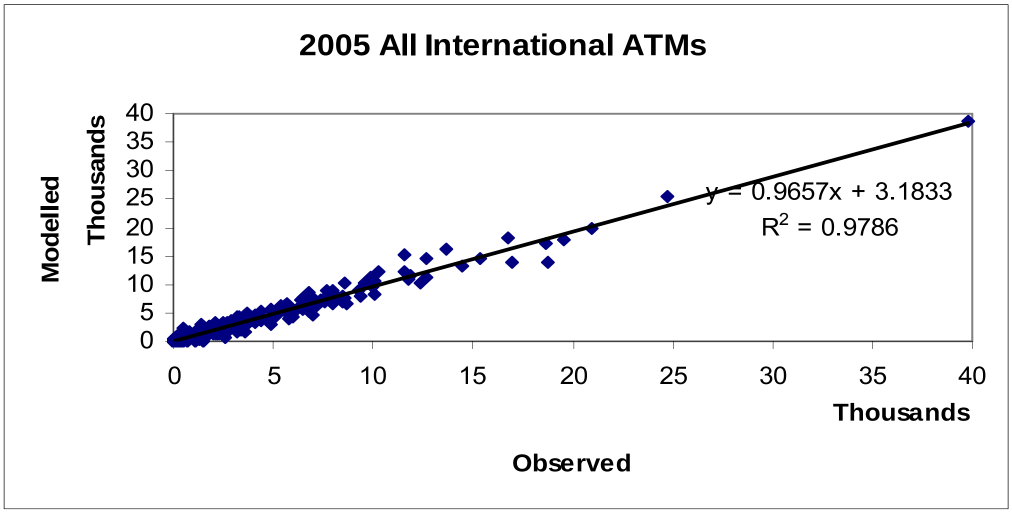


International flights

Passengers

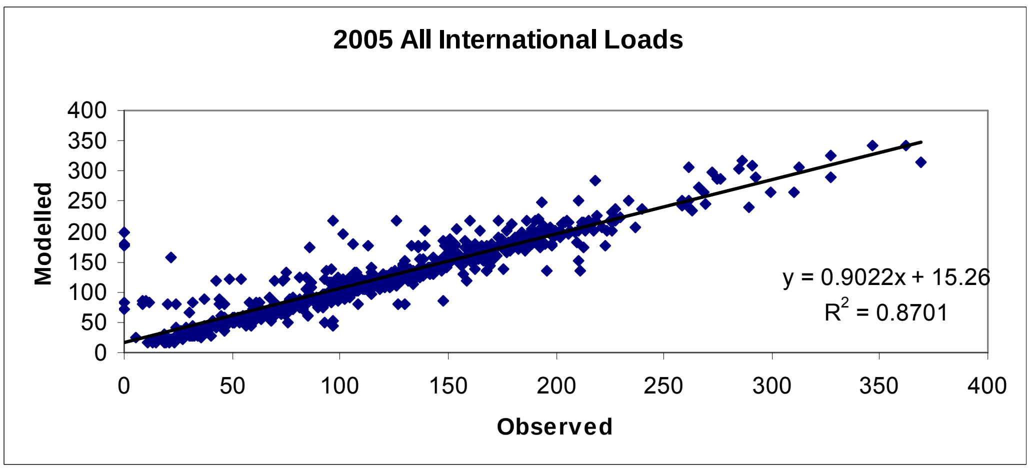


ATMs



2005 All International ATMs
Modelled
Thousands
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
Thousands
Observed
y = 0.9657x + 3.1833
R^2 = 0.9786

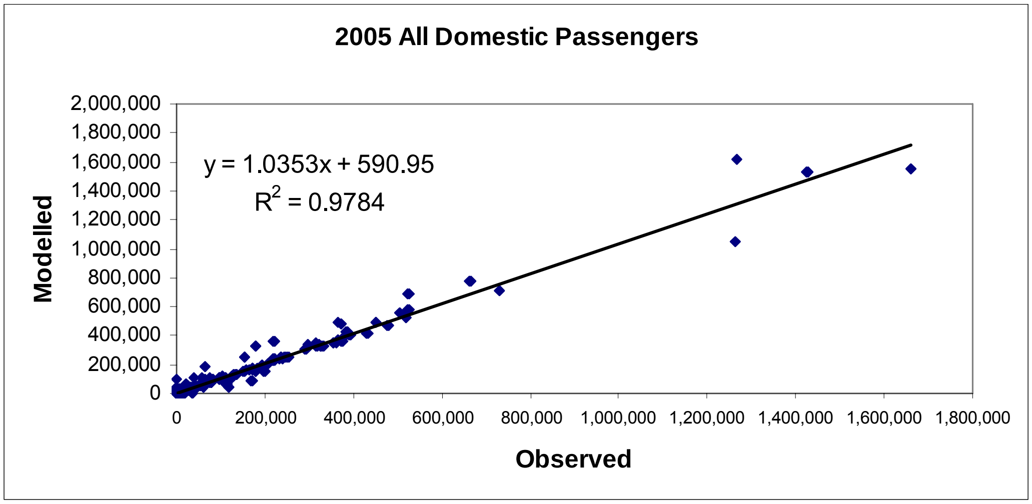
Loads



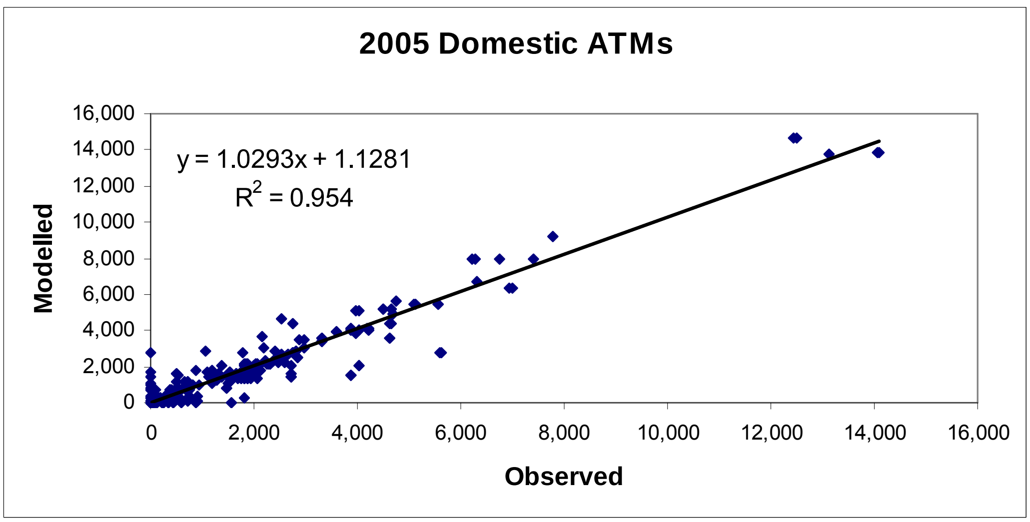
2005 All International Loads
Modelled
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Observed
y = 0.9022x + 15.26
R^2 = 0.8701

Domestic flights (scheduled)

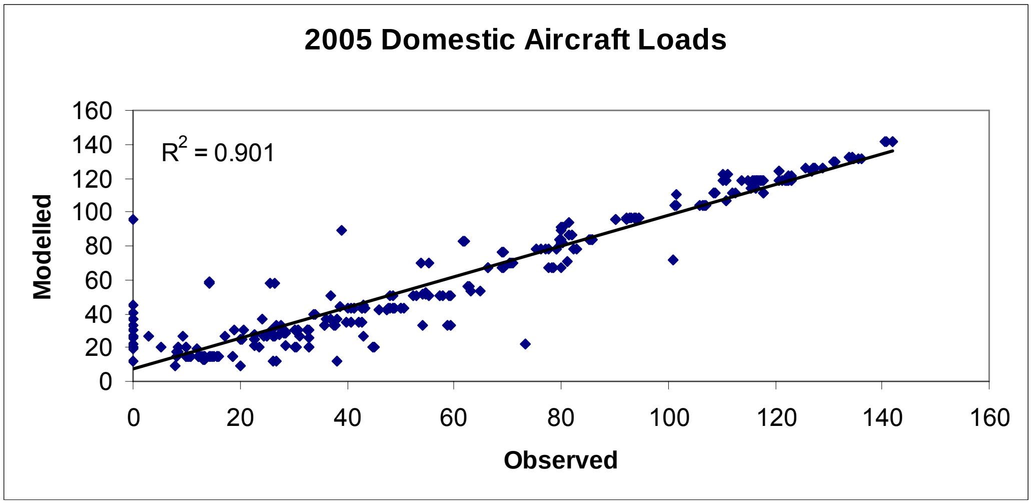
Passengers



ATMs



Loads



2005 Domestic Aircraft Loads
$R^2 = 0.901$
160
140
120
100
80
60
40
20
0
Modelled
0
20
40
60
80
100
120
140
160
Observed

Annex F: Airport demand forecasts

Introduction

1.1 Chapter 2 set out our method for forecasting air passenger demand, and the national and airport results. This annex sets out more detail of the airport forecasts.

1.2 As set out in chapter 2, the purpose of our forecasts is to inform strategic aviation policy. As such, it is necessary that the modelling accounts for the capacity and relative attractiveness of most of the airports offering commercial services. This results in forecasts of airport demand at each of these airports. These should be interpreted as the forecasts resulting from a modelling process necessary to provide a full picture of capacity and demands for the purpose of informing strategic aviation policy. The Air Transport White Paper set out airport capacity developments that the government supports. The forecasts should not in isolation be interpreted as supporting particular levels of demand at individual airports.

Airport passenger demand forecasts

1.3 Table F1 sets out our central forecast and range of passenger demand at each modelled airport, under the central 's12s2' scenario (see table 2.8 in chapter 2), in 2015 and 2030.

Table F1: Passenger demand forecasts at UK airports

	Low			Central			High		
Airport	2005	2015	2030	2005	2015	2030	2005	2015	2030
Heathrow	70	80	135	70	80	135	70	75	135
Gatwick	35	35	40	35	35	40	35	40	40
Manchester	20	30	45	20	30	45	20	35	50
Stansted	20	40	60	20	40	70	20	45	75
Birmingham	9	20	25	9	20	25	9	20	25
Glasgow	9	11	15	9	11	15	9	12	15
Luton	9	15	15	9	15	15	9	15	15
Edinburgh	8	13	20	8	13	20	8	13	20
Bristol	5	8	12	5	8	12	5	9	12
Newcastle	5	7	10	5	7	11	5	8	12
Belfast International	5	7	10	5	7	12	5	7	12
Liverpool	4	5	7	4	5	8	4	7	12
Nottingham East Midlands	4	6	10	4	7	11	4	8	15
Leeds/Bradford	3	4	6	3	4	6	3	4	7
Aberdeen	3	4	6	3	4	6	3	4	6
Prestwick	2	4	5	2	4	6	2	4	6
Belfast City	2	3	4	2	3	4	2	3	5
London City	2	3	4	2	3	4	2	3	4
Southampton	2	3	5	2	4	6	2	5	7
Cardiff	2	2	3	2	2	3	2	3	4
Durham Tees Valley	<1	<1	1	<1	<1	1	<1	1	1
Bournemouth	<1	2	4	<1	3	5	<1	3	6
Exeter	<1	1	2	<1	1	2	<1	2	2
Inverness	<1	1	2	<1	1	2	<1	1	2
Coventry	<1	2	2	<1	2	2	<1	2	2
Doncaster Sheffield	<1	<1	1	<1	2	2	<1	2	3
Norwich	<1	<1	<1	<1	<1	<1	<1	<1	1
Humberside	<1	<1	<1	<1	<1	<1	<1	<1	<1
Newquay	<1	<1	<1	<1	<1	<1	<1	<1	<1
Blackpool	<1	2	2	<1	2	3	<1	2	2
Plymouth	<1	<1	<1	<1	<1	<1	<1	<1	<1
TOTAL	230	310	450	230	320	480	230	335	505

Table Notes
1. 2005 figures are CAA actuals.
2. Range is underlying demand scenarios, not runway constraint options.
3. If throughput greater than 15m, throughput rounded to nearest 5m.
4. National total throughputs rounded to nearest 5m.
5. Modelled results Core s12s2 scenario (Stansted R2 in 2015, Heathrow R3 c. 2020).

1.4 Table F2 shows the airport demand forecasts for 2030 for some of the largest airports, under the central demand and the capacity scenarios supported by the Air Transport White Paper.

Table F2: Terminal passenger demand forecasts at main South East airports, by capacity scenario, 2030

		Heathrow	Gatwick	Stansted	Luton	London City	Total South East	Other	Total
s01	Planning System in SE	85	40	25	10	5	165	240	405
s02	Maximum Use	85	45	35	15	3	190	235	425
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	135	40	35	15	4	235	220	455
s07	Stansted R2 (480k in 2015)	90	45	75	15	4	225	220	445
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	135	40	70	15	4	270	210	480
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)	135	40	70	15	4	270	210	480
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)	135	40	70	15	4	270	215	480

Annex G: Detailed Demand and CO_2 Forecasts

Table G.1: Unconstrained terminal passengers by purpose and region

mppa		2010			2015			2020			2025			2030		
	2004 Base	Low	Central	High	Low	Central	High	Low	Central	High	Low	Central	High	Low	Central	High
INTERNATIONAL																
UK Business																
Short Haul	14	17	17	17	21	21	21	25	25	25	27	29	31	31	34	37
OECD	3	3	3	3	4	4	4	5	5	5	5	5	6	6	6	7
NIC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
LDC	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4
All Long Haul	5	6	6	6	7	7	7	8	8	8	9	10	10	10	11	12
All UK Business	19	23	23	23	28	28	28	33	33	33	36	38	41	41	45	49
UK Leisure																
Scheduled Short Haul	42	54	61	68	74	85	101	88	101	120	108	115	123	120	129	139
OECD	9	9	11	12	10	12	15	11	13	16	13	13	14	14	14	14
NIC	2	2	2	2	3	3	3	3	4	4	4	4	5	4	5	6
LDC	7	8	9	10	12	13	14	15	17	18	18	21	23	22	25	29
All Scheduled Long Haul	18	20	22	24	25	28	32	30	34	39	36	38	42	40	44	48
Short Haul Charter	32	32	34	35	32	33	35	31	32	34	32	32	32	31	31	31
Long Haul Charter	4	5	5	5	7	7	7	9	9	9	9	10	12	11	13	14
All Charter	36	37	39	40	38	40	41	40	41	43	41	42	43	42	43	45
All Short Haul	74	86	95	103	106	118	135	119	134	154	140	147	154	151	160	170
All Long Haul	22	25	27	29	32	35	39	38	42	47	45	49	53	51	56	63
All UK Leisure	95	112	122	133	138	153	174	157	176	201	185	196	208	201	216	233
Foreign Business																
Short Haul	10	11	11	11	13	13	13	14	14	14	15	16	16	17	18	18
OECD	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
NIC	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
LDC	1	2	2	2	3	3	3	5	5	5	6	6	7	8	8	9
All Long Haul	4	5	5	5	7	7	7	9	9	9	10	11	11	13	13	14
All Foreign Business	14	17	17	17	20	20	20	23	23	23	26	27	28	29	31	32
Foreign Leisure																
Short Haul	17	20	20	20	25	25	25	30	30	30	32	36	40	38	43	49
OECD	6	7	7	7	8	8	8	9	9	9	9	9	9	9	10	10
NIC	1	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5
LDC	3	4	4	4	6	6	6	7	7	7	8	9	9	10	10	11
All Long Haul	10	13	13	13	16	16	16	19	19	19	21	22	23	24	25	26
All Foreign Leisure	27	32	32	32	41	41	41	49	49	49	53	58	62	61	68	75
International to International Transfer	22	27	27	27	31	31	31	35	35	35	37	39	40	41	43	45
Total UK International	114	134	144	155	165	181	202	190	209	234	221	234	249	242	261	282
Total Foreign International	64	76	76	76	91	91	91	107	107	107	116	123	130	132	141	152
Total International	**177**	**210**	**220**	**231**	**257**	**272**	**293**	**297**	**316**	**341**	**337**	**357**	**379**	**374**	**402**	**434**
DOMESTIC (Internal "end to end")																
Business	20	25	25	26	31	31	31	36	36	36	39	42	46	45	50	55
Leisure	17	24	24	24	28	28	29	33	33	34	34	37	40	38	41	45
Miscellaneous	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	4
Total Domestic	**38**	**51**	**51**	**51**	**61**	**61**	**62**	**71**	**71**	**73**	**76**	**82**	**89**	**85**	**94**	**104**
GRAND TOTAL	**216**	**261**	**271**	**283**	**318**	**333**	**355**	**369**	**387**	**414**	**412**	**439**	**468**	**459**	**496**	**538**

Table Notes
1. 2004 figures are actuals.
2. International figures are terminal passengers and count domestic interlining passengers changing at hub airports.
3. Scheduled figures include both "full service" and "no frills" airlines.
4. Domestic passengers exclude those using domestic flights to connect to international flights at a hub airport.
5. Miscellaneous includes passengers at minor airports not surveyed in the source data and other non-surveyed passengers such as domestic charters, oil rig traffic etc. most, but not all, will be domestic.

Table G.2: Constrained terminal passengers, by journey purpose and year, South East airports

2005	Heathrow		Gatwick		Stansted		Luton		London City		Total London		Other Airports		National	
UK Business	11	24%	3	11%	3	14%	1	15%	1	34%	19	18%	20	22%	40	20%
UK Leisure	19	40%	20	68%	12	54%	5	58%	1	35%	57	52%	59	64%	116	57%
Foreign Business	7	15%	1	4%	1	7%	0	5%	0	11%	10	9%	4	4%	14	7%
Foreign Leisure	10	22%	5	17%	6	26%	2	21%	0	20%	23	21%	10	10%	33	16%
International-International Transfer	20		3		0		0		0		24		0		24	
Total	68		33		22		9		2		134		93		227	

2015	Heathrow		Gatwick		Stansted		Luton		London City		Total London		Other Airports		National	
UK Business	14	25%	4	11%	5	12%	2	13%	1	32%	26	17%	30	21%	56	19%
UK Leisure	23	41%	21	64%	21	54%	9	57%	1	38%	76	51%	90	63%	166	57%
Foreign Business	8	14%	2	5%	3	7%	1	6%	0	12%	14	9%	7	5%	21	7%
Foreign Leisure	12	21%	7	20%	11	27%	4	24%	1	18%	33	22%	16	11%	50	17%
International-International Transfer	22		3		0		1		0		26		0		27	
Total	79		36		40		17		3		175		144		319	

2030	Heathrow		Gatwick		Stansted		Luton		London City		Total London		Other Airports		National	
UK Business	24	25%	4	11%	9	12%	3	15%	1	36%	41	18%	48	23%	89	20%
UK Leisure	40	40%	24	63%	39	55%	9	56%	1	35%	113	49%	128	61%	241	55%
Foreign Business	13	13%	2	5%	4	6%	1	6%	0	12%	21	9%	11	5%	32	7%
Foreign Leisure	22	22%	8	21%	19	27%	4	23%	1	17%	54	24%	25	12%	78	18%
International-International Transfer	36		2		1		0		0		40		0		40	
Total	136		41		72		16		4		269		211		480	

Table G.3: Constrained terminal passengers, by international/domestic, scheduled/charter, and year

mppa	Heathrow	Gatwick	Stansted	Luton	London City	London total	London share	Other Airports	Total
2005									
International Scheduled	63	21	18	6	1	110	73%	41	151
International Charter	0	10	1	1	0	11	32%	22	34
Domestic (excl. Transfers)	5	3	3	2	0	12	29%	30	42
Total	68	33	22	9	2	134	59%	93	227
2010									
International Scheduled	68	23	24	9	3	126	69%	56	182
International Charter	0	9	1	0	0	11	31%	24	35
Domestic (excl. Transfers)	6	3	3	2	1	15	29%	36	51
Total	74	36	28	11	3	152	57%	116	268
2015									
International Scheduled	72	24	36	15	3	149	66%	79	227
International Charter	0	9	2	0	0	11	31%	25	36
Domestic (excl. Transfers)	7	3	3	2	1	16	29%	40	56
Total	79	36	40	17	3	175	55%	144	319
2020									
International Scheduled	86	25	48	15	2	176	65%	94	270
International Charter	0	9	2	0	0	12	32%	26	37
Domestic (excl. Transfers)	8	4	5	2	1	20	29%	49	69
Total	94	38	55	17	3	207	55%	168	376
2025									
International Scheduled	109	26	55	14	2	206	66%	106	312
International Charter	0	9	2	0	0	12	32%	26	38
Domestic (excl. Transfers)	10	5	5	3	1	24	30%	56	80
Total	119	40	62	17	3	241	56%	189	430
2030									
International Scheduled	124	26	64	13	3	231	65%	122	353
International Charter	0	9	3	0	0	12	31%	27	39
Domestic (excl. Transfers)	11	5	6	3	1	26	29%	63	89
Total	136	41	72	16	4	269	56%	212	481

Table Notes
1. Passengers are counted at the 31 UK airports included in the DfT model.
2. All figures are modelled, including 2005.
3. Modelled results from the Central Demand Case, Core s12s2 scenario (Stansted R2 in 2015, Heathrow R3 c. 2020).
4. International passengers include transfer passengers counted as additional arrivals and departures at the hub airport
5. Domestic passengers are those starting and finishing the journey in the UK..

Table G.4: Constrained terminal passengers, by domestic/short haul/long haul and year, South East airports only

mppa

2005	Heathrow	Gatwick	Stansted	Luton	Total
Long Haul	33	9	0	0	42
Short Haul	31	22	19	7	79
Domestic	5	3	3	2	13
Total	68	33	22	9	132
Long Haul Share	*49%*	*27%*	*0%*	*0%*	*32%*
2010					
Long Haul	35	11	0	0	46
Short Haul	33	22	25	9	89
Domestic	6	3	3	2	14
Total	74	36	28	11	149
Long Haul Share	*47%*	*31%*	*0%*	*0%*	*31%*
2015					
Long Haul	39	13	0	0	52
Short Haul	33	20	37	15	105
Domestic	7	3	3	2	15
Total	79	36	40	17	172
Long Haul Share	*49%*	*36%*	*0%*	*0%*	*30%*
2020					
Long Haul	46	15	0	0	61
Short Haul	39	19	50	15	123
Domestic	8	4	5	2	19
Total	94	38	55	17	204
Long Haul Share	*49%*	*39%*	*0%*	*0%*	*30%*
2025					
Long Haul	56	16	0	0	72
Short Haul	54	20	57	14	145
Domestic	10	5	5	3	23
Total	119	40	62	17	238
Long Haul Share	*47%*	*40%*	*0%*	*0%*	*30%*
2030					
Long Haul	63	17	0	0	80
Short Haul	61	19	66	13	159
Domestic	11	5	6	3	25
Total	136	41	72	16	265
Long Haul Share	*46%*	*41%*	*0%*	*0%*	*30%*

Table Notes

1. All figures are modelled, including 2005.
2. Modelled results from the Central Demand Case, Core s12s2 scenario (Stansted R2 in 2015, Heathrow R3 c. 2020)
3. Long haul includes medium haul e.g. United States and Middle East, but excludes Eastern Europe and Russia.

Table G.5: Constrained terminal passengers, journey purpose and destination detail, main airports

2005	Domestic (Excl. intl transfers)					Short Haul						Long Haul						Grand
mppa	UKBus	UKLei	Fo Bus	Fo Lei	Total	UKBus	UKLei	Fo Bus	Fo Lei	Ito I	Total	UKBus	UKLei	Fo Bus	Fo Lei	Ito I	Total	Total
Heathrow	3	2	0	0	5	5	8	4	5	9	31	3	9	3	6	11	33	68
Gatwick	1	1	0	0	3	2	14	1	3	2	22	1	5	0	2	1	9	33
Stansted	1	2	0	0	3	2	10	1	5	0	19	0	0	0	0	0	0	22
Luton	1	1	0	0	2	1	4	0	2	0	7	0	0	0	0	0	0	9
London City	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2
London Total	6	6	0	1	12	9	37	7	16	11	80	4	14	4	7	12	41	134
Manchester	2	1	0	0	3	1	11	1	2	0	15	0	3	0	1	0	4	22
Birmingham	1	1	0	0	1	1	5	1	1	0	7	0	1	0	0	0	1	9
Glasgow	2	2	0	0	4	0	3	0	0	0	4	0	1	0	0	0	1	9
Edinburgh	3	2	0	0	5	0	1	0	0	0	3	0	0	0	0	0	1	9
Bristol	1	1	0	0	1	0	3	0	1	0	4	0	0	0	0	0	0	6
Newcastle	1	1	0	0	2	0	3	0	0	0	3	0	0	0	0	0	0	5
Belfast International	1	2	0	0	3	0	1	0	0	0	1	0	0	0	0	0	0	5
Liverpool	0	1	0	0	1	0	2	0	1	0	3	0	0	0	0	0	0	5
East Midlands	0	0	0	0	1	0	2	0	0	0	3	0	0	0	0	0	0	4
Other Airports in Model	4	4	0	0	8	1	8	1	2	0	12	0	0	0	0	0	1	21
Regional Total	15	14	0	1	30	5	40	3	7	0	56	1	5	0	1	0	8	93
National Total	21	20	1	1	42	14	78	10	23	11	136	5	19	4	9	12	49	227

2015	Domestic (Excl. intl transfers)					Short Haul						Long Haul						Grand
mppa	UKBus	UKLei	Fo Bus	Fo Lei	Total	UKBus	UKLei	Fo Bus	Fo Lei	Ito I	Total	UKBus	UKLei	Fo Bus	Fo Lei	Ito I	Total	Total
Heathrow	5	2	0	0	7	5	9	4	5	10	33	4	12	4	7	13	39	79
Gatwick	1	2	0	0	3	1	13	1	3	1	20	1	7	1	3	2	13	36
Stansted	1	2	0	0	3	4	20	3	10	0	37	0	0	0	0	0	0	40
Luton	1	1	0	0	2	1	8	1	4	1	15	0	0	0	0	0	0	17
London City	0	0	0	0	1	1	1	0	1	0	3	0	0	0	0	0	0	3
London Total	8	7	0	1	16	13	51	9	23	12	107	5	19	4	10	14	52	175
Manchester	3	1	0	0	4	2	16	1	2	0	21	1	5	0	1	0	6	32
Birmingham	1	1	0	0	2	1	8	1	1	0	12	1	3	0	1	0	5	18
Glasgow	3	2	0	0	5	0	4	0	1	0	5	0	1	0	0	0	1	11
Edinburgh	4	3	0	0	8	1	2	0	1	0	4	0	1	0	0	0	1	13
Bristol	1	1	0	0	2	1	5	0	1	0	6	0	0	0	0	0	0	8
Newcastle	1	1	0	0	2	0	4	0	1	0	5	0	0	0	0	0	0	7
Belfast International	2	2	0	0	4	0	1	1	0	0	3	0	0	0	0	0	0	7
Liverpool	0	1	0	0	1	0	2	0	1	0	4	0	0	0	0	0	0	5
East Midlands	0	0	0	0	1	1	4	0	1	0	6	0	0	0	0	0	0	7
Other Airports in Model	5	5	0	0	11	2	16	1	4	0	23	0	0	0	0	0	1	35
Regional Total	20	18	0	1	40	9	62	6	12	0	89	2	10	1	3	0	15	144
National Total	28	25	1	2	56	22	112	15	35	12	196	6	28	5	13	14	67	319

2030	Domestic (Excl. intl transfers)					Short Haul						Long Haul						Grand
mppa	UKBus	UKLei	Fo Bus	Fo Lei	Total	UKBus	UKLei	Fo Bus	Fo Lei	Ito I	Total	UKBus	UKLei	Fo Bus	Fo Lei	Ito I	Total	Total
Heathrow	7	4	0	0	11	10	16	8	10	16	61	7	19	6	12	20	63	136
Gatwick	2	3	0	0	5	1	13	1	3	1	19	1	8	1	4	2	17	41
Stansted	2	3	0	0	6	7	35	4	19	1	66	0	0	0	0	0	0	72
Luton	1	2	0	0	3	1	7	1	3	0	13	0	0	0	0	0	0	16
London City	1	0	0	0	1	1	1	0	1	0	3	0	0	0	0	0	0	4
London Total	13	12	0	1	26	20	74	14	36	18	163	8	28	7	17	21	80	269
Manchester	4	2	0	0	7	3	21	2	3	0	29	1	7	1	2	0	10	46
Birmingham	1	1	0	0	3	2	10	1	2	0	16	1	4	1	1	0	7	25
Glasgow	5	3	0	0	8	1	5	0	1	0	6	0	1	0	1	0	2	16
Edinburgh	6	5	0	0	12	1	4	1	1	0	7	0	1	0	1	0	2	21
Bristol	1	2	0	0	3	1	7	0	1	0	9	0	0	0	0	0	0	12
Newcastle	2	2	0	0	4	1	5	0	1	0	7	0	0	0	0	0	0	11
Belfast International	2	4	0	0	7	0	2	1	0	0	4	0	0	0	0	0	0	11
Liverpool	1	1	0	0	2	1	3	1	1	0	7	0	0	0	0	0	0	8
East Midlands	1	1	0	0	1	1	6	1	1	0	10	0	0	0	0	0	0	11
Other Airports in Model	8	8	0	0	17	3	21	2	5	0	32	0	0	0	0	0	1	49
Regional Total	31	29	1	2	63	14	84	9	18	0	125	2	14	1	4	0	22	211
National Total	44	41	1	3	89	34	158	23	54	19	288	10	42	8	21	21	103	480

Table notes
1. Domestic total only includes "end to end" domestic travel and excludes transfers
2. Modelled results from the Central Demand Case, Core s12s2 scenario (Stansted R2 in 2015, Heathrow R3 c. 2020)
3. Long haul includes "medium haul" destinations to Midle East and North America.
4. UK to Channel Isles counted as short haul

Table G.6: Constrained terminal passengers, impact of option on regional passengers and surface journeys

	Maximum Use			Main Case (s12s2)		
Surface to SE Airports	2005	2015	2030	2005	2015	2030
Northern Ireland	0	0	0	0	0	0
Scotland	0	0	0	0	0	0
North	1	1	0	1	1	1
Midlands	5	5	2	5	6	8
Wales	1	1	0	1	1	1
South West	5	5	4	5	6	8
Regional Total	12	13	7	12	14	19
SE Passengers	93	133	167	93	136	212
Total Surface Passengers at SE Airports	***105***	***146***	***174***	***105***	***149***	***231***
Other Airports						
Northern Ireland	7	10	15	7	10	16
Scotland	24	33	47	24	33	51
North	33	49	71	33	49	72
Midlands	14	23	38	14	23	34
Wales	4	6	9	4	6	8
South West	7	12	20	7	12	18
Regional Total	88	133	199	88	132	199
SE Passengers	2	6	23	2	5	6
Total Surface Passengers at Other Airports	***90***	***139***	***222***	***90***	***138***	***205***
I to I Interliners at SE Airports	24	26	22	24	26	40
I to I Interliners at Regional Airports	0	1	4	0	0	0
Domestic Interliners at SE Airports	8	4	0	8	5	5
Domestic Interliners at Regional Airports	0	0	0	0	0	0
Grand Total	***227***	***317***	***423***	***227***	***318***	***481***
Passengers with Regional O-Ds						
Northern Ireland	7	10	15	7	10	16
Scotland	24	33	47	24	33	51
North	34	50	71	34	50	73
Midlands	19	29	40	19	29	42
Wales	4	7	9	4	7	9
South West	12	18	24	12	18	26
South East	95	140	190	95	141	219
Total Surface Passengers	***195***	***285***	***397***	***195***	***287***	***436***

Notes

1. SE Regional Airports: Heathrow, Gatwick, Stansted, Luton, London City, Southampton and Norwich.
2. SE Passengers are from London, South East and Eastern Regions.
3. Domestic Interliners are counted as surface passengers to first airport and interliners (*2) at the hub.
4. Passengers may not total exactly as a result of rounding to nearest million.
5. 2005 Figures are modelled.
6. All Figures include only the 31 modelled UK airports.

Table G.7: Air Transport Movements, by domestic/international, scheduled/charter, passenger/freight, and year

ATM 000s	International Scheduled	International Charter	Domestic	Freight	Total
2005	1,200	170	770	70	2,210
2010	1,430	180	840	70	2,520
2015	1,770	180	860	80	2,890
2020	2,050	190	1,020	90	3,350
2025	2,270	190	1,090	100	3,650
2030	2,510	190	1,160	120	3,980

Table Notes
1. ATMs are counted at the 31 UK airports included in the DfT model.
2. All figures are modelled, including 2005.
3. Modelled results from the Central Demand Case, Core s12s2 scenario (STN R2 in 2015, LHR R3 c. 2020)
4. ATMs exclude general aviation, air taxis, positional, diplomatic, military and other miscellaneous flights.
5. ATMs rounded to the nearest 10,000, total may not sum due to this rounding.

Table G.8: Air Transport Movements, by South East airport and year

ATM 000s	Heathrow	Gatwick	Stansted	Luton	London City	Total London	London Share	Other Airports	Total
2005	470	250	180	80	60	1,040	47%	1,170	2,210
2010	490	260	220	90	80	1,150	46%	1,380	2,520
2015	480	260	280	130	80	1,240	43%	1,650	2,890
2020	550	260	400	130	70	1,410	42%	1,950	3,350
2025	660	260	440	130	70	1,550	42%	2,090	3,650
2030	720	260	490	120	80	1,680	42%	2,300	3,980

Table Notes
1. Other ATMs are counted at the remaining 26 UK airports included in the DfT model.
2. All figures are modelled, including 2005-2006
3. Individual airports may marginally exceed runway capacity in a system-wide equilibrium solution.
4. Model results for the Central Demand Case, Core s12s2 scenario (Stansted R2 in 2015, Heathrow R3 c. 2020)
5. ATMs exclude general aviation, air taxis, positional, diplomatic, military and other miscellaneous flights.
6. ATMs rounded to the nearest 10,000, totals may not sum due to this rounding.

Table G.9: CO2 emissions by UK airport, 2030/2050, central and range

	2030			2050		
	Low	**Central**	High	Low	**Central**	High
Heathrow	24	25	26	20	22	24
Gatwick	5	5	6	4	5	5
Manchester	5	5	6	5	5	6
Stansted	3	3	4	3	3	4
Birmingham	3	3	3	2	3	3
Edinburgh	2	2	2	2	3	3
Glasgow	1	1	2	1	2	2
Luton	1	1	1	1	1	1
Bristol	1	1	1	1	1	1
Newcastle	1	1	1	1	1	1
Belfast International	1	1	1	1	1	1
Nottingham East Midlands	1	1	1	1	1	1
Aberdeen	-	1	1	1	1	1
Liverpool	-	-	1	-	1	1
Southampton	-	-	1	-	1	1
Leeds/Bradford	-	-	-	-	1	1
Bournemouth	-	-	-	-	-	-
London City	-	-	-	-	-	-
Prestwick	-	-	-	-	-	-
Cardiff	-	-	-	-	-	1
Belfast City	-	-	-	-	-	-
Doncaster Sheffield	-	-	-	-	-	-
Durham Tees Valley	-	-	-	-	-	-
Coventry	-	-	-	-	-	-
Inverness	-	-	-	-	-	-
Blackpool	-	-	-	-	-	-
Exeter	-	-	-	-	-	-
Norwich	-	-	-	-	-	-
Plymouth	-	-	-	-	-	-
Newquay	-	-	-	-	-	-
Humberside	-	-	-	-	-	-
Ground	2	2	2	2	2	2
Freight	2	2	2	3	4	4
Total	55	59	63	53	60	67

Table Notes
1. Low CO2 assumes low demand scenario and the high fuel efficiency case (e3a)
2. High CO2 assumes high demand scenario and the low fuel efficeincy case (e2a)
3. All cases are for the option 's12s2': Stansted R2 in 2015, Heathrow R3 around 2020.
4. Airports sorted on 2030 central CO_2 emissions.
5. CO2 emissions from UK departures only.
6. Total includes about +1MtCO_2 uprate to ensure consistency with DEFRA 2005 outturn estimate
7. "-" means non-zero, but rounds to zero at 0dp

Table G.10: CO_2 emissions at airport level 2005 and 2030 detailed

	Total CO_2 ($mtCO_2$) in 2005	Share of 2005 Total CO_2	Total CO2 (mtCO2) in 2030	Share of 2030 Total CO2
Heathrow	18.2	48.7%	24.9	42.3%
Gatwick	4.8	12.7%	5.4	9.2%
Manchester	2.7	7.2%	5.0	8.5%
Stansted	1.4	3.6%	3.3	5.7%
Birmingham	1.0	2.7%	3.0	5.1%
Edinburgh	0.8	2.2%	1.8	3.1%
Glasgow	1.0	2.7%	1.5	2.5%
Luton	0.6	1.7%	0.9	1.5%
Bristol	0.4	1.2%	0.7	1.3%
Newcastle	0.4	1.1%	0.7	1.2%
Belfast International	0.4	1.0%	0.7	1.2%
Nottingham East Midlands	0.3	0.8%	0.6	1.0%
Aberdeen	0.3	0.7%	0.5	0.9%
Liverpool	0.3	0.8%	0.5	0.8%
Southampton	0.2	0.4%	0.4	0.8%
Leeds/Bradford	0.2	0.6%	0.4	0.6%
Bournemouth	0.1	0.2%	0.4	0.6%
London City	0.2	0.5%	0.3	0.5%
Prestwick	0.1	0.4%	0.3	0.4%
Cardiff	0.2	0.5%	0.3	0.4%
Belfast City	0.2	0.4%	0.3	0.4%
Doncaster Sheffield	0.0	0.1%	0.2	0.4%
Durham Tees Valley	0.1	0.3%	0.2	0.3%
Coventry	0.1	0.2%	0.2	0.3%
Inverness	0.1	0.2%	0.2	0.3%
Blackpool	0.0	0.1%	0.1	0.3%
Exeter	0.1	0.2%	0.1	0.2%
Norwich	0.1	0.2%	0.1	0.2%
Plymouth	0.0	0.1%	0.0	0.1%
Newquay	0.0	0.1%	0.0	0.0%
Humberside	0.0	0.1%	0.0	0.0%
Ground	1.4		2.2	
Freight	0.6		2.4	
Total (incl. DEFRA uprate)	37.5		58.9	

Table Notes

1. Total Includes around +1 $MtCO_2$ adjustment to ensure consistency with DEFRA outturn
2. CO_2 counted for UK departures only.
3. Option 's12s2': Stansted R2 in 2015, Heathrow R3 around 2020.
4. Table sorted by CO_2 in 2030.

Table G.11: ATMs (short vs long haul), available seat-kms, average flight length, and CO2 emissions (short vs long haul), by UK airport, 2005

2005	Short Haul & Domestic ATMs (000s)	Long Haul ATMs (000s)	Available Seat Kms (m)	Average Flight Length (km)	Short Haul & Domestic CO_2 ($mtCO_2$)	Long Haul CO_2 ($mtCO_2$)	Total CO_2 ($mtCO_2$)
Heathrow	333	139	419,725	2,837	3	16	18
Gatwick	212	38	122,369	2,025	2	3	5
Manchester	183	18	70,850	1,549	1	1	3
Stansted	167	1	38,034	1,150	1	0	1
Birmingham	109	4	22,295	1,144	1	0	1
Glasgow	91	5	20,736	1,058	1	0	1
Luton	76	0	15,793	1,136	1	0	1
Edinburgh	110	2	10,753	683	1	0	1
Bristol	64	0	9,760	944	0	0	0
Newcastle	53	0	9,543	980	0	0	0
Nottingham East Midlands	33	0	7,838	1,180	0	0	0
Liverpool	48	0	6,809	818	0	0	0
Belfast International	43	1	5,942	755	0	0	0
Cardiff	20	0	4,357	1,124	0	0	0
Leeds/Bradford	41	0	4,186	692	0	0	0
Prestwick	18	0	3,978	1,120	0	0	0
Aberdeen	83	0	3,084	409	0	0	0
London City	60	0	2,537	542	0	0	0
Durham Tees Valley	21	0	1,964	556	0	0	0
Southampton	45	0	1,888	481	0	0	0
Bournemouth	9	0	1,759	1,094	0	0	0
Coventry	8	0	1,540	1,229	0	0	0
Belfast City	36	0	1,444	345	0	0	0
Exeter	12	0	1,436	813	0	0	0
Doncaster Sheffield	5	0	1,364	1,501	0	0	0
Norwich	16	0	1,056	577	0	0	0
Humberside	11	0	815	501	0	0	0
Inverness	15	0	720	440	0	0	0
Blackpool	4	0	479	776	0	0	0
Newquay	10	0	232	270	0	0	0
Plymouth	6	0	110	366	0	0	0
Total	1,942	207	793,397	1,496	14	20	34
Total including freight, ground delay emissions and adjustment to DEFRA 2005 estimate							37.5

Notes
1. Seat-Kms and average distances are next stop only.
2. Distances are Great Circle and uprated by 9% for indirect routeing.
3. CO_2 emissions from UK departures only.
4. CO_2 emissions exclude freight and ground (delay) emissions.
5. Airports sorted on descending available seat-kms.
6. "-" means non-zero, but rounds to zero at 0dp.

Table G.12: ATMs (short vs long haul), available seat-kms, average flight length, and CO2 emissions (short vs long haul), by UK airport, 2030

2030	Short Haul & Domestic ATMs (000s)	Long Haul ATMs (000s)	Available Seat-Kms (m)	Average Flight Length (km)	Short Haul & Domestic CO_2 ($mtCO_2$)	Long Haul CO_2 ($mtCO_2$)	Total CO_2 ($mtCO_2$)
Heathrow	507	211	765,717	2,943	3	21	25
Gatwick	185	74	190,325	2,660	1	4	5
Manchester	341	43	169,738	1,741	2	3	5
Stansted	470	0	114,886	1,198	3	0	3
Birmingham	193	39	94,916	1,783	1	2	3
Glasgow	149	10	43,232	1,172	1	1	1
Edinburgh	209	13	37,237	1,007	1	1	2
Luton	120	0	28,730	1,238	1	0	1
Bristol	125	0	18,799	933	1	0	1
Newcastle	104	0	18,427	1,009	1	0	1
Nottingham East Midlands	98	1	17,083	1,065	1	0	1
Belfast International	96	3	15,081	874	1	0	1
Liverpool	101	0	10,122	864	0	0	0
Bournemouth	53	0	9,319	1,394	0	0	0
Leeds/Bradford	72	0	8,651	848	0	0	0
Prestwick	35	0	8,490	1,201	0	0	0
Aberdeen	121	1	7,595	623	1	0	1
Doncaster Sheffield	21	0	6,668	1,918	0	0	0
Southampton	95	0	6,656	693	0	0	0
Cardiff	38	1	6,583	1,026	0	0	0
London City	80	0	6,437	721	0	0	0
Blackpool	18	0	5,428	1,515	0	0	0
Coventry	20	0	5,179	1,564	0	0	0
Durham Tees Valley	44	0	3,243	757	0	0	0
Exeter	23	0	3,019	925	0	0	0
Belfast City	55	0	2,412	345	0	0	0
Inverness	32	0	1,778	450	0	0	0
Norwich	27	0	1,331	570	0	0	0
Humberside	11	0	379	367	0	0	0
Newquay	10	0	235	243	0	0	0
Plymouth	9	0	203	370	0	0	0
Total	3,463	396	1,607,899	1,590	22	31	53
Total including freight, ground delay emissions and adjustment to DEFRA 2005 estimate							58.9

Notes
1. Seat-Kms and average distances are next stop only.
2. Distances are Great Circle and uprated by 9% for indirect routeing.
3. Option 's12s2': Stansted R2 in 2015, HeathrowR3 around 2020.
4. CO_2 emissions from UK departures only.
5. CO_2 emissions exclude freight and ground (delay) emissions.
6. Airports sorted on descending available seat-kms.
7. "-" means non-zero, but rounds to zero at 0dp.

Table G.13: Carbon dioxide emissions by South East Airport, by development scenario, 2030

Code	Scenario	Heathrow	Gatwick	Stansted	Luton	London City	Total South East	Other Airports	Passenger ATM Ground emissions	Freight Aircraft	Total CO2
s01	Planning System in SE	16	4	1	1	0	22	23	2	2	51
s02	Maximum Use	16	6	2	1	0	26	22	2	2	53
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	25	4	2	1	0	32	19	2	2	57
s07	Stansted R2 (480k in 2015)	17	7	3	1	0	29	20	2	2	54
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	25	5	3	1	0	35	18	2	2	59
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k in 2020, rising to 702k in 2030)	25	5	3	1	0	35	18	2	2	59
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020) then R3 (605k in 2020, rising to 702k in 2030)	25	5	3	1	0	35	18	2	2	59

Table Notes
1.Total Includes around +1MtCO_2 adjustment to ensure consistency with DEFRA outturn estimate.
2. CO_2 counted for UK departures only.
3. South East is main London Airports only.

Table G.14: Carbon dioxide emissions by South East Airport, by development scenario, 2050

Code	Scenario	Heathrow	Gatwick	Stansted	Luton	London City	Total South East	Other Airports	Passenger ATM Ground emissions	Freight Aircraft	Total CO2
s01	Planning System in SE	14	4	1	1	0	20	26	2	4	52
s02	Maximum Use	15	6	2	1	0	23	25	2	4	54
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	22	4	1	1	0	29	22	2	4	58
s07	Stansted R2 (480k in 2015)	15	7	3	1	0	26	23	2	4	56
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	22	5	3	1	0	32	22	2	4	60
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k in 2020, rising to 702k in 2030)	22	5	3	1	0	32	22	2	4	60
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020) then R3 (605k in 2020, rising to 702k in 2030)	23	5	3	1	0	32	22	2	4	61

Table Notes
1.Total Includes around +1MtCO_2 adjustment to ensure consistency with DEFRA outturn estimate.
2. CO2 counted for UK departures only.
3. South East is main London Airports only

Table G.15: UK aviation carbon dioxide emissions, by capacity scenario and year

Code	Scenario	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
s01	Planning System in SE	37	42	45	48	50	51	52	53	55	52
s02	Maximum Use	37	42	46	49	50	53	54	55	55	54
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	37	42	46	49	52	57	58	59	58	58
s07	Stansted R2 (480k in 2015)	37	42	46	50	52	54	57	57	57	56
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	37	42	46	50	54	59	60	61	61	60
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k in 2020, rising to 702k in 2030)	37	42	46	50	54	59	60	61	61	60
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020) then R3 (605k in 2020, rising to 702k in 2030)	37	42	47	50	54	59	60	61	61	61

Table Notes
1.Total Includes around +1MtCO_2 adjustment to ensure consistency with DEFRA outturn estimate.
2. CO2 counted for UK departures only.

Annex H: Appraisal Methodology

Introduction

1.1 The Government's 2003 Air Transport White Paper, *The Future of Air Transport*, set out a sustainable, long term strategy for the development of air travel to 2030. The appraisal of key development options in the South East was reported in Passenger Forecasts: Additional Analysis in 2004.

1.2 Since then, there have been a number of developments relevant to this appraisal. In 2006 the Government published the Stern Review and the Eddington study. Following the recommendations in these reports, the Department for Transport has revised its Transport Appraisal Guidance to include a requirement that appraisal of transport schemes should include quantification and monetisation of impacts on carbon emissions. We have therefore extended our appraisal methodology to include the cost of extra carbon dioxide emissions resulting from airport developments.

1.3 As outlined in chapter 2, we have also updated our modelling assumptions to account for recent developments. For example, we have adopted the latest forecasts of oil prices from BERR and economic growth from HMT and the IMF, and the revised shadow price of carbon dioxide values provided by DEFRA. We have also updated our airport capacity assumptions in line with the latest plans indicated by airport operators. Furthermore, our process of continual development has delivered a number of incremental improvements to our forecasting methodology since the last forecasts. These include the estimation of delay reduction benefits at Heathrow, and the extension of the appraisal period to bring it into line with DfT Transport Appraisal Guidance. In light of these developments, we have refreshed our appraisal of key development options supported in the 2003 ATWP.

1.4 This annex provides a detailed description of the current airport appraisal methodology. The appraisal consists of a cost-benefit analysis that compares the monetised direct benefits of airport developments to airport users and producers (net of the cost of extra carbon dioxide emissions), with the associated capital costs, together with a record of those costs that cannot currently be monetised.

Benefits

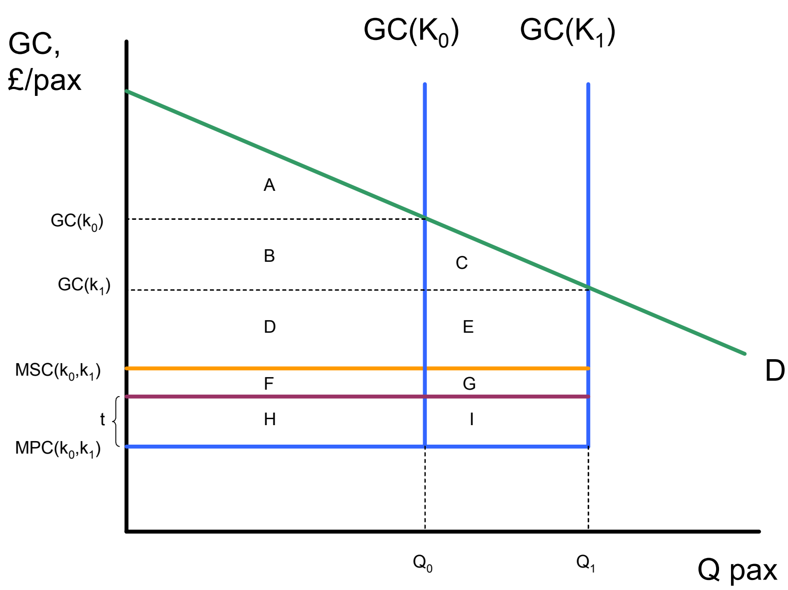
Monetised Benefits

1.5 The appraisal of the benefits from additional airport capacity is intrinsically linked with the process for forecasting the redistribution of demand between constrained airports.

1.6 Chapter 2 explained that when forecast demand at an airport exceeds capacity, our National Air Passenger Allocation Model adds a 'shadow cost' (or 'fare premium') to the cost of travelling from the constrained airport, equal to the increase in cost necessary to reduce demand for the airport to its capacity. The model then re-forecasts demand, and iterates until demand is at or below capacity at each airport. Adding capacity to a constrained airport reduces its shadow cost, because a smaller reduction in demand is required to be within capacity. It can also reduce shadow costs at alternative constrained airports, because overspill demand from the airport receiving the capacity will be reduced. These shadow costs, and changes in forecast passenger numbers, are used to measure one component of the value of allowing extra travel by increasing capacity at a constrained airport.

1.7 Figure H1 shows the market for travel at a hypothetical airport. The horizontal axis shows the number of passengers travelling through the airport, while the vertical axis shows the generalised costs (time any money costs expressed as money, including any shadow cost) of such travel. At the lower capacity level, K_0, throughput is restricted to Q_0, and passengers incur travel costs of GC_{k0}, which includes an element of shadow cost. Adding capacity moves the generalised cost curve to the right (GC_{ko} shifts to GC_{k1}), allowing Q_1-Q_0 more trips to be made, and reduces shadow costs so that travel costs fall from GC_{k0} to GC_{k1}.

Figure H1: Demand and capacity at a hypothetical airport



1.8 The diagram also represents carbon dioxide emissions by the marginal social cost curve ($MSC_{k0,k1}$) lying above the marginal private cost curve ($MPC_{k0,k1}$).

1.9 The impact of increasing capacity from K_0 to K_1 is to reduce the shadow costs, and hence generalised costs of travel, from GC_{k0} to GC_{k1}, and increase travel from Q_0 to Q_1. [71]:

- Consumers gain: B+C
- Producers gain: -B+E+G
- Government revenue: +I
- External costs: -G-I

1.10 In our appraisal methodology we measure these benefits in the following categories:

- Generated user benefits: C
- Producer benefits: E+G
- APD revenue: +I
- Carbon costs: -G-I

1.11 That is, we net off the transfer of benefits from producers to consumers (B), but otherwise estimate the areas in the diagram. Additionally, we estimate the benefit to existing users of increased flight frequencies due to increased demand, additional freighter traffic, and delay reduction benefits, which are not straightforward to represent in this diagrammatic analysis (although freight and existing users benefits turn out very small).

1.12 The exact formulae used are as follows:

Generated Users Benefit

$$C = \sum_{a,m,t}\left[\frac{(Q_1^{a,m,t} - Q_o^{a,m,t})(sc_0^{a,m,t} - sc_1^{a,m,t})}{2}\right]$$

where

a	=	airport
m	=	market segment
t	=	year
$Q_i^{a,m,t}$	=	number of passengers in scenario i={1,2}, at airport a, in market segment m, in year t
$sc_i^{a,m}$	=	shadow cost for market segment m at airport a, in scenario i={1,2}, in year t

[71] Airport charge regulation at designated airports could alter the relative sizes of generated user and producer benefits from those indicated here, but the net effect should not be altered within this hypothetical framework.

Producer Benefit

$$E+G=\sum_{a,m,t}\left[(Q_1^{a,m,t}-Q_o^{a,m,t})(r_0^{a,m,t}-c_0^{a,m,t}\right]$$

where

a	=	airport
m	=	market segment
t	=	year
$Q_i^{a,m,t}$	=	number of passengers in scenario i={1,2}, at airport a, in market segment m, in year t
$r_0^{a,m,t}$	=	revenue per passenger, for market segment m at airport a, in year t
$c_0^{a,m,t}$	=	operating cost per passenger, for market segment m at airport a, in year t

APD revenue

$$I=\sum_{a,m,t}\left[Q_1^{a,m,t}.d_1^{a,m,t}-Q_o^{a,m,t}.d_o^{a,m,t}.\right]$$

where

a	=	airport
m	=	market segment
t	=	year
$Q_i^{a,m,t}$	=	number of passengers in scenario i={1,2}, at airport a, in market segment m, in year t
$d_i^{a,m,t}$	=	APD per passenger in scenario i={1,2}, for market segment m at airport a, in year t

Carbon dioxide disbenefits

1.13 Aviation contributes to climate change through emissions of carbon dioxide, and the warming effects of non-carbon emissions released at altitude. The increase in carbon dioxide emissions under each airport development scenario has been assessed using the CO_2 forecasting model outlined in chapter 3.

1.14 For the purposes of valuing the climate change impacts of extra air travel resulting from airport development, these have been uplifted to account for the warming effects of non-carbon emissions at altitude by multiplying in-flight emissions (i.e. all other than ground emissions) by the central radiative forcing factor, equal to 1.9 (see chapter 3 for more detail on the radiative forcing factor). This is consistent with the approach taken in the Emissions Cost Assessment[72]. The resulting uplifted carbon dioxide emissions have then been valued using the new

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[72] Ref to ECA

DEFRA guidance on the shadow price of carbon dioxide (see chapter 3). The formula used is:

$$-G = -\sum_{a,m,t}\left[(A_1^{a,m,t}C_1^{a,m,t} - A_o^{a,m,t}.C_0^{a,m,t})SPC_t\right]$$

where

a	=	airport
m	=	market segment
t	=	year
$A_i^{a,m,t}$	=	number of flights in scenario i={1,2}, at airport a, in market segment m, in year t
$C_i^{a,m,t}$	=	Carbon dioxide emissions per flight in scenario i={1,2}, for market segment m at airport a, in year t (with in-flight element uprated by the radiative forcing factor)
SPC_t	=	Shadow price of carbon, in year t

Existing Users Benefit

1.15 Adding capacity to an airport potentially allows an increase in frequency of flights on existing routes. This gives a benefit to those passengers who would have used the airport without the capacity increase, because it increases the choice of travel times, and could reduce waiting times. It is standard transport modelling practice to assume that the time passengers wait before departure varies between passengers, rather than being a fixed value. While it can be a reasonable assumption to assume passengers arrive evenly between services for some forms of transport (e.g. frequent bus or tube services), this is unlikely to the case for aviation where passengers are more likely to time their arrival at the airport more carefully.

1.16 The formula to calculate this benefit (below) therefore calculates the (hourly) change in the interval between flights between scenarios, but weights it to reflect the likelihood that passengers will aim to arrive near their scheduled departure time, and the proportion of travellers who have flexible tickets (the 'wait time' and 'fare' factors). This weighted interval change is then scaled up to an annual figure, multiplied by the number of passengers in the base case, and monetised using the appropriate value of time.

$$EU = \sum_{a,m,t}\left[(Q_0^{a,m,t}.hpd.wtf.vot^{m,t}.ff.dpy.(wt_o^{a,m,t} - wt_1^{a,m,t})\right]$$

where

a	=	airport
m	=	market segment
t	=	year
hpd	=	hours per day
wtf	=	wait time factor

vot^{mt} = value of time in market segment m in year t
ff = fare factor
dpy = days per year
wt_i^{amt} = average interval between flights at airport a, in market segment m, in year t, in scenario i={1,2}

and

$$wt_i^{a,m,t} = \frac{l_i^{a,m,t}}{A_i^{a,m,t}}$$

where

l_i^{amt} = number of routes operating at airport a, in market segment m, in year t, in scenario i={1,2}

Generated Freight Users Benefit

1.17 This is calculated the same way as the Generated Users Benefit for passengers, except that the change in shadow cost per ATM is multiplied by the number of additional freighter ATMs, divided by two, and summed across all airports and years.

Delay Reduction Benefits

1.18 Airport delay imposes costs on society in terms of increased costs for airlines, passengers and the wider community. The airlines bear additional costs on the fleet as well as flying and ground personnel, since delays prevent them from operating in optimum conditions. This might also result in additional long-term costs from loss of competitiveness. The delay related costs for users are mostly airline passenger's opportunity cost, measured by the value of their time. Delays also impose costs on the wider community through environmental costs (from increased emissions, noise, etc) as well as additional costs incurred by other parties such as travel agents, tour operators and airport operators.

1.19 The closer to capacity an airport operates, the more likely it is to experience delays to flights. With the rapid rise in air traffic in recent years, airport delay has become a problem at Heathrow - with both the average length of delay and the percentage of more serious delays, of 30 minutes or more has substantially risen between 2002 and 2006. Between 2002 and 2006 average delay increased by 15.3%, from 16.8 to 18.8 minutes. The percentage of flights delayed by serious delays (more than 30minutes) rose from 15.2% in 2002, to 18.4% in 2006[73].

[73] CAA Airport Statistics (2006)

1.20 The White Paper 2003 and Progress Report 2006 stressed the importance of making better use of the current runways and suggest this may involve the introduction of mixed mode operations at Heathrow airport. This would mean using each runway for both arriving and departing aircraft, rather than current segregated mode where each runway generally has either arriving or departing aircraft. The introduction of mixed mode is likely to lead to the potential reduction in delay and hence economic benefits.

1.21 We have attempted to quantify the benefits of reducing delay through mixed mode operations. The assessment has relied on the following set of assumptions:

- NATS modelling has been used to provide estimates for the airbourne delay reductions from mixed mode with additional capacity in 2015 (540k ATMs). The results show that average airborne flight delay could be reduced by 3 minutes. No formal analysis has been done for mixed mode within existing capacity in 2015. We have cautiously assumed the delay reduction would be no greater than under the scenario of mixed mode operating with additional capacity.

- The main economic benefits is reduced travel times for passengers and lower operating costs for airlines. The methodology for calculating these benefits makes assumptions on the number of passengers associated with the various ATMs assumption. For passengers, assumptions are made on the values of time and grown over time. Information for airline delay cost per minute was obtained from Westminster Study (2004)[74] and EUROCONTROL[75].

- The main environmental benefits are reduction in carbon dioxide emissions. The calculation of environmental benefits has relied on assumptions on fuel burn for each aircraft within the DfT Air Passenger Model fleet mix and the DEFRA shadow price of carbon dioxide per tonne.

1.22 No assessment is currently made of the potential delay reduction benefits at other airports, either through additional capacity at those airports (e.g. Stansted), or through reduced traffic from adding capacity elsewhere (e.g. Gatwick). Also, we have not included possible reductions in delays on the ground (e.g. delays while taxiing to and from the runway). Hence the current estimates are likely to understate the overall benefits from reduced delays.

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[74] University of Westminster, "Evaluating the true cost to airlines of one minute airbourne or ground delay", Performance Review Commission, Eurocontrol (2004).
[75] European Organisation for the Safety of Air Navigation, " Standard Inputs for EUROCONTROL Cost Benefit Analyses (2005).

Air noise disbenefits

1.23 Additional capacity would lead to increase in the number of movements under both mixed mode and Heathrow third runway. This would lead to additional air and road noise. We have attempted to quantify the air noise impacts. No assessment has been for the road noise since this would depend on the surface access strategy to accompany possible development options.

1.24 The quantification of air noise impacts has relied on noise modelling conducted by ERCD for the Project of Sustainable Development of Heathrow. The ERCD noise modelling results were for 2015 mixed mode within existing capacity (480k ATMs), 2015 mixed with additional capacity (540k ATMs) and 2030 for Heathrow third runway (702k ATMs). A number of assumptions are made:

- The quantification of air noise for Heathrow third runway relies on the 2030 noise modelling position. It assumes that the difference in the number of households affected between the base (480k ATMs in segregated mode) and third runway scenario (702k ATMs) is indicative for the period 2020 and 2080. We have assumed that technological improvements beyond 2030 would affect the base case and Heathrow third runway option, and therefore the difference in the number of households over time and direction of noise changes in each of the years would remain broadly the same. For the period between 2020 and 2030 we have therefore slightly overestimated the noise impacts since capacity would be lower than the assumed 702k ATMs.

- In the absence of specific Government recommended values for airport noise, we have relied on values from Pearce and Pearce (2000)[76] and the DfT WebTAG values for road and rail noise to provide an appropriate range of air noise costs. In line with WebTAG the noise values are assumed to grow in line with GDP from the current year to 2080.

1.25 Similar assumptions are made for quantifying the impact of mixed mode options. In particular, we have relied on the 2015 noise modelling positions to quantifying the impacts on noise changes before 2020.

Non-monetised benefits

1.26 The following are currently not taken into account when valuing the benefits of airport development:

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76 Setting Environmental Taxes for Aircraft : A Case Study of the UK (2000) - Brian Pearce and David Pearce.

- the extra value that could be placed on providing capacity at peak times;
- benefits to international-to-international interliner passengers; and,
- wider economic benefits, as identified in the Eddington Report, through raising productivity and improving competitiveness.
- Local environmental impacts (e.g. noise, local air pollution, landscape impacts).

1.27 The 2006 Eddington Study highlighted that transport can have significant impacts on the wider economy and put forward the case for considering the contribution of transport to productivity and growth. Analysis for the Eddington Study noted several routes through which international gateways to the UK can generate wider economic benefits through: attracting globally mobile resources to the UK, supporting UK trade, and encouraging the agglomeration of economic activity in UK hubs around Heathrow or the London financial business districts.

1.28 Business, capital investment and labour are increasingly globally mobile resources. There is limited quantitative evidence on the relationship between transport and globally mobile resources. However, the Eddington Study noted the survey evidence that suggests that good international and domestic transport links can be important in attracting, retaining and expanding UK business activity. Survey evidence on the importance of good Heathrow (and other) air services in attracting and maintaining globally mobile investment is reported in the recent Oxford Economic Forecasting (OEF)[77] paper. The Eddington study also noted the potential contribution of transport in supporting UK trade. The study reports the European Council of Ministers' conclusion that airport and port infrastructure are one of the critical factors for economic growth, business location and tourism.

1.29 The attraction of globally mobile resources to the UK may also help support important UK agglomerations around Heathrow. The OEF report notes some survey evidence on the importance of Heathrow for firms locating in the London financial business district. If Heathrow supports these agglomerations, increasing the economic activity located there, there are strong theoretical and evidential bases for this increasing the productivity of the agglomerations.

1.30 The Eddington study recognised that while these benefits from trade and globally mobile resources are difficult to quantify, and are currently not incorporated within estimates of economic benefits (especially for specific transport projects), they are potentially significant.

1.31 Some studies have attempted to quantify the relationship between connectivity and economic growth. Oxford Economic Forecasting recently estimated that increasing UK business use of air travel by 10%

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[77] Oxford Economic Forecasting, The Economic Contribution of the Aviation Industry in the UK, Autumn 2006.

could boost productivity and thus GDP by 0.6%. OEF applied this result to estimate that a third runway at Heathrow could increase UK GDP by £7bn pa (0.3%) by 2030. Looking globally, IATA[78] has estimated that increasing a nation's connectivity by 10% could raise its GDP by 0.07%, although the impact appears stronger for less developed nations.

1.32 These results are a welcome contribution to the evidence base for the economic impacts of airport development, but further research is required to fully understand the direction of causality, and the extent of any overlap between GDP impacts and the benefits measured by the standard economic appraisal methodology.

Costs

Monetised Costs

1.33 The infrastructure cost estimates for adding a new runway and associated infrastructure at Stansted and Heathrow supporting the Air Transport White Paper were developed as part of the SERAS exercise which scoped the costs and benefits of many potential airport development options. We have updated the cost estimates for Stansted and Heathrow to account for changes in construction costs and the evolution of airport operators' development plans since the SERAS exercise. Table H1 summarises the infrastructure costs for the development scenarios at Stansted and Heathrow.

[78] http://www.iata.org/NR/rdonlyres/A6234C7A-4E68-4931-BE36-D6C6CDD5963F/0/aviation_economic_benefits.pdf

Table H1: Estimated infrastructure costs of Stansted and Heathrow development scenarios, £bn, 2006 prices

Scenario		Base case		Infrastructure costs
s05	Heathrow R3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	£6.8 to £7.6
s07	Stansted R2 (480k in 2015)	s02	Maximum Use	£4.3
s12s2	Stansted R2 (480k in 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£6.8 to £7.6
s12s2mm1	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2019) then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£7.1 to £7.9
s12s2mm2	Stansted R2 (480k in 2015), Heathrow Mixed Mode (480k 2010-2015 & 540k 2015-2020), then R3 (605k 2020, rising to 702k in 2030)	s07	Stansted R2 2015	£9 to £9.8
s12s2	Stansted R2 (480k 2015), Heathrow R3 (605k in 2020, rising to 702k in 2030)	s02	Maximum Use	£11.1 to £11.9

Non-monetised costs

1.34 The following costs from additional capacity are currently not monetised:

- additional local air quality emissions;
- impacts from additional road traffic congestion. These included climate change impacts and noise impacts;
- land use impacts in form of lost greenfield and agricultural land;
- impacts on heritage and any community severence effects;
- biodiversity and water related impacts;

ANNEX I: Improvements made to the CO_2 modelling since Aviation and Global Warming, 2004

1.1 Since the UK aviation carbon dioxide emissions forecasts in Aviation and Global Warming (2004) were produced to support The Future of Air Transport White Paper, significant improvements have been made to our modelling capability. Key improvements are:

- The fuel burn calculations to 2030 are based on detailed annual ATM demand projections by airport route and specific aircraft type, taken directly from the passenger demand forecasting models.
- The fuel efficiency of the fleet is forecast to 2030 using the European Environment Agency's CORINAIR Emission Inventory Guidebook and our fleet mix model, with annual projections of the efficiency of new aircraft and assumptions about retirement ages.
- The carbon dioxide forecast range is found directly by varying inputs to the demand and / or fuel efficiency projections.
- The base year carbon dioxide forecast now validates closely with the published DEFRA estimate.

The carbon dioxide forecasts and analysis it supports have been further improved by:

- Integrating fuel efficiency forecasts into the fares component of the National Passenger Demand Model. This allows fuel efficiency to be more robustly captured
- Integrating the carbon dioxide forecasting methods with the National Air Passenger Allocation Model. This means forecasts for each capacity scenario are more feasible, and the central case forecast is now tied directly to the development scenario of an extra runway at both Stansted and Heathrow (rather than 3 additional runways in the South East as was assumed in *Aviation and Global Warming,* 2004).
- Adopting the latest DEFRA guidance on the shadow price of carbon dioxide emissions, and the February 2007 rise in APD rates.

1.2 Our carbon dioxide forecasting method is therefore more robust and flexible than previous versions. As with all our modelling, we aim for continuous improvement, and further upgrades will continue to be made over time.

ANNEX J: The value of UK aviation's climate change impact

Introduction

1.1 The 2004 report supporting the Air Transport White Paper, *Aviation and Global Warming*, presented the value of UK aviation's climate change impact, using:

- DEFRA actual aviation CO_2 emissions in 2000 and DfT forecast aviation CO_2 emissions in 2030;
- DEFRA guidance on the social cost of carbon emissions; and,
- the evidence based central value for the 'radiative forcing factor' (used to inflate CO_2 emissions to account for the climate change effects of non-carbon emissions at altitude)

1.2 It found that, using a radiative forcing factor of 2.5 to account for the non-CO_2 impact of aviation, the value (in 2000 prices) of emissions in 2000 was estimated at £1.4bn, rising to £4.8bn for emissions in 2030.

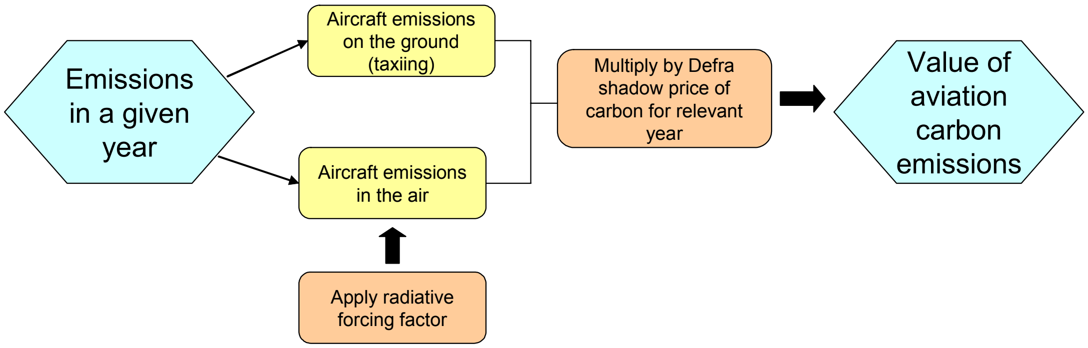
1.3 These estimates can now be updated using the new CO_2 forecasts reported in this report, the latest DEFRA guidance on the shadow price of carbon dioxide emissions, and our latest estimates of the radiative forcing factor.

Method and Results

1.4 Figure J1 below illustrates the method we use to estimate the value of UK aviation's climate change impact. In a given year, emissions are split between 'ground' and 'in air' emissions. 'In air' emissions are uprated by the radiative forcing factor[79], added to 'ground' emissions, and multiplied by the shadow price of carbon dioxide appropriate to the year in question.

[79] This is because the factor is intended to capture the impact of emissions at altitude

Figure J1: Process used to estimate the value of aviation's climate change impact



Carbon dioxide forecasts

1.5 Chapter 3 explained that the official UK inventory of carbon dioxide emissions includes only domestic, not international, aviation CO_2 emissions[80]. This is because there is currently no internationally agreed method for allocating emissions from international air travel to nations. However, if the UK's allocation were emissions from domestic flights plus departing international flights[81], DEFRA statistics show the UK's aviation emissions would have been 37.5MtCO_2 in 2005. Chapter 3 also showed that on the same basis, the central case forecast of carbon dioxide emissions from UK aviation in 2030 is 58.9MtCO_2.

Radiative forcing factor

1.6 In our analysis, a 'radiative forcing factor' is used to inflate CO_2 emissions from aircraft in the air to account for the climate change effects of non-carbon emissions at altitude. Chapter 3 has also explained that the most recent evidence suggests an appropriate central value for this factor is 1.9, within the range 1 to 4. This central value is lower than the factor of 2.5 assumed in Aviation and Global Warming in 2004, which reflected the IPCC (1999) estimates.

Shadow price of carbon dioxide

1.7 DEFRA's latest guidance on the value of carbon emissions (published in 2007[82]) suggested the appropriate way to value carbon dioxide emissions is to use a shadow price of carbon. This derives from the social cost of carbon (i.e. the value placed by society as a whole on the

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[80] This is actual CO_2 so does not include a radiative forcing index to account for the non-CO2 effects of aviation.
[81] Currently recorded as a memo item in the Defra statistics
[82] This was updated in 2007 "How to use the Shadow Price of Carbon in policy appraisal", interim guidance, Defra August 2007 (http://www.defra.gov.uk/environment/climatechange/research/carboncost/pdf/HowtouseSPC.pdf)

damage caused by an additional unit of carbon dioxide) but goes further by taking more account of uncertainty, by being based on a stabilisation trajectory, and being in line with the marginal abatement costs of reaching the stabilisation goal.

1.8 DEFRA's guidance advises that the shadow price of carbon dioxide in 2000 (at 2000 prices) is £19/tCO_2 which is the same as the previous guidance[83]. However, the rate of annual increase (in real terms) is now higher, as it rises at 2% per year (rather than the previous £1/tonne of carbon per annum). To reflect the uncertainty around the value of carbon in future years, we also present a sensitivity range of the shadow price of carbon 20% above the central value and 10% below. This gives the following 2005 and 2030 central values and ranges

Table J1 Values placed on carbon dioxide per tonne, Defra shadow price (2006 prices)

	2005	2030
- central	24.23	39.75
- high (central + 20%)	29.10	47.70
- low (central - 10%)	21.81	35.78

Results

1.9 The updated estimated value of the climate change impacts of UK aviation is set out in the tables below. It shows that the (undiscounted) central value is estimated at £1.7bn in 2005, and is expected to rise to £4.3bn in 2030 (in 2006 prices[84]).

1.10 Table J2 sets out the values, valued in the year in which the costs are incurred i.e. the 2030 value accounts for the growth in the value people place in carbon over the period 2005 to 2030.

Table J2: the value of aviation's climate change impacts (2006 prices), undiscounted

		2005 (£bn)	2030 (£bn)
Radiative forcing factor	1	0.9	2.3
	1.9 - central	1.7	4.3
	4	3.5	8.5
Shadow price of carbon	Central + 20%	2.0	5.1
	Central	1.7	4.3
	Central – 10%	1.5	3.9

[83] This is equivalent to £70 per tonne of carbon in 2000 at 2000 prices.
[84] Figures are presented in 2006 values to be consistent with our other modelling results.

1.11 For appraisal purposes, we often need to present values in a common and comparable metric, therefore they are discounted into a present value (here 2006). Table J3 presents the discounted costs of carbon.

Table J3: the value of aviation's climate change impacts (2006 prices) discounted

		2005 (£bn)	2030 (£bn)
Radiative forcing factor	1	0.9	1.0
	1.9 - central	1.7	1.9
	4	3.5	3.7
Shadow price of carbon	Central + 20%	2.0	2.2
	Central	1.7	1.9
	Central – 10%	1.5	1.7

1.12 The central estimates are lower than in 'Aviation and Global Warming', reflecting the net effect of:

- a slightly lower carbon dioxide forecast;
- a lower central value for the radiative forcing factor; but,
- a faster growth rate of the shadow price of carbon dioxide.

ANNEX K: Aviation's Share of UK Climate Change Emissions

Introduction

1.1 The Environmental Audit Committee report 'Aviation: Sustainability and the Government Response' (2003-4) presented DfT estimates for aviation's share of UK total climate change emissions in 2000, 2030 and 2050. Results were reported with and without uplifting the carbon dioxide figures by the central radiative forcing factor to account for the climate change impacts of non-carbon emissions at altitude. The forecasts and projections of aviation CO_2 emissions in chapter 3 have been used to update this analysis.

Method and Results

1.2 The CO_2 forecasts in chapter 3 are used in table K1 to show aviation's share of total UK emissions. This has been estimated by showing the results both if we do not account for the climate change effect of aviation emissions at altitude (i.e. no radiative forcing factor is applied); and if this account is taken by applying a radiative forcing factor of 1.9.

1.3 Total UK emissions for 2020 and 2050 (only those years for which we have targets) are presented assuming that the UK domestic targets are met for CO_2 reductions by those years. As the UK aviation CO_2 forecasts from Chapter 3 have been used, this does not account for the potential benefits of economic instruments for aviation emissions like the EU emissions trading scheme, whereas in other sectors the impact of policies to reduce CO_2 is taken into account. For illustration, under the current proposal, emissions from aviation would be capped at the average of 2004-06 levels and aviation emissions above that level would be matched by reductions made elsewhere in the economy.

1.4 When the radiative forcing effect of aviation emissions is accounted for in the lower half of the table, for consistency as this is considering more than CO_2, account has been taken of the non-CO_2 greenhouse gas emissions from other sectors in the UK economy to provide an uplifted UK total[85].

1.5 An estimate of aviation's share of total UK climate change emissions is found by dividing aviation's total by the UK total level of emissions.

1.6 The results are reported in table K1 below. They show that with no radiative forcing factor, UK aviation emissions are projected to rise

[85] It should be noted that international shipping has not been accounted for in the UK total; if it were, aviation's share of total emissions (domestic + international) would be slightly smaller at 6.3% as reported in Chapter 3.

from 6.4% of the UK total in 2005 to 20.6% in 2050. Using the central value for the radiative forcing factor, this becomes a rise from 9.9% to in 2005 to 29.0% in 2050.

Table K1: Aviation's share of total UK climate change emissions

Radiative forcing factor = 1 (i.e. no account taken of radiative forcing)

Year	UK aviation and total emissions, MtCO2			
	Aviation (domestic + international) actual & central forecast	UK inventory (including domestic aviation but excluding international aviation) actual & UK targets	Combined total emissions (UK inventory + international aviation)	Aviation as % of combined total
2005	37.5	554.2	589.2	6.4%
2020**	50	438.2 - 402.7	485.8 - 450.3	10.3% - 11.1%
2050	60.3	236.9	293.1	20.6%

* Current inventory definition includes domestic aviation and shipping, but excludes international aviation and shipping. Assumes targets met in other sectors
** For 2020, the target is for a 26-32% reduction
*** For 2050, the target is to reduce carbon dioxide emissions 50% below 1990 levels

Radiative forcing factor = 1.9

Year	UK aviation and total emissions, MtCO2			
	Aviation (domestic + international) actual & central forecast	UK inventory (including domestic aviation but excluding international aviation) actual & UK targets	Combined total emissions (UK inventory + international aviation)	Aviation as % of combined total
2005	71.25	656.32	722.82	9.9%
2020	95	529.6 - 494.1	620.1 - 584.6	15.0% - 15.9%
2050	114.57	288.7	395.64	29.0%

* Current inventory definition includes domestic aviation, but excludes international aviation
** Includes GHG's in the rest of the economy which have been estimated at 99.9MtCO2e in 2005; 89.2MtCO2e in 2020 and 48.3MtCO2e in 2050