Department for Transport

UK Air Passenger Demand and CO_2 Forecasts

January 2009

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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 was set out in *Passenger Forecasts: Additional Analysis*[3] and *Aviation and Global Warming*[4] in 2004.

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

1.3 Following the commitment in the 2006 *Progress Report*, the Government published *UK Air Passenger Demand and* CO_2 *Forecasts*[5] in 2007. This explained in detail our demand forecasting, carbon dioxide (CO_2) forecasting, and appraisal methods, and reported updated forecasts and economic appraisal results.

1.4 This report updates *UK Air Passenger Demand and* CO_2 *Forecasts 2007*. Since 2007 several developments have been taken into account and these are explained in the chapters that follow. These include:

- BERR has published revised projections of oil prices;
- HMT has published revised UK GDP forecasts;
- the IMF has updated its forecasts of international economic growth;
- airport capacity assumptions have been updated in line with the latest plans indicated by airport operators;
- the process of continual development has delivered a number of

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[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.

[5] *UK Air Passenger Demand and* CO_2 *Forecasts*, Department for Transport, Nov 2007.

incremental improvements to our forecasting methodology; and,

- several significant climate change policy developments have taken place. These are explained in the main chapters along with additional information and illustrative figures to provide a greater understanding of the broader context and possible range of policy outcomes.

Key results

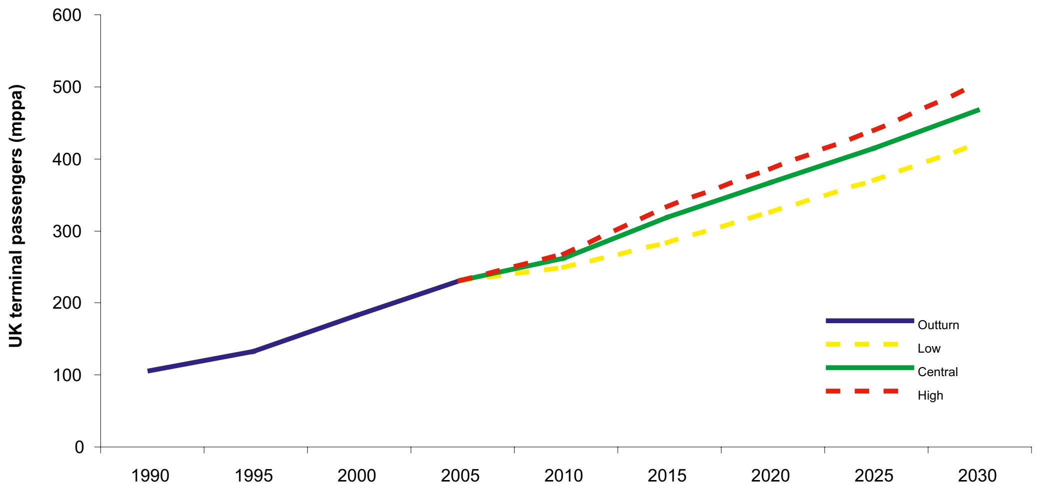
Passenger demand

1.5 Our passenger demand forecasting methodology remains essentially the same as that reported in *UK Air Passenger Demand and* CO_2 *Forecasts 2007*. The forecasts have been updated to incorporate:

- the most recent information on planned future airport capacities;
- the latest outturn data for aviation CO_2;
- HMT's Budget 2008 GDP forecasts;
- new IMF overseas GDP projections;
- BERR's 2008 oil price projections;
- new exchange rate assumptions; and,
- improvements to elements of the modelling.

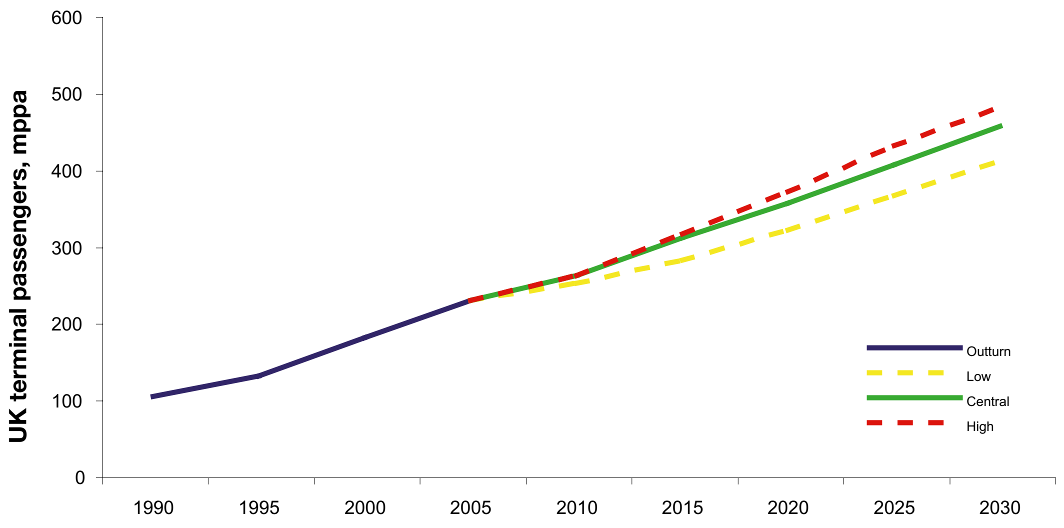
1.6 Figure 1.1 shows that, if not constrained by airport capacity, air travel demand at UK airports is forecast to grow strongly under the central case, from 241 million passengers per annum (mppa) in 2007 to 465mppa in 2030 (within the range 415-500mppa).

Figure 1.1: Unconstrained demand forecast



1.7 However, continued demand growth would eventually become constrained by airport capacity. Figure 1.2 shows that, even with the additional capacity supported in the White Paper, capacity constraints limit the 2030 central demand forecast to 455mppa (within the range 410mppa to 480mppa).

Figure 1.2: Constrained demand forecast

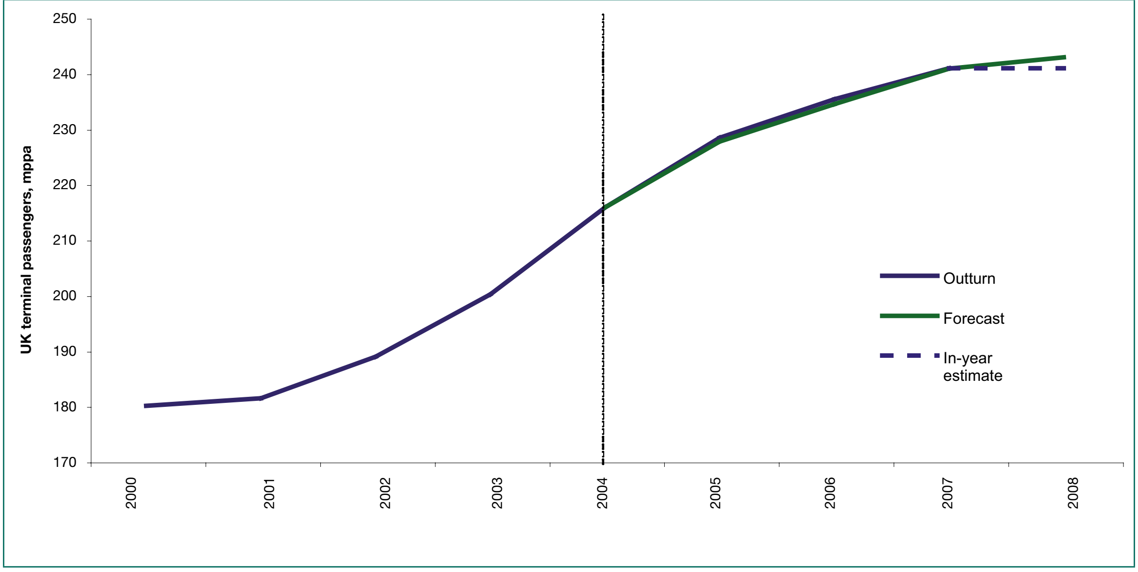


Model performance since 2005

1.8 As our model begins forecasting from 2005, we can use the latest version to investigate the causes of the more recent slower growth. This is achieved by looking at the ‘forecasts’ for 2005 to 2008 provided by the latest version of the model, which are based on the latest outturn data on GDP, oil prices, Air Passenger Duty (APD) etc, and which were not available for the previous forecasts.

1.9 Figure 1.3 shows that the latest model’s (central case) forecasts of constrained demand, based on the latest outturn data on GDP, oil prices, and APD, successfully predict the slower growth in 2005-08. Hence we may conclude that: the model structure is accurate; recent slower growth is a short term result; and, we should expect a return to growth once economic growth picks up again.

Figure 1.3: Outturn and forecast passenger demand, 2005-2008



Carbon dioxide emissions

1.10 Our aviation CO_2 forecasting methodology remains essentially the same as that reported in *UK Air Passenger Demand and CO_2 Forecasts 2007*.

Nature, purpose and context

1.11 We forecast CO_2 emissions from all flights departing UK airports, constrained to match the DECC outturn estimate of UK aviation CO_2 emissions in the base year. 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. However, our approach is consistent with the DECC outturns, and the UNFCCC recommended approach for reporting on carbon dioxide emissions from international aviation[6].

1.12 The CO_2 forecasts are intended to be ‘central’, but there may be elements of conservatism. We assume that industry will make technological gains consistent with the manufacturers’ ACARE target for fuel efficiency such that a proportion of aircraft coming into service in 2020 are 40% more fuel efficient than those in service in 2000[7]. This is challenging, but the industry is on track to deliver it. However, beyond the continued deployment over time of such aircraft in the fleet which raises the average efficiency of the fleet, due to the uncertainty around future developments, we do not assume any further major technological advances, nor do we assume the use of low-carbon fuels, although we know that test trials with biofuels are already being carried out.

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

[7] A further 9% gain in efficiency is assumed to derive from improvements to air traffic management. Therefore a total efficiency gain of some 50% is assumed for some aircraft by 2020 in line with the ACARE target, as further explained in Chapter 3.

1.13 The industry has suggested that significant developments in fuel efficiency are possible over the coming decades. For example, Sustainable Aviation[8] suggest that technological developments and the adoption of low-carbon alternative fuels could increase fuel efficiency significantly by 2050.

1.14 The Government has a comprehensive approach to reduce aviation's climate change impacts. This includes supporting and encouraging research and development into new technology, improvements in air traffic management, the development and adoption of better operating practices and the use of economic instruments. This recognises that no single measure provides a complete solution to aviation's climate change impact.

1.15 The Government has worked to bring international aviation within the European Union Emissions Trading Scheme (EU ETS). The EU Parliament and Council have now agreed that aviation will be included in the EU ETS from 2012. The scheme will require airlines which operate flights into, within or out of the EU to surrender allowances to cover their annual CO_2 emissions. This means that overall emissions from sectors included in the EU ETS will not be increased by any growth in CO_2 emissions from aviation, as is shown in Chapter 3.

1.16 If fuel efficiency improves significantly as the industry has suggested due to the adoption of new technologies and low-carbon fuels, aviation CO_2 emissions would be lower than forecast here. The overall level of emissions from aviation would still be contained by the ETS cap, but within this, the aviation industry itself would be making greater CO_2 reductions.

1.17 Our aviation CO_2 forecasts are set against a backdrop of action on overall UK CO_2 emissions: the Climate Change Act 2008 sets a target to reduce UK greenhouse gas emissions to 80% below their 1990 level by 2050.

Method

1.18 Our method of forecasting aviation CO_2 emissions to 2030 combines:

- detailed forecasts of air transport movements (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 detailed fleet turnover model.

1.19 Beyond 2030, we use simpler, yet still robust, methods to project aviation carbon dioxide emissions. This longer term view is important given the time frame of our climate change policies and the long lifetimes of large infrastructure projects such as airport capacity[9].

Results

1.20 The action on overall UK CO_2 emissions in the Climate Change Act means that national emissions are expected to fall substantially to 2050. Within that, the demand forecasts and technological assumptions outlined

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[8] CO_2 Roadmap, Sustainable Aviation, December 2008.

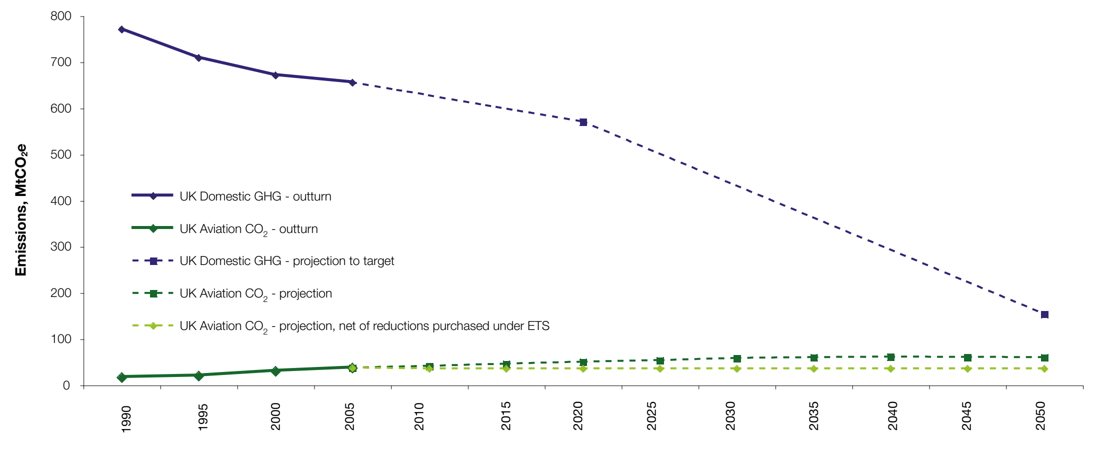
[9] For appraisal purposes, the projections also extend to 2080 to inform our analysis of the airport developments supported in the Air Transport White Paper.

above mean that UK aviation CO_2 emissions (covering both domestic and international aviation) are forecast to grow from 37.5MtCO_2 in 2005 to 58.4MtCO_2 in 2030, within the range 51.8MtCO_2 to 61.6MtCO_2. After 2030, the growth in aviation emissions is projected to slow, partly due to market maturity and capacity constraints slowing demand growth. By 2050 aviation emissions are projected to have stabilised, and reach 59.9MtCO_2 within the range 53.0MtCO_2 to 65.0MtCO_2.

1.21 Figure 1.4 illustrates this forecast of aviation CO_2 emissions alongside the projected domestic greenhouse gas emissions consistent with the Climate Change Act 2050 target. The aviation line and the domestic economy line are shown independently in this figure, reflecting that no decision has yet been taken on how international aviation relates to any UK targets in the long term[10]. Nevertheless, it can be seen that falling overall UK emissions mean that – even with aviation emissions stabilising after 2030 – aviation's share of UK greenhouse gas emissions rises to 2050.

1.22 Figure 1.4 shows the forecast profile of emissions from UK aviation under the assumptions of fuel efficiency described earlier. As explained in this chapter, because aviation will be joining the EU ETS from 2012, any emissions growth above the aviation cap will be matched one-for-one by reductions in other sectors, through the purchase of allowances. Across the EU, there would therefore be no overall increase in emissions from sectors included in the EU ETS.

Figure 1.4: UK national and aviation emissions forecasts 2005-2050



Monetised net benefits of additional capacity in the South East

1.23 The monetised net benefits of key development scenarios in the South East reported in *UK Air Passenger Demand and CO_2 Forecasts* 2007 have been updated in light of the developments outlined above, revised capital cost estimates, and improvements to modelling methods.

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[10] UK domestic GHG emissions include domestic aviation because these emissions are included in the UK target for 2050. It does not include international aviation CO_2 emissions. The UK aviation CO_2 emissions include both the domestic and international aviation emissions. Annex K contains further information on estimating aviation's future share of total emissions.

1.24 The updated analysis shows that the development of a second runway and associated terminal infrastructure at Stansted would deliver a net benefit of £10bn[11]. A third runway and sixth terminal at Heathrow would deliver a net benefit of £5.5bn. Together, they would deliver a net benefit of £15.5bn, with a strong Benefit-Cost Ratio of 2.2.

1.25 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 developments at Stansted and Heathrow is robust to these tests.

Table 1.1: Sensitivity of ATWP net benefits to key tests

	Stansted second runway		**Heathrow third runway**		**Both**	
Sensitivity test	NPV (£bn)	BCR	NPV (£bn)	BCR	NPV (£bn)	BCR
Central case	£10.0	3.1	£5.5	1.7	£15.5	2.2
Low end of demand range	£7.1	2.5	£5.0	1.7	£12.1	2.0
High end of demand range	£11.3	3.4	£6.0	1.8	£17.3	2.4
Low GDP	£8.2	2.7	£5.3	1.7	£13.5	2.1
High GDP	£10.8	3.3	£6.7	1.9	£17.5	2.4
PBR Nov 2008 GDP forecast	£8.7	2.8	£5.4	1.7	£14.0	2.1
Lower shadow price of CO_2	£10.5	3.2	£5.7	1.7	£16.2	2.3
Higher shadow price of CO_2	£9.1	2.9	£4.2	1.6	£13.4	2.1
EU ETS	£9.6	3.0	£8.2	2.1	£17.8	2.4
Lower radiative forcing factor	£11.0	3.3	£7.8	2.0	£18.8	2.5
Higher radiative forcing factor	£4.3	1.9	£2.0	1.3	£6.3	1.5
BERR low oil price	£10.3	3.2	£6.1	1.8	£16.4	2.3
BERR high high oil price	£7.5	2.6	£5.3	1.7	£12.8	2.0
Low fuel efficiency	£9.5	3.0	£5.0	1.6	£14.5	2.2
High fuel efficiency	£10.1	3.1	£6.1	1.8	£16.2	2.3
PBR Nov 2008 APD bands and rates	£11.1	3.3	£6.4	1.8	£17.5	2.4

Notes:

1. 2006 prices, NPVs discounted to 2006.

2. '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 DfT NATA. BCRs reported for road and rail schemes, which divide the net benefits by the net effect on government spending.

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[11] Net present value of costs and benefits, 2006 prices

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 updated economic growth forecasts from HMT and IMF, the latest oil price projections from BERR, and assume that aviation will in future meet its climate change costs.
- National demand, unconstrained by airport capacities, is forecast to rise from 241mppa in 2007 to 465mppa in 2030 (within a range of 415mppa to 500 mppa). Accounting for capacity constraints remaining after delivery of the ATWP-supported airport developments reduces 2030 demand to 455mppa (within a range of 410mppa to 480mppa).

2.1 This chapter comprises three sections that set out:

- in section 2.1, an overview, including the nature and purpose of the forecasts;
- in section 2.2, the methodology, assumptions and validation of the forecasting models; and
- in section 2.3, the forecasts.

2.1 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*[12]. This was supported by forecasts of demand for air travel at UK airports which were reported in *Air Traffic Forecasts for the United Kingdom*[13] in 2000. Further supporting analysis of demand forecasts, and carbon emissions forecasts from UK aviation, were set out in *Passenger Forecasts: Additional Analysis*[14], *Aviation and the Environment: Using Economic Instruments*[15], and *Aviation and Global Warming*[16] in 2004.

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[12] *The Future of Air Transport*, Department for Transport, Dec 2003.

[13] *Air Traffic Forecasts for the United Kingdom 2000*, DETR, May 2000.

[14] *Passenger Forecasts: Additional Analysis*, Department for Transport, Dec 2003.

[15] *Aviation and the Environment: Using Economic Instruments*, HM Treasury and Department for Transport, Mar 2003.

[16] *Aviation and Global Warming*, Department for Transport, Jan 2004.

2.3 Following the commitment in the 2006 *Progress Report*, the Government published *UK Air Passenger Demand and CO_2 Forecasts*[17] in 2007. This explained in detail our demand forecasting, CO_2 forecasting, and appraisal methods, and reported updated forecasts and economic appraisal results.

Nature and purpose of forecasts

2.4 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.

2.5 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 80% below 1990 levels by 2050. Also, they are inputs to the appraisal of airport developments supported by the Air Transport White Paper.

2.6 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.

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[17] *UK Air Passenger Demand and CO_2 Forecasts*, Department for Transport, Nov 2007.

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.

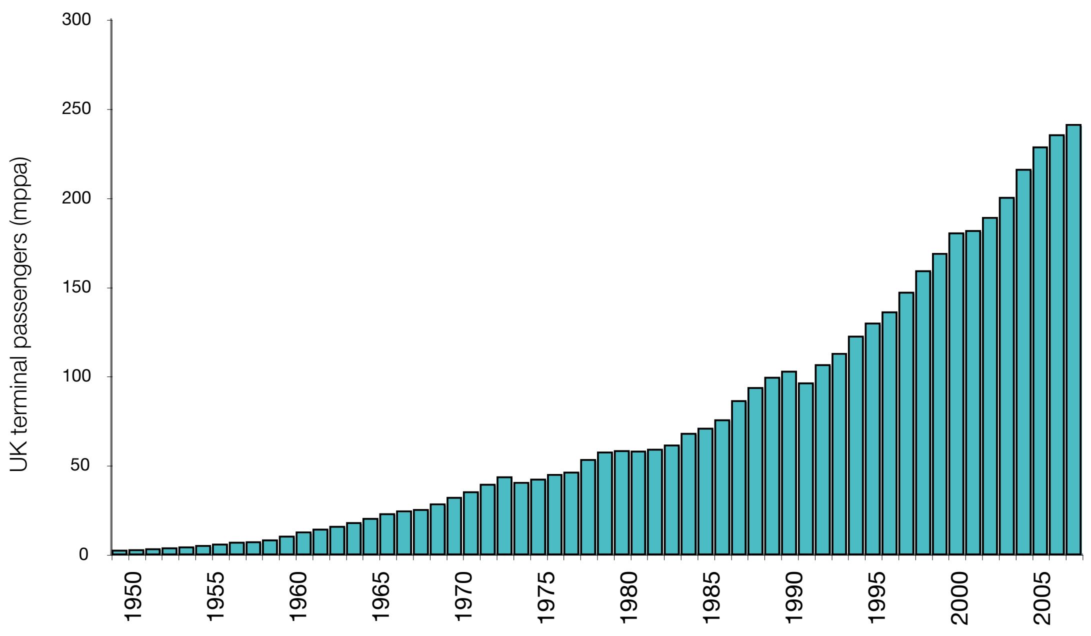
A round trip would involve double the terminal passengers of a one-way trip. The full definitions of terminal passengers and air transport movements is available on the CAA website at:

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

Context and interpretation of passenger demand forecasts

2.7 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 1950-2007



2.8 For many of the purposes to which the demand forecasts are put, the longer term trend is more relevant than short term fluctuations around it. However, our forecasts are capable of capturing the effects of some short term fluctuations (such as economic growth and oil prices), to the extent that accurate forecasts of them are available. In the longer term, such fluctuations are rarely predictable, and so do not feature in our forecasts. There are also, of course, some short term influences on demand which are not captured by our forecasts. Hence, while our forecasts are primarily intended for longer term purposes, they should be able to capture some, though not all, shorter term influences.

2.2 METHODOLOGY, ASSUMPTIONS AND VALIDATION

2.9 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.

2.10 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.

2.11 Figure 2.2 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

2.12 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.

2.13 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.

2.14 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 2.3);
- 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 2.2: Overview of UK air passenger demand and CO_2 forecasting framework

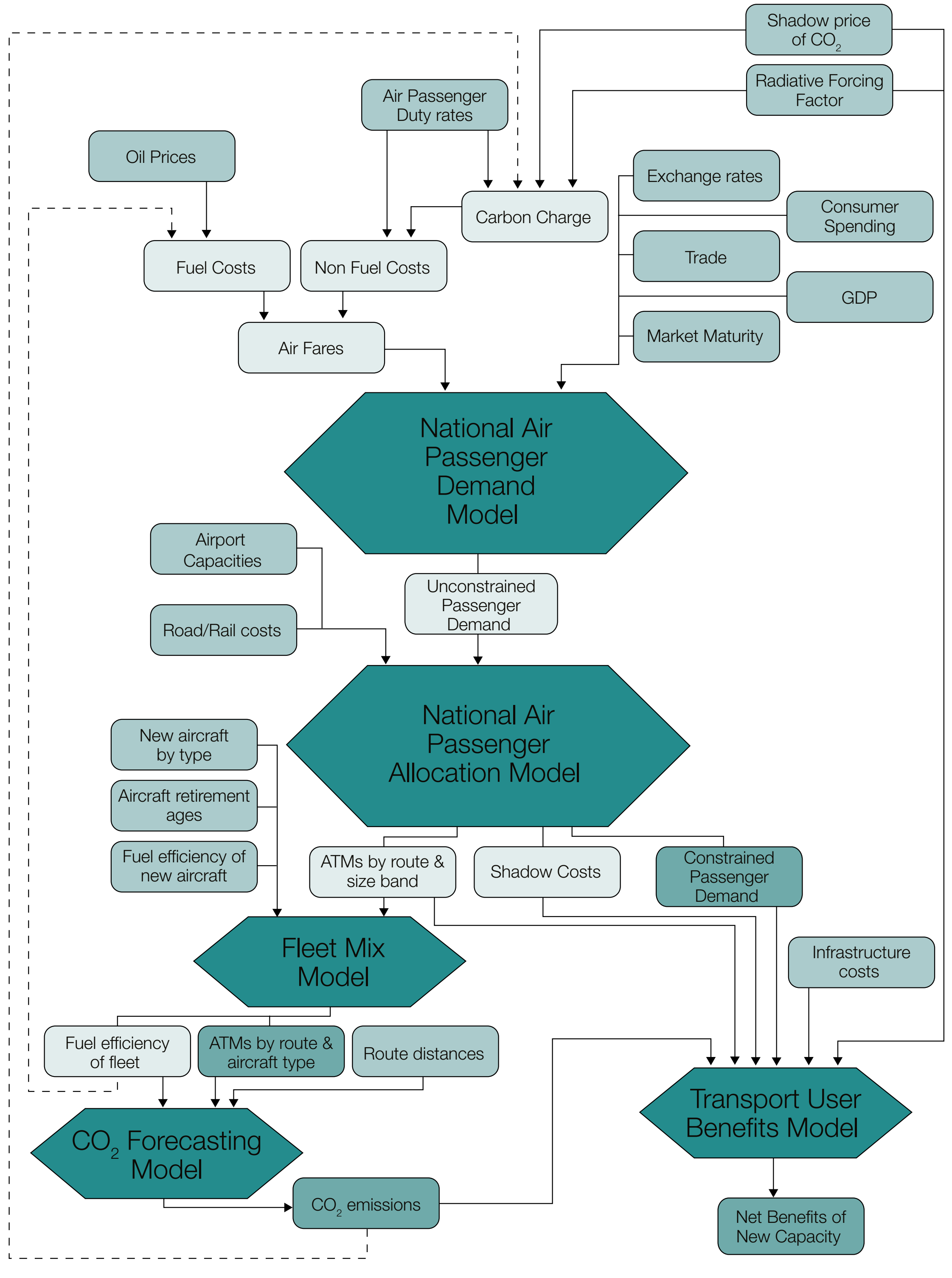
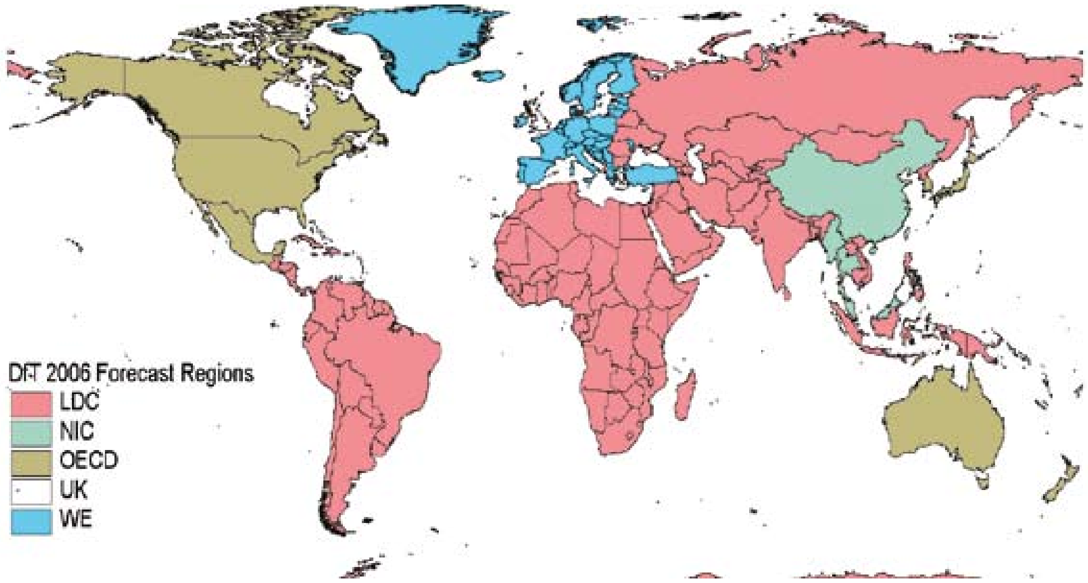


Figure 2.3: Global regions used in the unconstrained demand forecasting models



2.15 Overall, this gives twenty one markets for which separate econometric models are estimated and used to forecast demand. Box 2.2 explains more about our econometric modelling approach, and Annex A gives more detail on our econometric models.

Econometric results

2.16 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.

2.17 Table 2.1 below summarises the central estimates for the long run price elasticities[18]. This shows that income is a strong driver in the UK scheduled markets, with the estimated income elasticity of demand ranging from 1.4 to 1.5. This falls to 0.6-0.7 for the foreign scheduled markets, and 0.4 for the charter market, but the overall average income elasticity is strong at 1.3. Air fare effects are more variable. The UK leisure sector showed a strong price elasticity of -1.0, while the foreign leisure market was found to be lower, at -0.2. No air fare effect could be identified for the business sector. Charter and domestic travel showed some fare effects (-0.4 and -0.3 respectively).

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[18] 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 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

		Elasticity of demand with respect to	
Sector	Share of Passenger demand 2005	Income	Air Fares
UK Business	8%	1.4	–
UK Leisure	29%	1.5	-1.0
UK Charter	16%	0.4	-0.4
Foreign Business	6%	0.6	–
Foreign Leisure	11%	0.7	-0.2
International to International Interliners	11%	0.7	-0.3
Domestic	17%	2.1	-0.3
Overall	100%	1.3	-0.5

Notes:

No significant long run price elasticity found for business

Income variable depends on sector

Price elasticities are point estimates, income elasticities are arc estimates.

Results are elasticity of terminal passengers to income or fares; for trip elasticities, the domestic value should be halved.

2.18 The resulting overall air fare elasticity is -0.46. 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.

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.

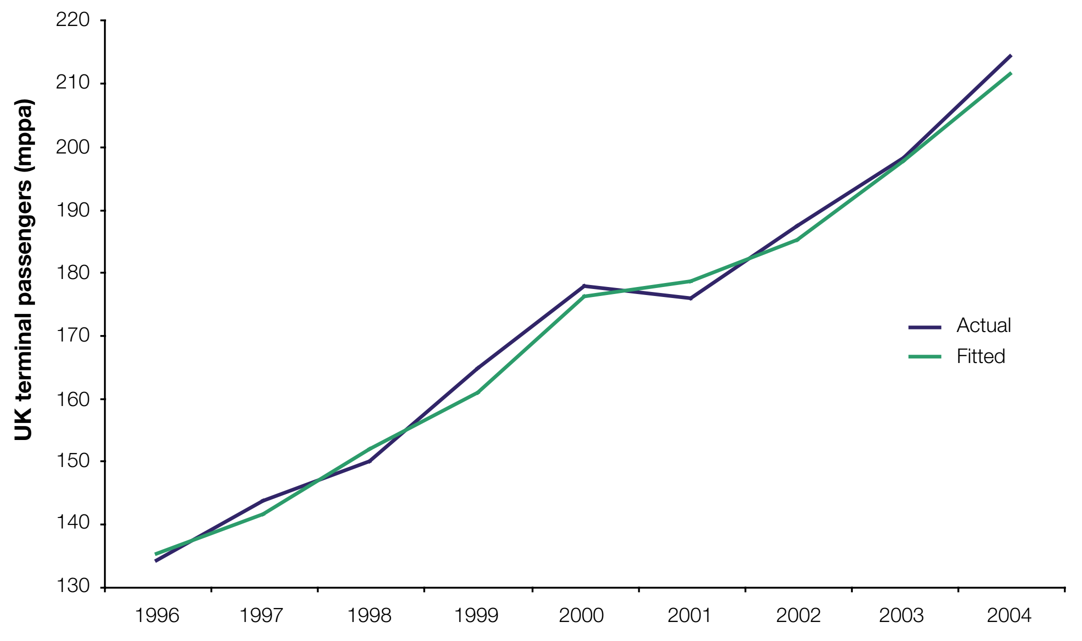
For example, the price elasticity of UK national leisure travel is found to be in the range -0.7 to -0.8 (outbound) by CAA, -0.6 by Dargay & Hanley, and -0.8 (-1.0 short haul, -0.4 long haul) by Dargay, Menaz & Cairns. These results lie within the 90% confidence range around our finding of -1.0 +/-0.5. 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, similar to our Foreign Leisure elasticity (-0.2). 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.

Model fit

2.19 The models resulting from this estimation process show a strong ability to fit the past data. Figure 2.4 shows that, when aggregated to the national level, the models accurately predict the trend in passenger demand, while also capturing shorter term movements.

Figure 2.4: Actual and fitted UK terminal passengers, 1996-2004



Note: not every model is fitted to data prior to 1996, so totals consistent with CAA outturn data can be presented from 1996 only.

Central case assumptions

2.20 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.

Macroeconomic factors

2.21 Growth assumptions for UK and foreign GDP, and UK consumer spending, are based on DfT WebTAG guidance[19], the HMT 2008 Budget and 2007 Pre-Budget Report[20] and the IMF World Economic Outlook[21]. 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.

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[19] *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.

[20] *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.

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

2.22 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.

2.23 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 at the average of the previous twelve months.

Air fares

2.24 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).

2.25 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 BERR central oil price projection, which falls (in 2007 prices) from $73 per barrel in 2007 to $68 per barrel in 2015, before rising back to $75 per barrel in 2030[22]. Fuel efficiency growth assumptions are derived from our fleet mix model, which is explained in Chapter 3.

2.26 Analysis of airline cost data shows that non-fuel costs have trended downwards in the last decade, for both short- and long-haul operations. From 2000 to 2005, they declined by around 5% per annum (pa). This was 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 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.

2.27 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.

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[22] *Communication on BERR Fossil Fuel Price Assumptions*, BERR, May 2008.

2.28 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. In line with the Aviation Emissions Cost Assessment methodology[23] we count revenues from Air Passenger Duty (APD) as part of the aviation industry's contribution to meeting its climate change costs.

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

2.30 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 DECC 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. While a multipier has significant weaknesses and does not necessarily apply with future technologies, we believe it represents an acceptable tool in this circumstance to ensure that the wider climate impact of aviation is not underestimated.

Market maturity

2.31 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.

2.32 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.

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[23] *Aviation Emissions Cost Assessment 2008*, Department for Transport, 2008, available at: http://www.dft.gov.uk/pgr/aviation/environmentalissues/aviationemissionscostassess/aviationemissionscost.pdf.

Box 2.4: Shadow price of carbon dioxide emissions

The current DECC guidance on the shadow price of carbon gives a 2000 shadow price of carbon dioxide emissions of £19/tCO_2 (in 2000 prices), rising by 2% pa in real terms. This 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 -10% to +20%, or £17/tCO_2 to £23/tCO_2. This range has been adopted in our sensitivity tests.

DECC announced alongside this guidance that they intended to review their guidance on the shadow price of carbon dioxide during 2008. This Review is ongoing and is due to report in March 2009.

Sensitivity test assumptions

2.33 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 set 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: trend growth

2.34 The economic activity ‘trend growth’ 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.

Economic activity: PBR 2008 GDP forecasts

2.35 As the HMT Pre-Budget Report 2008 UK GDP forecasts[24] became available late in our forecasting process, we have included them as a sensitivity test.

Oil prices

2.36 The oil price test varies the projection of oil prices within the BERR oil price projection range of (2030 values in 2007 prices): low ($45 per barrel); high ($105 per barrel); and, ‘high high’ ($150 per barrel)[25].

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[24] *Pre-Budget Report 2008: Facing global challenges: supporting people through difficult times*, HM Treasury, Nov 2008.

[25] Note that elsewhere in this document oil price may be in the 2004 price base of the econometric models.

Air Passenger Duty

2.37 As the HMT *Pre-Budget Report 2008* announcement revising the structure and rates of APD was made late in our forecasting process, the new version of APD has been included as a sensitivity test.

EU Emissions Trading Scheme

2.38 This assumes aviation enters the EU Emissions Trading Scheme in 2012 (see Box 3.1). It is assumed that APD is retained as in the central case, but the additional cost to ensure fares reflect climate change costs is removed, as it is redundant under this test.

Other non-fuel costs

2.39 For the period over which other non-fuel costs (i.e. costs other than fuel and APD) 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

2.40 Box 2.4 explains that in line with current 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

2.41 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

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

Forecast range

2.43 The overall range of forecast demand summarises all these uncertainties. The range is found by taking the lowest and highest demand forecast resulting from these sensitivity tests in each year.

Constrained demand forecasts to 2030

2.44 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.

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

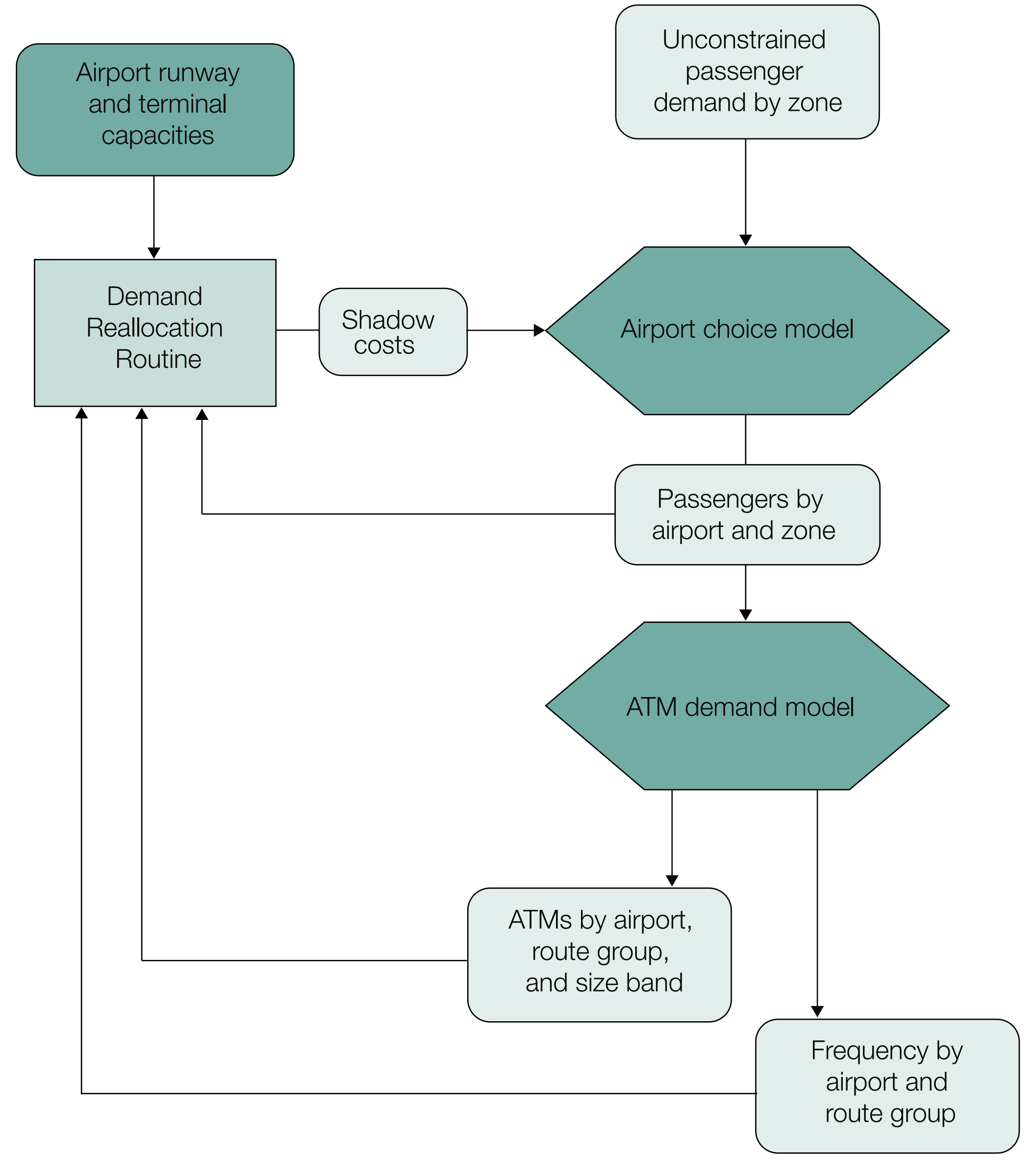
- the Passenger Airport Choice Model forecasts how passenger demand will split between UK airports;

- 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.

2.46 Figure 2.5 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 2.5: National Air Passenger Allocation Model



Passenger Airport Choice Model

2.47 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.

2.48 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

2.49 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.

2.50 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.

2.51 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.

2.52 To do this, the model splits the UK into 455 zones (see Figure 2.6), 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;
- flight duration and frequency;
- air fares;
- travellers' preferences for particular airports; and,
- travellers' value of time (which varies by journey purpose).

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 2.7. 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 that the airport will attract.

2.53 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 *UK Air Passenger Demand and* CO_2 *Forecasts* 2007.

Using the Passenger Airport Choice Model to forecast airport choice

2.54 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 networks and conditions:
  - traffic growth extends road journey times but improvements implemented as part of the Government's 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 2.6: Zones used in National Air Passenger Allocation Model

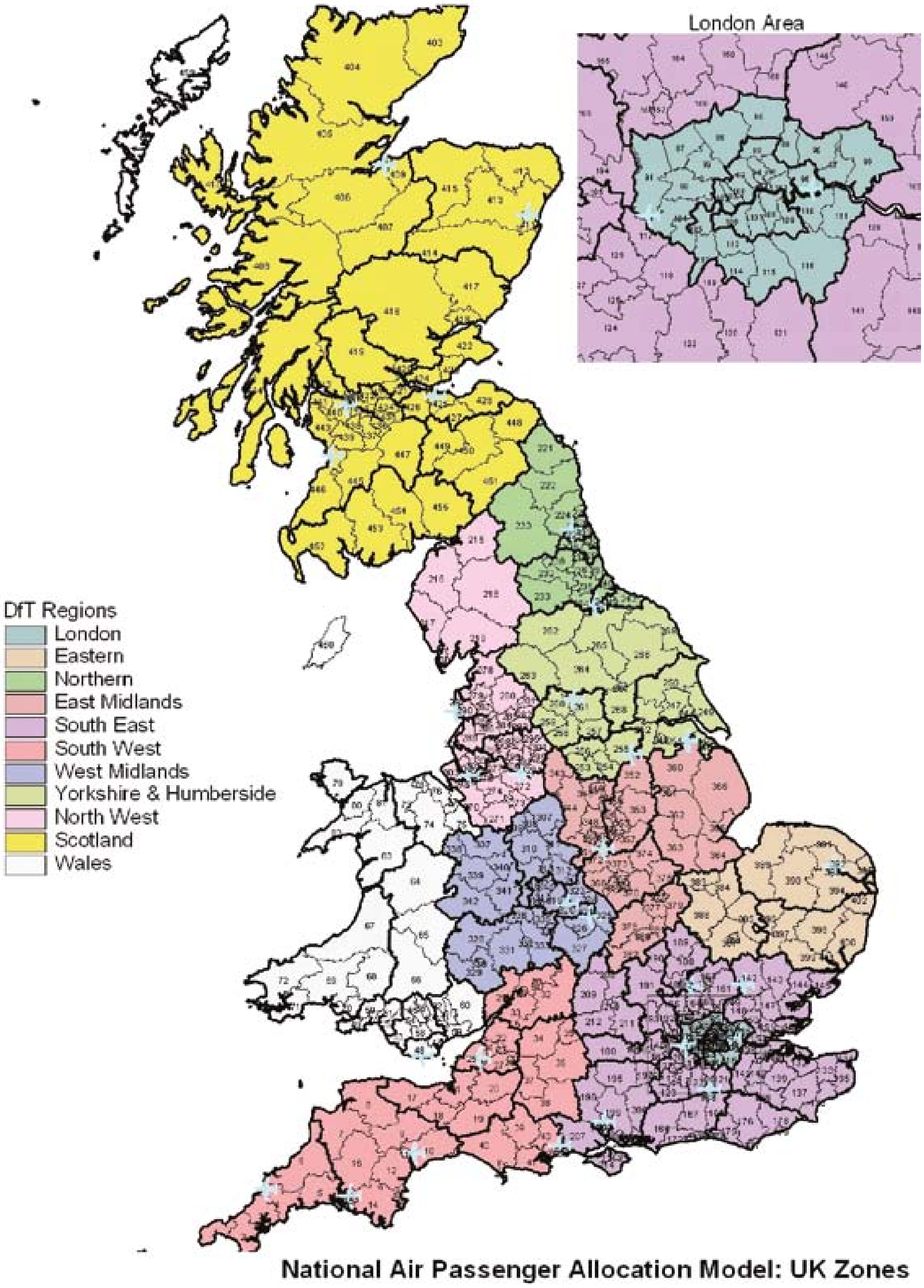
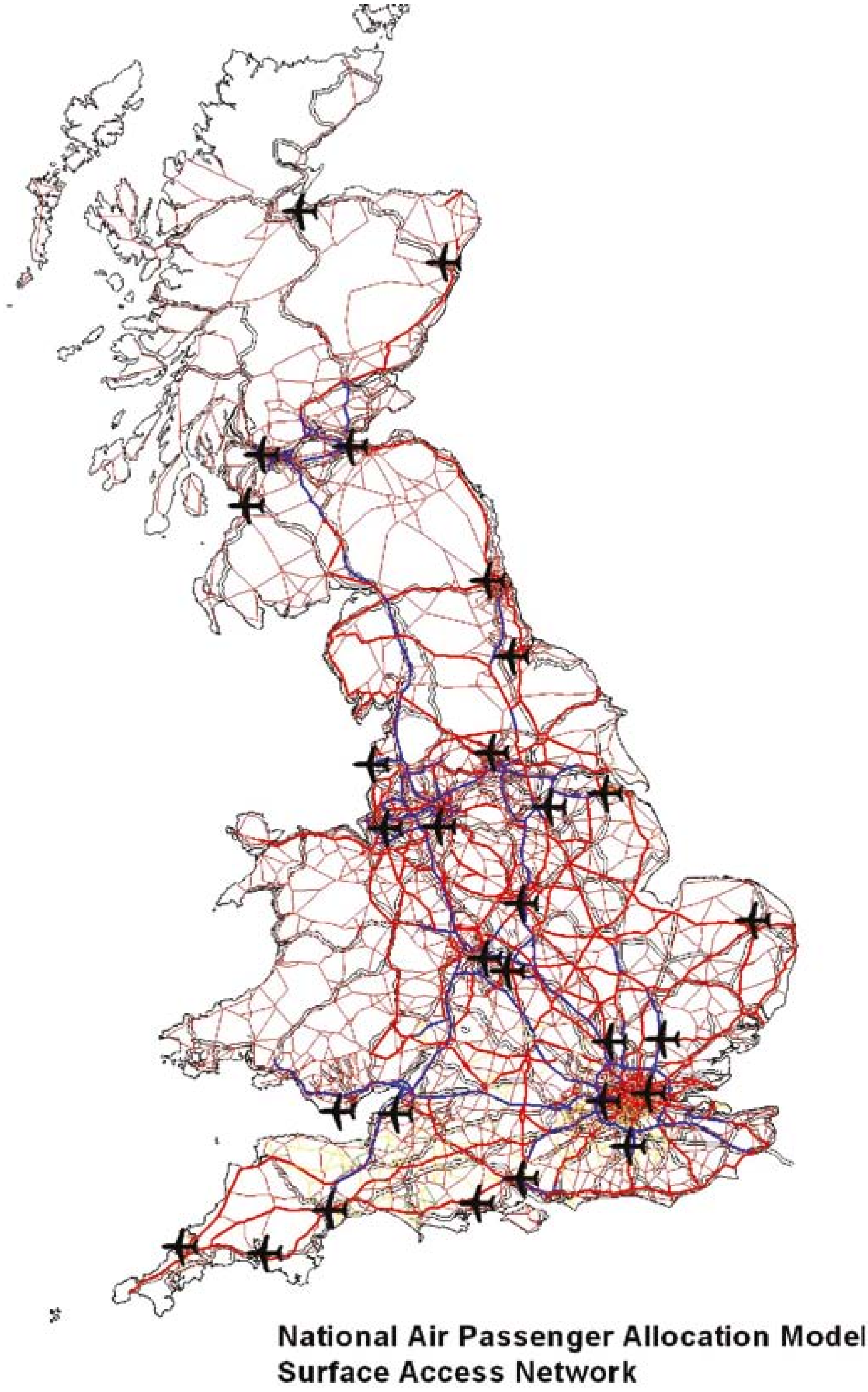


Figure 2.7: Surface access network used in the National Air Passenger Allocation Model



2.55 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.

Passenger Model Validation – airport level

2.56 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.

2.57 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 +/-2% at the three largest London area airports, and to within +/-0.4mppa 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 +/-5%, with the accuracy widening to +/-10% in one case (although this accounts for 4mppa, 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	66.5	-1.2	-2%
Gatwick	32.7	32.6	-0.1	0%
Stansted	22.0	22.3	0.3	1%
Luton	9.1	9.5	0.4	4%
London City	2.0	1.8	-0.2	-11%
London Subtotal	133.5	132.6	-0.9	-1%
Manchester	22.1	21.7	-0.3	-2%
Birmingham	9.3	8.9	-0.4	-4%
Glasgow	8.8	9.2	0.4	4%
Edinburgh	8.4	8.5	0.1	1%
Bristol	5.2	5.5	0.3	6%
Newcastle	5.2	5.2	0.0	1%
Belfast International	4.8	4.9	0.1	1%
Liverpool	4.4	4.4	0.0	0%
East Midlands	4.2	3.7	-0.4	-10%
Other Airports in Model	20.1	20.5	0.4	2%
Total in Model	226.0	225.2	-0.8	0%
Other Non-Modelled Airports	2.2			
National Total	228.2			

2.58 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

2.59 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[26] which each carried more than 25,000 passengers per annum in 2005[27]. 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%.

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[26] 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".

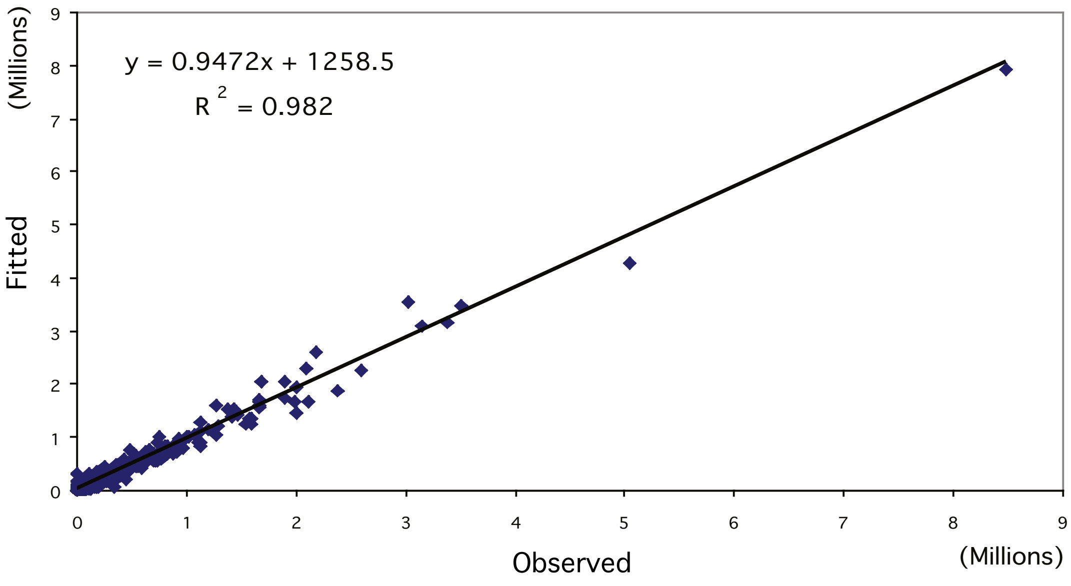
[27] Validation in practice extended to all routes with more than 5,000 passengers in 2005, extending the total calibration exercise to include close to 1,000 separate routes.

2.60 Figure 2.8 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.

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

Error band	Proportion of routes	Cumulative proportion
0%-5%	33%	33%
5%-10%	22%	55%
10%-20%	22%	77%
20%-30%	14%	91%
30%-40%	5%	96%
40%-50%	2%	97%
50%+	3%	100%

Figure 2.8: Scatter plot of actual and fitted passenger numbers by route, all flights (domestic and international), 2005



ATM Demand Model

2.61 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.

2.62 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.

2.63 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.

2.64 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

2.65 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.

2.66 Table 2.4 below reports actual and predicted air transport movements at individual airports with over 3mppa demand (these comprise 91% of passenger demand). It shows that the model predicts ATMs accurately at London area airports. Heathrow, Gatwick, and Stansted ATMs are predicted to within +/-2%. The tolerance widens at London City and Luton, but their relatively small throughput means total London area traffic is accurately forecast to within +/-1%.

2.67 The ATM predictions at the larger airports outside the London area are similarly accurate, all being within +/-7% of actual figures.

2.68 At the airports with 3mppa demand or less (comprising 17% of total ATMs), the model predicts ATM demand to within 15% in 84% 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 2005	Fitted	Difference	Difference (%)
Heathrow	474	462	-12	-2%
Gatwick	253	250	-4	-1%
Stansted	180	184	4	2%
Luton	79	86	7	9%
London City	61	55	-6	-10%
London Subtotal	1,046	1,036	-10	-1%
Manchester	218	206	-12	-5%
Birmingham	114	111	-3	-2%
Glasgow	100	97	-2	-2%
Edinburgh	119	119	0	0%
Bristol	64	64	0	-1%
Newcastle	57	54	-3	-5%
Belfast International	49	48	0	-1%
Liverpool	50	47	-3	-5%
East Midlands	54	50	-4	-7%
Other Airports in Model	393	364	-29	-7%
Total in Model	2,264	2,196	-67	-3%
Other Non-Model	137			
National Total	2,401			

ATM Model Validation – route level

2.69 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.

2.70 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.

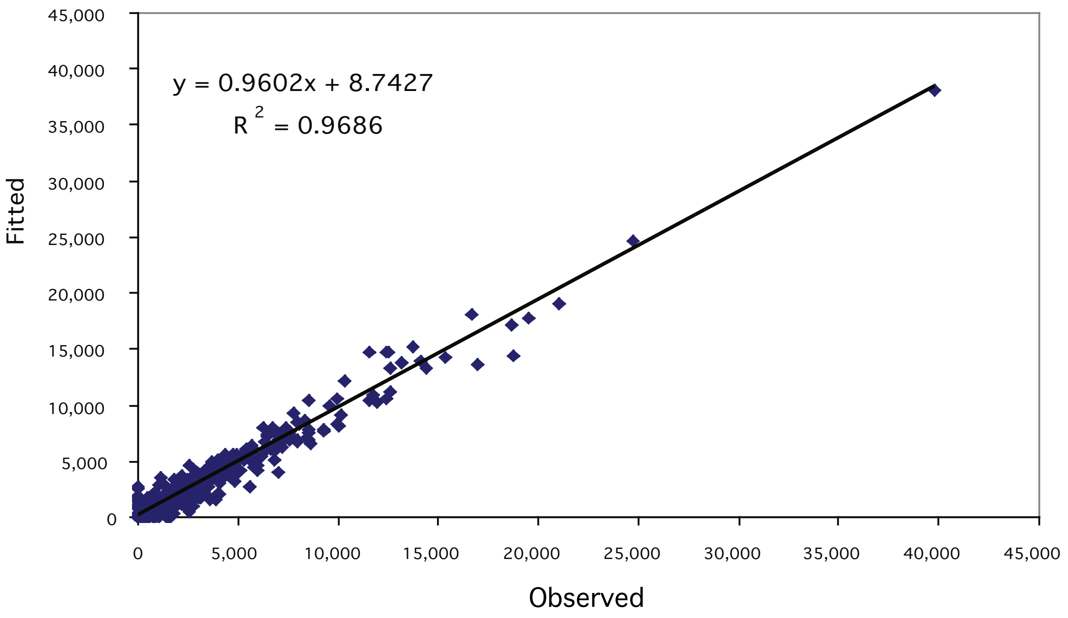
2.71 Table 2.5 shows that about 40% of passengers are on routes where ATMs are predicted to within +/-10% of actual, and two-thirds of passengers are on routes where ATMs are predicted to within +/-20%.

2.72 Figure 2.9 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%	39%
10%-20%	25%	65%
20%-30%	14%	78%
30%-40%	7%	86%
40%-50%	4%	89%
50%+	11%	100%

Figure 2.9: Scatter plot of actual and fitted ATMs by route, all flights (domestic and international), 2005



Demand Reallocation Routine

2.73 As illustrated in Figure 2.5, 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.

2.74 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.

2.75 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[28].

2.76 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.

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

Airport capacity assumptions

2.78 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.

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

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 as well as 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, since airports with a high proportion of seasonal holiday traffic will have less effective capacity than airports which can make full use of their runways all year round. In addition, airports which depend heavily on premium business traffic can make relatively less use of their off-peak periods.

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 capacity inputs 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 stringent conditions laid down in the ATWP. The results reported in that document are used as the Heathrow capacity input assumptions in our current forecasting.

2.79 The ATWP 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.

2.80 We consider seven future capacity scenarios, updated with the 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 Luton (135,000 ATMs in 2015) and a 6mppa terminal increase at Gatwick
s05	Maximum use, plus Heathrow third runway (605,000 ATMs in 2020, rising to 702,000 ATMs in 2030)
s07	Maximum use, plus Stansted second runway (480,000 ATMs in 2015)
s12s2	Maximum use, plus Stansted second runway (480,000 ATMs in 2015), Heathrow third runway (605,000 ATMs in 2020, rising to 702,000 ATMs in 2030)
s12s2mm1	Maximum use, plus Stansted second runway (480,000 ATMs in 2015), Heathrow mixed mode (480,000 ATMs 2010-2019) then third runway (605,000 ATMs 2020, rising to 702,000 ATMs in 2030)
s12s2mm2	Maximum use, plus Stansted second runway (480,000 ATMs in 2015), Heathrow mixed mode (480,000 ATMs 2010-2015 & 540,000 ATMs 2015-2020), then third runway (605,000 ATMs 2020, rising to 702,000 ATMs in 2030)
s12s2_2015	Maximum use, plus Stansted second runway (480,000 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)
s12s2_2025	Maximum use, plus Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 in 2025, rising to 702,000 in 2030)
s12s2_605/122	Maximum use, plus Stansted second runway (480,000 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)
s12s2_605/129	Maximum use, plus Stansted second runway (480,000 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)

Notes:

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.

The 'planning case' (s01) has been amended since *UK Air Passenger Demand and* CO_2 *Forecasts 2007* to include the granting of planning permission to London City to 120,000 ATMs per annum, and Stansted to 35mppa and 259,000 ATMs off its existing runway.

Four new scenarios have been added since *UK Air Passenger Demand and* CO_2 *Forecasts 2007*. These have been developed to allow examination of the net benefits of additional capacity at Heathrow to factors such as opening date, 2030 runway capacity, and 2030 terminal capacity. Of the two scenarios where runway capacity is assumed to be 605,000 ATMs in 2030, the assumption of 129mppa terminal capacity is currently seen as more appropriate than 122mppa, given the likelihood of reduced runway capacity encouraging greater use of larger aircraft and higher load factors.

2.81 The ‘maximum use’ scenario (code ‘s02’) involves each airport developing as necessary to fully utilise its current runway capacity, if sufficient demand exists. This includes the increase in capacity (with a single runway) at Stansted to 35mppa and London City’s planning approval to 120,000 ATMs per annum, ‘in the planning case’. It also includes a terminal expansion and limited improvements to the taxiways at Luton.

2.82 Table 2.7 shows the 2030 South East runway capacities by development scenario. 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 2.7: Runway capacity assumptions, ’000 ATMs pa, 2005 and 2030

		s01	**s02**	**s05**	**s07**	**s12s2**	**s12s2mm1**	**s12s2mm2**	**s12s2_2015**	**s12s2_2025**	**s12s2_605/122**	**s12s2_605/129**
Airport	2005	Planning system in SE	Maximum use	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 in 2015)	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2019) then third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	Stansted second runway (480,000 2015), Heathrow third runway opens 605,000 2025, rising to 702,000 in 2030)	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity
Heathrow	480	480	480	702	480	702	702	702	702	702	605	605
Gatwick	260	260	260	260	260	260	260	260	260	260	260	260
Stansted	241	241	259	259	480	480	480	480	480	480	480	480
Luton	100	100	135	135	135	135	135	135	135	135	135	135
London City	73	120	120	120	120	120	120	120	120	120	120	120
London, Total	1,154	1,201	1,254	1,476	1,475	1,697	1,697	1,697	1,697	1,697	1,600	1,600

Table 2.8: Terminal capacity assumptions, mppa, 2005 and 2030

		s01	**s02**	**s05**	**s07**	**s12s2**	**s12s2mm1**	**s12s2mm2**	**s12s2_2015**	**s12s2_2025**	**s12s2_605/122**	**s12s2_605/129**
Airport	2005	Planning system in SE	Maximum use	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 in 2015)	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2019) then third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	Stansted second runway (480,000 2015), Heathrow third runway opens 605,000 2025, rising to 702,000 in 2030)	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity
Heathrow	72	86	86	135	86	135	135	135	135	135	122	129
Gatwick	40	40	47	47	47	47	47	47	47	47	47	47
Stansted	25	25	35	35	82	82	82	82	82	82	82	82
Luton	10	10	17	17	17	17	17	17	17	17	17	17
London City	5	8	8	8	8	8	8	8	8	8	8	8
London, Total	152	169	193	242	240	289	289	289	289	289	276	283

2.3 PASSENGER AND ATM FORECASTS

Passenger Demand Forecasts

2.83 This section summarises the 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. Annexes F and G provide more detailed results.

National unconstrained demand forecasts

2.84 As explained above, the 'unconstrained' demand forecast shows the demand for air travel that would be expected if there were no airport capacity constraints[29]. 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.

2.85 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 241 million passengers per annum (mppa) in 2007 to 465mppa in 2030 under the central case, within a range of 415 to 500 mppa. Figure 2.10 illustrates the central, low and high case unconstrained forecasts. Annexes F and G provide more detailed results.

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

	Low	Central	High
2005	228	228	228
2010	245	260	265
2015	280	315	330
2020	325	365	385
2025	370	410	435
2030	415	465	500

Note: Figures in forecast years rounded to 5mppa

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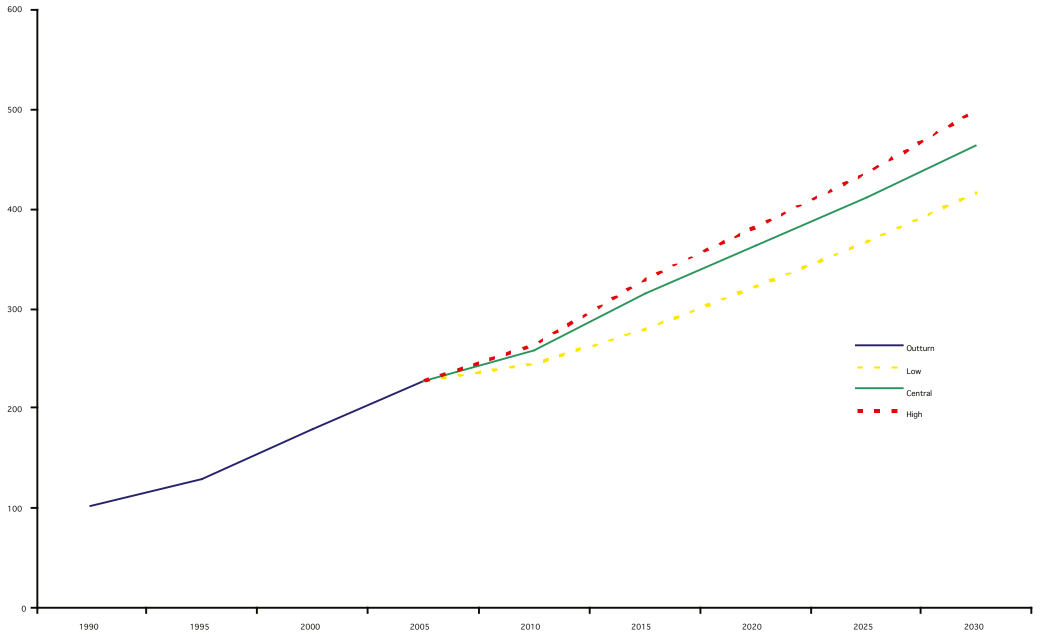
[29] Air passenger demand is in practice also reduced by the use of Air Passenger Duty to ensure aviation meets its climate change costs. Without APD, our central 2030 forecast of unconstrained air passenger would be 485mppa.

Figure 2.10: Unconstrained demand – historic with central, low and high forecasts, million passengers per annum



2.86 Section 2.2 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 forecasts against sensitivity ranges of key input variables.

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

Scenario	Difference from central case assumptions	2030 demand (mppa)	Difference from central case (mppa)	Difference from central case (%)
Central case	–	465	–	
Low GDP	GDP grows ¼% pa slower	430	-35	-8%
High GDP	GDP grows ¼% pa faster	500	35	8%
PBR Nov 2008 GDP forecast	Pre-Budget Report 2008 GDP forecasts	445	-20	-4%
BERR High High oil price	Increase from $38 to $136 per barrel by 2030 (2004 price base)	415	-50	-11%
BERR High oil price	Increase from $38 to $95 per barrel by 2030 (2004 price base)	445	-20	-4%
BERR Low oil price	Increase from $38 to $41 per barrel by 2030 (2004 price base)	490	25	5%
EU ETS	Aviation enters EU ETS scheme (central case APD retained)	445	-20	-4%
Higher shadow price of CO_2	Shadow price of carbon raised by 20%	460	-5	-1%
Lower shadow price of CO_2	Shadow price of carbon lowered by 10%	465	neg	neg
Higher radiative forcing factor	Radiative forcing factor raised from 1.9 to 4.0	440	-25	-5%
Lower radiative forcing factor	Radiative forcing factor dropped from 1.9 to 1.0	470	5	1%
Higher airline non-fuel costs	Airline non-fuel costs increased by 0.5% pa 2005-2020	455	-10	-2%
Lower airline non-fuel costs	Airline non-fuel costs reduced by 0.5% pa 2005-2020	470	5	1%
Lower fuel efficiency	5% ACARE replacement stock 2020-2030	465	neg	neg
Higher fuel efficiency	5% ACARE replacement stock 2020, 50% ACARE by 2030	465	neg	neg
PBR Nov 2008 APD bands and rates	Pre-Budget Report 2008 four band APD in 2010	465	neg	neg

Notes:

All mppa figures rounded to nearest 5mppa

‘neg’ means a result which is non-zero, but rounds to zero

National constrained demand forecasts

Central case

2.87 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 tables 2.7 and 2.8), 2030 national demand is forecast to rise to 455mppa in the central case, within the range 410mppa to 480mppa. Annexes F and G give 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[30]

	Low	**Central**	**High**
2005	228	228	228
2010	250	260	260
2015	280	310	315
2020	320	355	370
2025	365	405	430
2030	410	455	480

Note: Figures in forecast years rounded to 5mppa

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[30] 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 2.9). 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.

Box 2.7: Forecast terminal passengers and journeys

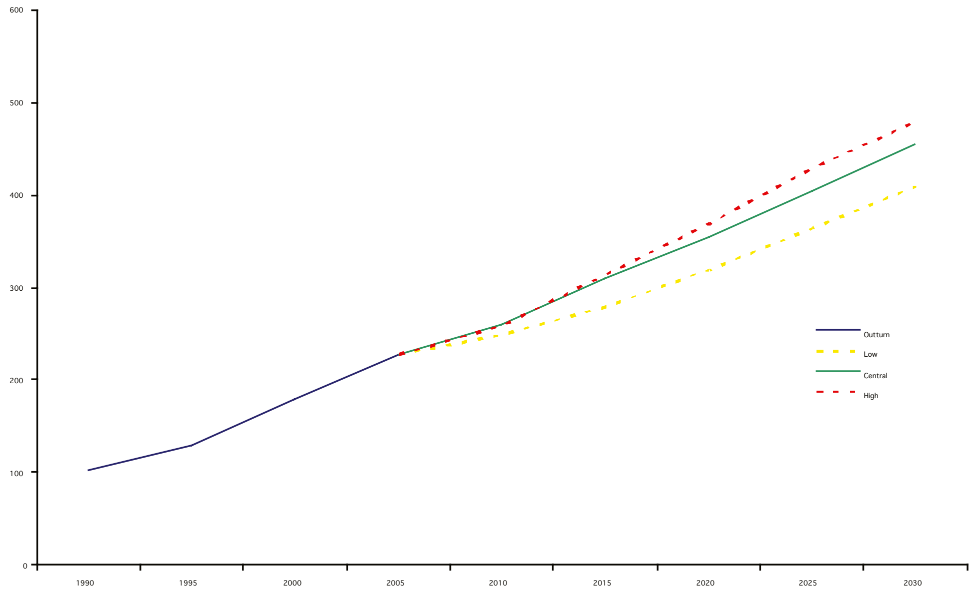
Interpreting the forecasts is aided by knowing what they imply for the average number of journeys by UK residents, and total foreign visitors, by air. To convert the central 2030 constrained forecast of 455mppa into journeys requires a careful application of the definition of terminal passengers set 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 415m terminal passengers;
- 90m terminal passengers account for 22.5m internal domestic return journeys, leaving 325m terminal passengers (162.5m return journeys on international trips);
- of the remaining 325m terminal passengers over two thirds (230m) will be UK residents; and
- hence our forecast implies that there will be about 115m return international journeys made by UK residents and some 48m visits made 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.

2.88 Figure 2.11 further illustrates the central, high and low case results for the central ‘s12s2’ capacity scenario. Comparing these results with the unconstrained forecasts in Table 2.9 and Figure 2.10 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 12mppa in 2015. But in 2020 and 2025, when the extra capacity supported at Stansted and Heathrow is delivered, the capacity effect drops to 8 mppa. By 2030 much of the new capacity is taken up, and the capacity effect rises again to 10mppa.

Figure 2.11: Constrained demand – historic with central, low, and high forecasts, million passengers per annum



Sensitivity tests

2.89 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	–	455	–	
Low GDP	GDP grows ¼% pa slower	425	-30	-7%
High GDP	GDP grows ¼% pa faster	480	25	5%
PBR Nov 2008 GDP forecast	Pre-Budget Report 2008 GDP forecasts	435	-20	-4%
BERR High High oil price	Increase from \$38 to \$136 per barrel by 2030 (2004 price base)	410	-45	-10%
BERR High oil price	Increase from \$38 to \$95 per barrel by 2030 (2004 price base)	435	-20	-4%
BERR Low oil price	Increase from \$38 to \$41 per barrel by 2030 (2004 price base)	470	15	3%
EU ETS	Aviation enters EU ETS scheme (central case APD retained)	435	-20	-4%
Higher shadow price of CO_2	Shadow price of carbon raised by 20%	445	-10	-2%
Lower shadow price of CO_2	Shadow price of carbon lowered by 10%	455	neg	neg
Higher radiative forcing factor	Radiative forcing factor raised from 1.9 to 4.0	430	-25	-5%
Lower radiative forcing factor	Radiative forcing factor dropped from 1.9 to 1.0	460	5	1%
Higher airline non-fuel costs	Airline non-fuel costs increased by 0.5% pa 2005-2020	445	-10	-2%
Lower airline non-fuel costs	Airline non-fuel costs reduced by 0.5% pa 2005-2020	460	5	1%
Lower fuel efficiency	5% ACARE replacement stock 2020-2030	450	-5	-1%
Higher fuel efficiency	5% ACARE replacement stock 2020, 50% ACARE by 2030	455	neg	neg
PBR Nov 2008 APD bands and rates	Pre-Budget Report 2008 four band APD in 2010	450	-5	-1%

Notes:

All mppa figures rounded to nearest 5mppa

‘neg’ means a result which is non-zero, but rounds to zero

Capacity scenarios

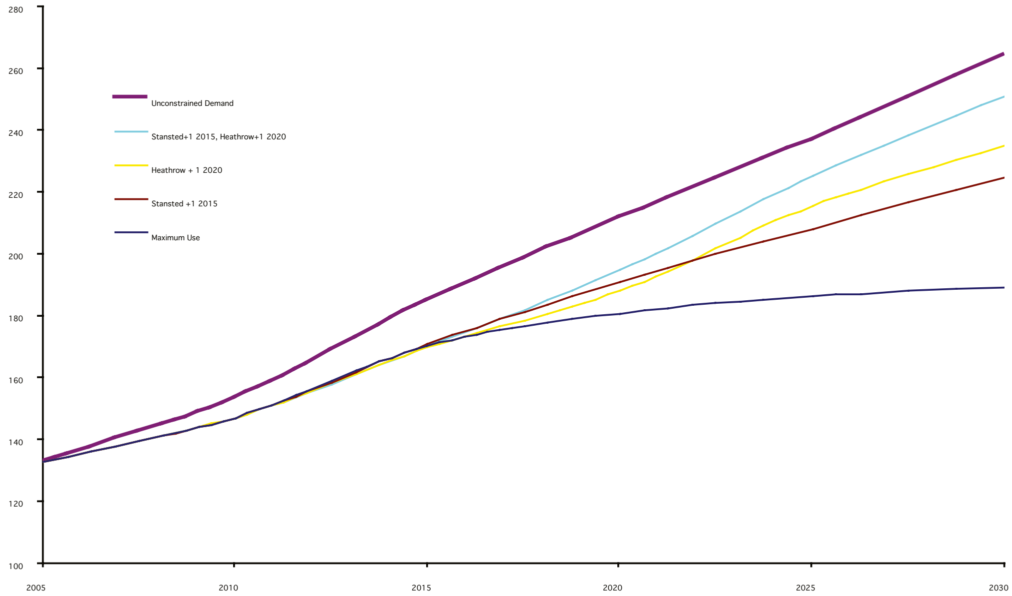
2.90 Table 2.13 shows the forecast of constrained demand by capacity scenario and year (assuming the central unconstrained demand case). It demonstrates that an extra runway at either Stansted or Heathrow accommodates a greater throughput. Stansted's earlier opening date means that between 2015 and 2020 Stansted is able to deliver a greater contribution to serving growing demand, but thereafter Heathrow has the greater effect. 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	255	305	340	370	400
s02	Maximum use	260	310	345	375	405
s05	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	260	305	350	400	440
s07	Stansted second runway (480,000 in 2015)	260	310	350	390	430
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	260	310	355	405	455
s12s2mm1	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2019), then third runway (605,000 in 2020, rising to 702,000 in 2030)	260	310	355	405	455
s12s2mm2	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 in 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	260	315	355	400	450
s12s2_2015	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	260	310	360	405	450
s12s2_2025	Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 in 2025, rising to 702,000 in 2030)	260	310	350	395	450
s12s2_605/122	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)	260	310	360	400	445
s12s2_605/129	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)	260	310	360	400	445

2.91 Figure 2.12 illustrates the position for the South East airports. As with the national picture, 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 between 2015 and 2020. However, by 2025 the position is reversed. 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 2.12: Constrained terminal passenger demand forecasts at main South East airports, by capacity scenario, million passengers per annum



Performance of previous forecasts, and current model performance since 2005

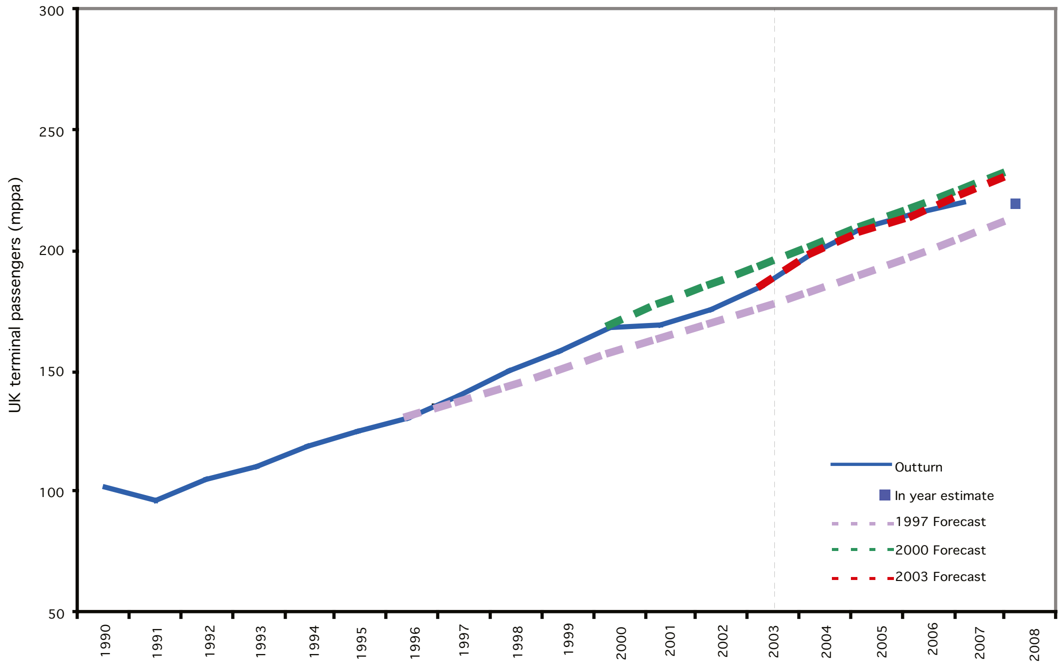
Previous forecasts

2.92 The Department for Transport has issued forecasts of UK air passenger demand for many years. Up to 2000, these were unconstrained demand forecasts only. However, for the ATWP in 2003, unconstrained demand forecasts were combined with the National Airport Passenger Allocation Model to produce constrained passenger demand forecasts for the first time. These were updated in the 2006 ATWP *Progress Report*, and in the 2007 *UK Air Passenger Demand and* CO_2 *Forecasts*.

2.93 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 also necessary to allow sufficient time since the forecasts were produced to observe the trend in outturn. We therefore consider the performance of the 1997, 2000, and 2003 forecasts.

2.94 Figure 2.13 below compares these three forecasts against outturn, and DfT's in-year estimate of the likely 2008 outturn[31]. As noted above, the 1997 and 2000 forecasts are unconstrained, while the 2003 forecasts are constrained by capacity. Demand growth exceeded the 1997 forecast, but 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 recovered from the very slow growth in 2001, and returned to the forecast in 2005. The 2003 forecast proved very accurate to 2006, after which the slowing of growth has caused demand to dip below the forecast.

Figure 2.13: 1997, 2000, and 2003 unconstrained demand forecasts versus outturn, million passengers per annum



Model Performance since 2005

2.95 As our model begins forecasting from 2005, we can use the latest version to investigate the causes of the more recent slower growth. This is achieved by looking at the 'forecasts' for 2005 to 2008 provided by the latest version of the model, which are based on more recent outturn data on GDP, oil prices, APD etc, and which were not available for the 2003 forecasts. If the latest forecasts for 2005 to 2008 match the outturn data well, it would tell us that the structure and parameters of the current model are accurate, and that variances between earlier forecast generations and outturn are explained by input variables not turning out as forecast. It would also tell us that the recent slower growth in demand is due to short term, cyclical

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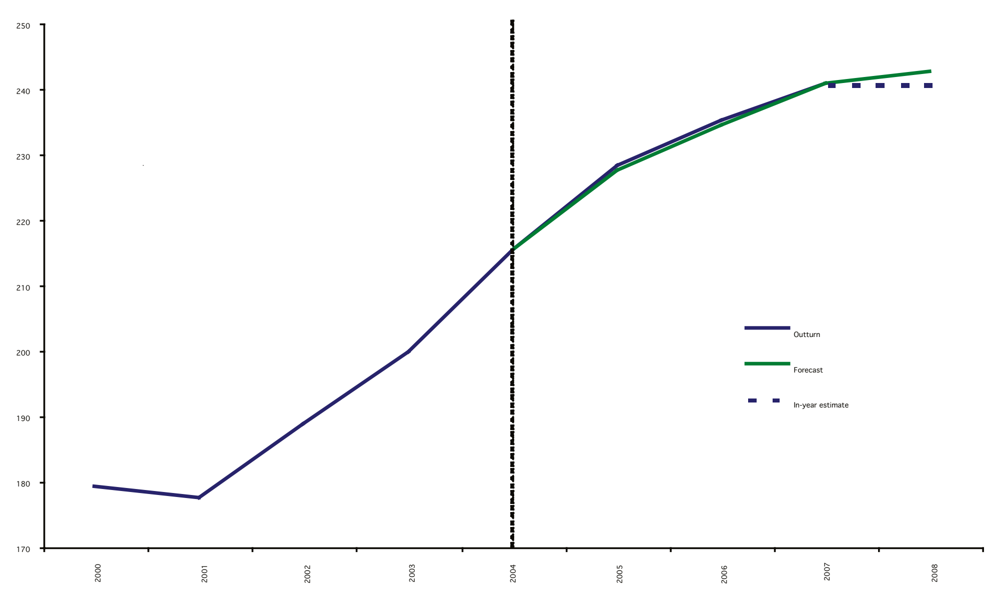
[31] DfT's 'in year estimate' assumes the percentage growth in demand from 2007 to 2008 equals that between the first nine months of the two years.

factors, rather than a change in the way economic growth and air fares drive demand growth.

2.96 Figure 2.14 shows that the latest model's (central case) forecasts of constrained demand, based on the current outturn data on GDP, oil prices, and APD, successfully predict the slower growth in 2005-08[32]. Hence we may conclude that: the model structure is accurate; recent slower growth is a short term result; and, we should expect a return to growth once economic growth picks up again.

Figure 2.14: Outturn and forecast passenger demand, 2005-2008



2.97 This mirrors the findings in the CAA's 2008 report *Recent Trends in Growth of UK Air Passenger Demand*[33], which showed that there had been two years of relatively slower growth resulting from "the current economic environment and competition from domestic rail services, rather than any longer term, structural change in demand for air services".

Airport Forecasts

2.98 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.

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[32] As set out in section 2.2, this central case forecast is based on the HMT Budget 2008 GDP forecasts. Subsequent downward revisions to HMT's 2008 GDP forecast (on which the 'PBR 2008 GDP' sensitivity test is based; results reported earlier in this section) reduce the 2008 constrained demand forecast by about 2mppa, matching the in-year estimate even more closely.

[33] *Recent Trends in growth of UK air passenger demand*, CAA, January 2008.

2.99 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 ATWP set out airport capacity developments that the Government supports and these are incorporated in the modelling. However, the forecasts should not be interpreted in isolation 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	65	80	135
Gatwick	35	35	40
Stansted	20	35	55
Luton	10	15	15
London City	2	4	5
London	132	169	250
annual growth rate		2.5%	2.6%
Others	93	139	203
annual growth rate		4.1%	2.6%
Total	225	308	453
annual growth rate		3.2%	2.6%

Notes:

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

2. Columns may not sum to total due to rounding

3. Compound annual growth rates shown are 2005-2015 and 2015-2030.

2.100 The ATWP 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

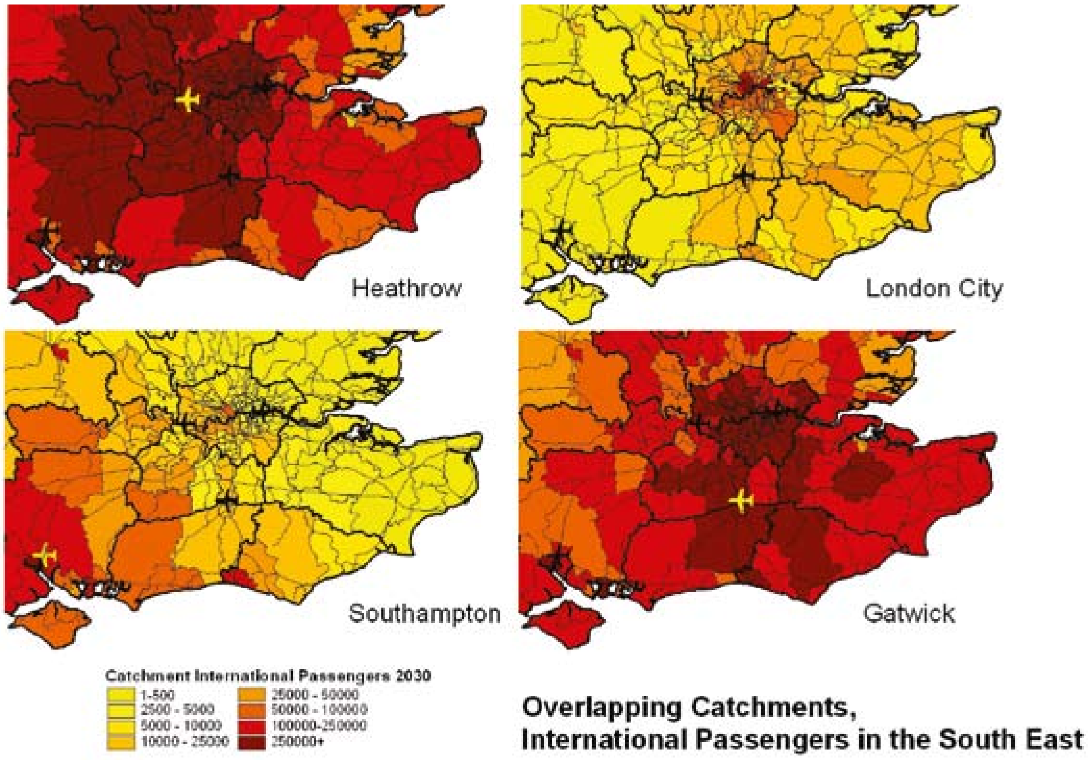
Following the ATWP recommendation, nearly all airport operators have produced their own demand forecasts. Several of these (including those of the largest London and regional airports) are broadly similar to our current and previous forecasts. Where local master plan forecasts differ from our forecasts, 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.

2.101 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 2.15 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 2.15: Projected overlapping catchments from four South East airports in 2030



2.102 Table 2.15 overleaf 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, million passengers per annum

		Heathrow	Gatwick	Stansted	Luton	London City	Total London	Other	Total
s01	Planning system in SE	90	40	35	10	5	180	220	400
s02	Maximum use	90	40	35	15	5	185	220	405
s05	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	135	40	35	15	5	230	210	440
s07	Stansted second runway (480,000 in 2015)	90	40	70	15	5	220	210	430
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	135	40	55	15	5	250	205	455
s12s2mm1	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2019), then third runway (605,000 in 2020, rising to 702,000 in 2030)	135	40	55	15	5	250	205	455
s12s2mm2	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	135	40	55	15	5	250	200	450
s12s2_2015	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	135	40	55	15	5	250	200	450
s12s2_2025	Stansted second runway (480,000 2015), Heathrow third runway opens 605,000 2025, rising to 702,000 in 2030)	125	40	60	15	5	245	205	450
s12s2_605/122	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity	115	40	60	15	5	235	210	445
s12s2_605/129	Stansted second runway (480,000 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity	115	40	60	15	5	235	210	445

Note: Forecasts rounded to nearest 5mppa.

Projections beyond 2030

2.103 The UK has a commitment to reduce its CO_2 emissions by 80% 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. While it is for consideration how international aviation (which is not part of the UK emissions inventory) should relate to this target, for the purposes of forecasting UK aviation CO_2 emissions and appraising airport developments, it is therefore necessary to project UK terminal passengers and ATMs to 2080. In line with DfT 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, assuming no further airport capacity expansion beyond the 's12s2' capacity scenario.

2.104 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, for all demand cases, in each market sector at each airport for the five years before 2030 in the central growth case continues until terminal capacity is reached, subject to the rate being positive, and less than double the national unconstrained demand projection.

2.105 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.

2.106 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.

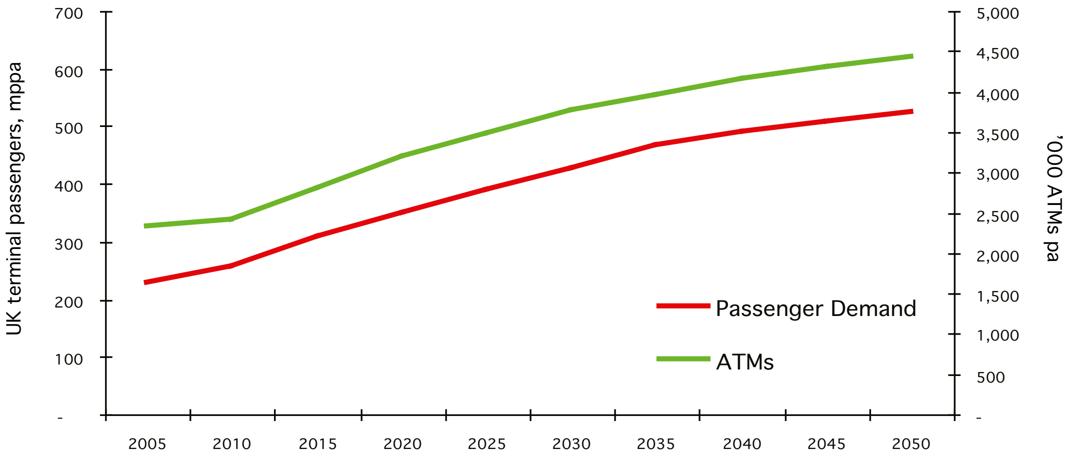
Results

2.107 Table 2.16 and Figure 2.16 below show the resulting national projections of constrained passenger 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	’000 ATMs
2005	228	2,333
2010	258	2,416
2020	350	3,190
2030	427	3,759
2040	490	4,148
2050	525	4,423

Figure 2.16 Projected constrained passenger and ATM demand, to 2050



Sensitivity tests

2.108 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 2005
- The UK's total CO_2 emissions were 2.0% of the global total in 2005
- UK domestic aviation accounted for 0.4% of the UK's carbon dioxide emissions in 2006
- If international emissions from shipping and aviation are added to the UK total for 2006, UK aviation (domestic and international) accounted for 6.4% of the UK's CO_2 emissions
- UK aviation's CO_2 emissions have grown strongly in past decades, rising from 12.5 $MtCO_2$ in 1985, to 21.5 $MtCO_2$ in 1995 and 37.9 $MtCO_2$ in 2006. This reflects demand growing faster than fuel efficiency
- Significant developments have taken place in climate change policy and it is important to understand these when interpreting UK aviation emissions forecasts. They include the Royal assent given to the Climate Change Act which sets a target for UK greenhouse gas emissions for 2050 and the inclusion of aviation in the EU ETS from 2012, meaning aviation's CO_2 emissions will be capped
- The Government's comprehensive strategy to address climate change means that overall UK emissions are expected to fall significantly over the period to 2050. Within the overall level of emissions, emissions by sector will be expected to differ
- In aviation, emissions are forecast to continue rising in the next two decades, as demand continues to grow faster than fuel efficiency. By 2030, emissions are forecast to rise to 58.4 $MtCO_2$, within the range 51.8$MtCO_2$ to 61.6 $MtCO_2$
- After 2030, the growth in aviation emissions is projected to slow and stabilise, as demand matures and is constrained by airport capacity. By 2050, UK aviation CO_2 emissions are projected to stabilise and reach 59.9 $MtCO_2$, within the range 53.0 $MtCO_2$ to 65.0 $MtCO_2$
- The inclusion of aviation in the EU ETS from 2012 will place a cap on its emissions. Growth in this sector will require it to secure reductions in other sectors through the purchase of allowances, so that overall EU emissions will not grow

- If the aviation industry expectations for fuel efficiency improvements to 2050 from major technological developments and lower-carbon fuels are realised, then UK aviation CO_2 emissions could be significantly lower than forecast here
- With overall UK emissions dropping to meet the Climate Change Act 2050 target, even with aviation emissions stabilising after 2030, aviation's share of UK CO_2 emissions is expected to rise. Depending on the policy outcome, of which no one outcome is more likely than another, aviation's share of UK emissions in 2050 could be in the range 19-54%

Introduction

3.1 The *Future of Air Transport White Paper*[33] 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*[34] 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 *UK Air Passenger Demand and CO_2 Forecasts 2007* met the Government's commitment made in the 2006 *Future of Air Transport Progress Report* to publish revised CO_2 emissions forecasts. This chapter updates those forecasts to 2030 and projections to 2050, reflecting the latest demand forecasts and outturn data. It also explains the nature and purpose, interpretation, and context of the forecasts.

3.4 Significant developments have taken place in climate change policy over the last year and include:

i) The Climate Change Act 2008 has received Royal assent, setting a target to reduce UK domestic greenhouse gas emissions by 80% below 1990 levels by 2050.

ii) An agreement has been reached in Europe such that aviation will be included in the EU emissions trading scheme (ETS) from 2012, which covers carbon dioxide emissions. Under the emissions trading scheme, aviation emissions of carbon dioxide from all departing and arriving flights are capped. In 2012 this cap will be 97% of average annual emissions for the 2004-06 period, changing to 95% of those emissions from 2013. Under the ETS, aviation emissions would not be able to grow above the cap except by purchasing emissions allowances from other sectors. This means that overall emissions from sectors included in the EU ETS will not be increased by any growth in CO_2 emissions from aviation.

iii) The Committee on Climate Change recommended on 1 December 2008 that the scope of the targets and budgets in the Climate Change Act

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[33] *The Future of Air Transport*, Department for Transport, Dec 2003, Cm6406.

[34] See *Aviation and Global Warming*, Department for Transport, January 2004.

should not be extended to include international aviation and shipping. However, like the Government, the Committee on Climate Change also believes that international aviation and shipping emissions should be included in the UK's climate change strategy. This could mean that in due course these emissions are included in some separate framework, or it could mean they are included within the UK's domestic framework – these matters are the subject of ongoing international discussions.

3.5 Reflecting these developments, in this report we have set the forecasts of aviation CO_2 emissions in their full context, and have extended the analysis of the results.

Nature and purpose of the forecasts

3.6 We forecast carbon dioxide emissions produced by all flights departing UK airports to 2030, adjusted to match the DECC estimate of outturn (i.e. published) aviation CO_2 emissions (using the UNFCCC reporting method) in the base year[35]. 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.

3.7 These forecasts have been produced on the airport capacity scenario involving an additional runway at Heathrow with a capacity of 605,000 ATMs in 2020 rising to 702,000 ATMs in 2030, plus a second runway at Stansted from 2015[36]. Any lower level of airport capacity, and therefore aircraft activity, would have a corresponding impact on UK aviation CO_2 emissions. Alternative capacity scenarios have been explored, as set out in Annex G.

3.8 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. Also, the scope 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. The sources of emissions covered in the forecasts in this chapter are set out in Table 3.1 below. Our approach is consistent with the DECC outturn estimates and the UNFCCC recommended approach for reporting on carbon dioxide emissions from international aviation[37].

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[35] 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. DECC's estimates of outturn CO_2 emissions from aviation are based on the amount of aviation fuel uplifted from bunkers. Our 'forecast' for 2005 is about $5MtCO_2$ (15%) below the latest revised DECC estimate for that year. A similar normalisation factor is required by DECC when converting aviation fuel sales data to CO_2 bunker emissions data for domestic and international civil aviation. In our modelling the normalisation also 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 adjusted our CO_2 forecast upwards to ensure consistency with the DECC estimate.

[36] This is scenario s12s2 in Table 2.6.

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

Table 3.1: 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*	✓
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	✗

* Emissions from freight carried in the belly hold of passenger aircraft are captured in the passenger aircraft emissions

** Surface access emissions are counted separately for the purposes of estimating net benefits of additional airport capacity.

3.9 These forecasts are used to help develop, monitor and inform long term strategic UK aviation and climate change policy. In particular, they 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[38];
- develop and inform Government policy in the context of meeting our targets for reducing greenhouse gas emissions by 2050. The Committee on Climate Change has advised that this target should be a reduction of greenhouse gases to 80% below 1990 levels; and,
- estimate the carbon dioxide impacts of airport developments supported in the ATWP for the purposes of strategic appraisal.

Context of aviation carbon dioxide emissions

3.10 This section sets out how aviation CO_2 emissions have grown, and how they currently compare to total emissions, at the national and global level. Box 3.1 explains the policy context, including the recent agreement to include aviation in the EU ETS and the implications of the Climate Change Act 2008.

3.11 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,

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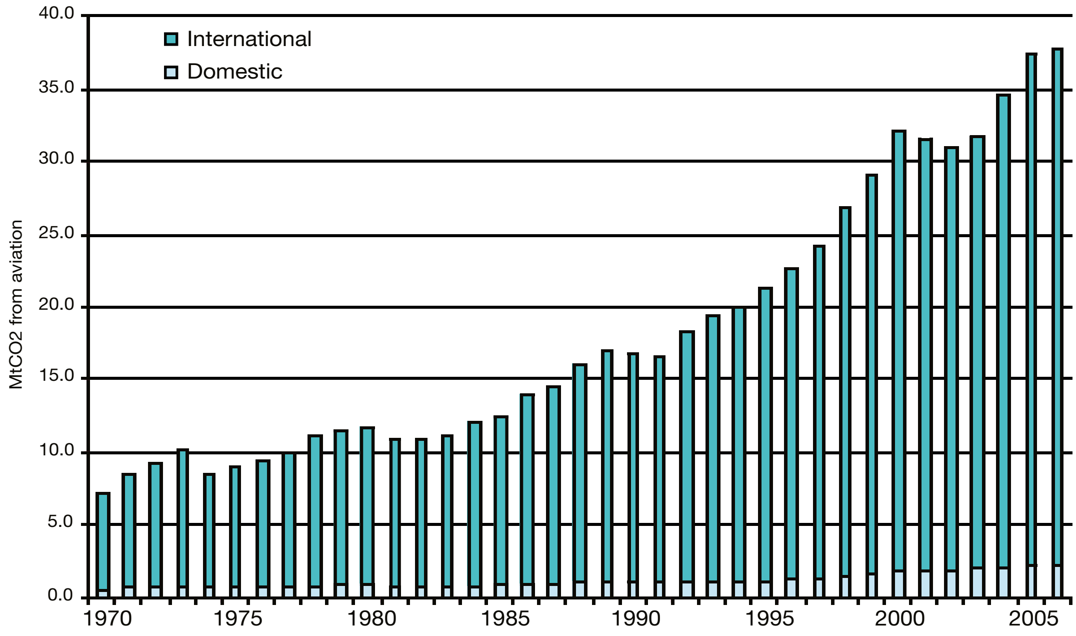
[38] See *The Future of Air Transport Progress Report*, Department for Transport, Dec 2006.

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 domestic flights, has been the main source of emissions growth, consistently accounting for over 90% of emissions.

Figure 3.1: UK aviation emissions, $MtCO_2$, 1970-2006



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

3.12 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 3.2 shows that globally, while transport as a whole accounts for 23% of total emissions, international aviation comprises only 1.5%.

Table 3.2: Global carbon dioxide emissions in 2005

	Carbon dioxide ($MtCO_2$)	**% of global total**
Country level emissions		
Global (sectoral approach)	27,136	–
Europe (EU 27)	3,976	14.7%
UK	530	2.0%
Transport emissions		
World transport	6,337	23.4%
of which:		
International aviation	416	1.5%
Domestic aviation	314	1.2%

Source: IEA Word Energy Outlook 2006

3.13 At the UK level, Table 3.3 shows that domestic aviation accounts for 0.4% of UK CO$_2$ emissions. If international shipping and aviation emissions are added to the total in 2006, UK aviation (domestic and international) accounted for 6.4% of UK CO$_2$ emissions and total transport accounted for 28.9%.

Table 3.3: UK carbon dioxide emissions

	2006 (MtCO$_2$)	**% of total UK***
Total UK emissions excluding international shipping and aviation	554.5	–
Total UK emissions including international shipping and aviation	596.9	–
Total transport	172.7	28.9
– *Road*	*120.3*	*20.2*
– *Rail*	*2.2*	*0.4*
– *Shipping*	*12.3*	*2.1*
– *Aviation*	*37.9*	*6.4*
– *domestic*	*–2.3*	*–0.4*
– *international*	*–35.6*	*–6.0*

Note

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

Box 3.1: UK Aviation CO_2 Emissions and Policy

The Government has a comprehensive approach to reduce aviation's climate change impacts. This includes supporting and encouraging research and development into new technology, improvements in air traffic management, the development and adoption of better operating practices and the use of economic instruments. This recognises that no single measure provides a complete solution to aviation's climate change impact.

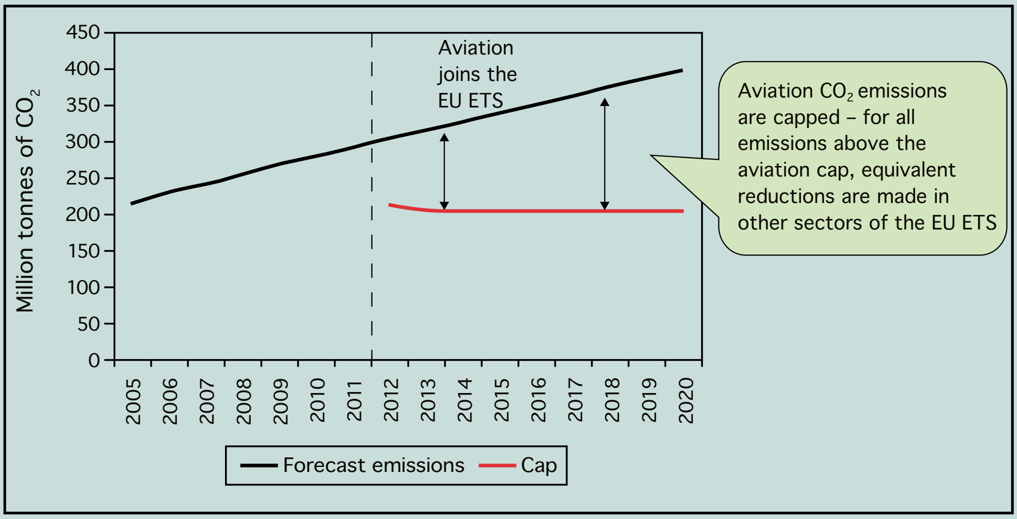
EU Emissions Trading Scheme

The Government has worked to bring international aviation within the European Union Emissions Trading Scheme (EU ETS). The EU Parliament and Council have now agreed that aviation will be included in the EU ETS from 2012. The scheme will require airlines who operate flights into, within and out of the EU to surrender allowances to cover their annual CO_2 emissions. In 2012, the emissions cap for the aviation sector will be set at 97% of the average level of emissions over the period 2004-2006 and will tighten to 95% of average 2004-2006 emissions from 2013. For CO_2 emissions above that level, operators will be required to buy allowances from other EU ETS sectors where reductions have taken place.

Therefore, although aviation demand and emissions are expected to continue to grow for the UK (as explained in Chapter 2 and here) and in other EU countries, this growth should not result in any overall growth in carbon dioxide emissions from sectors included in the emissions trading scheme, because the aviation sector will have to pay for reductions to be made elsewhere. The overall result will be that the net contribution of aviation to CO_2 emissions in the EU will not exceed the level of the cap.

For illustration, the chart below shows the ETS in operation.

Aviation in the EU ETS



Aviation CO_2 emissions are capped – for all emissions above the aviation cap, equivalent reductions are made in other sectors of the EU ETS

Climate Change Act

The Committee on Climate Change has recommended that the scope of the targets and budgets in the Climate Change Act should not be extended to include international aviation and shipping. However, like the Government, the Committee on Climate Change also believes that international aviation and shipping emissions should be included in the UK's climate change strategy. This could mean that in due course these emissions are included in some separate framework, or it could mean they are included within the UK's domestic framework – these matters are the subject of ongoing international discussions.

Interpreting the forecasts

3.14 The forecasts of UK aviation CO_2 emissions should be interpreted within the context of the broader UK and EU policy developments described above. In particular, any growth in aviation's CO_2 emissions should be seen as one part of the falling overall UK CO_2 emissions required to meet the Climate Change Act 2050 target. And, as described above, aviation will join the EU ETS from 2012; this will set a cap on aviation emissions. Any emissions from the sector above the cap must be matched by commensurate reductions in other sectors by purchasing allowances. Therefore, although this chapter presents forecast CO_2 emissions for UK aviation, under the ETS any growth shown above the level of the cap will not represent an increase in overall emissions.

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. While they can capture some short term demand effects to the extent driving variables (e.g. economic growth) can be accurately forecast, they are not primarily intended to predict short term deviations from the trend, as could be caused by an unforeseen 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. The range in each year is found by taking the demand range, and applying a further sensitivity test on fuel efficiency.

3.17 A further issue to note is that the impact of aviation on climate change is not caused solely by carbon dioxide 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)[39] to have a total radiative forcing of 2.7 times that of its CO_2 radiative forcing[40] – the so-called Radiative Forcing Index, or RFI. More recently, radiative forcing was evaluated by Sausen et al. (2005)[41]; 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[42] 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.

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 the 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.

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

[40] 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'.

[41] 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

[42] 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.

3.21 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 apply a multiplier value of 1.9 to the figure for carbon dioxide 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. Over time, as aircraft and fuel technology develops and operational practices change, the current relationship between aircraft CO_2 and non-CO_2 emissions may change. It is not possible to quantify this at present, but as any potential changes become apparent this would be taken into account in future forecasts.

Methodology and assumptions

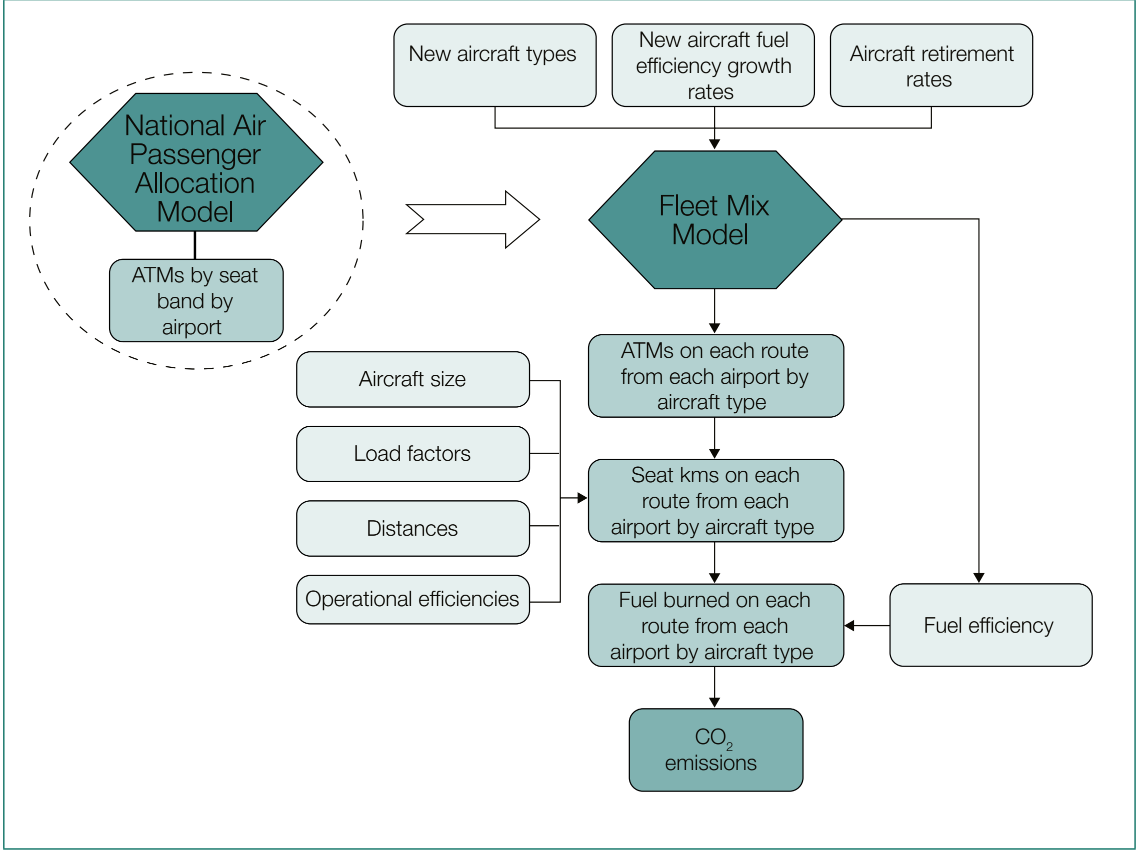
3.24 Aviation carbon dioxide emissions are, of course, directly related to the amount of aviation fuel consumed. There are therefore two key drivers of aviation carbon dioxide emissions:

1. **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,

2. **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 transport 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 D summarises the key improvements over the previous forecasts.

Figure 3.2: Forecasting aviation CO_2 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:

1. a new aircraft of the same type;
2. a new aircraft of an existing but different type; or,
3. 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%[43].

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.

2.31 Forecasts of UK freight demand, split between bellyhold and freighters, were produced prior to the ATWP using MDS-Transmodal and Halcrow forecasts.[44] 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 ATWP forecast (driven by GDP) will resume. The freighter share of this tonnage is assumed to rise in

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[43] IPCC *Aviation and the Global Environment*, 8.2.2.3 states that ATM routeing problems 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%.

[44] *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.

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.

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[45]. 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[46]. 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[47]:

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

[46] 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.

[47] 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.

- **Air traffic management and operational efficiencies**: By better co-ordinating and controlling air transport 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 kilometres 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.

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[48].

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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[48] 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.

The IPCC (1999)

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.

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 and 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 kilometre (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.

Box 3.2 (continued): Trends in aircraft fuel efficiency

Sustainable Aviation (2008)[50]

Sustainable Aviation[51] (SA) set out an assessment of CO_2 emissions from UK aviation over 2000 to 2050. This takes account of their view of what can be achieved through improvements in operations, technology and sustainable fuels. SA estimate that CO_2 emissions from UK aviation can be reduced to 2000 levels through these improvements.

In summary, SA estimate that a CO_2 reduction of 10% to 2020 (none is assumed thereafter) is possible due to the combined contribution of improvements to operations and air traffic management. Also, a 1.5% per annum improvement in efficiency to 2020 will be achieved through new technology, reflecting recent trends, followed by the deployment across the fleet of radically new technologies which would offer a further 25% fuel efficiency improvement where deployed. Combined, SA state that overall this would allow a 45% improvement in fuel efficiency in aircraft where they have been implemented. Overall, SA assume ACARE driven technology could deliver some 50% improvement in fuel efficiency relative to 2000.

In the longer term, lower carbon sustainable fuel blends are assumed to be available from 2020, reaching full market penetration by 2030. SA estimate this would deliver a 10% reduction in life cycle CO_2 fleet-wide beyond 2030. In addition, further technology developments are said to offer 0.5% per annum efficiency gains with radically new technologies such as blended wing being introduced from 2030, offering an additional 20% fuel-efficiency gain. Combined, SA estimate these longer term measures offer a 38% saving in CO_2 per passenger km in 2050 relative to 2000.

All effects overall are estimated by SA to offer a reduction in CO_2 per passenger km in 2050 relative to 2000 of 69%, returning CO_2 emissions from UK aviation to around 2000 levels by 2050.

On the metric of fuel efficiency used by the DfT, we estimate this might be equivalent to an annual average improvement of around 2.37% per annum over 2000 to 2050.

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[49] CO_2 Roadmap, Sustainable Aviation, December 2008 http://www.sustainableaviation.co.uk/images/stories/key%20documents/sa%20road%20map%20final%20dec%2008.pdf

[50] Sustainable Aviation is an initiative from a coalition of industry partners including, the Airport Operators Association; The British Air Transport Association; NATS and the Society of British Aerospace Companies. These bodies and some of their constituent companies developed the SA strategy in 2004-05 with input from a wide range of stakeholders. The strategy contains 8 overarching goals and 34 commitments to drive towards these goals.

Projecting fuel efficiency of new aircraft

3.42 As described above, the forecasts presented here are intended to be 'central' but there may be elements of conservatism as explained below. A challenging but achievable target for fuel efficiency is assumed, but beyond this we do not assume any further major technological advances, nor do we assume the use of low carbon fuels. If such developments take place in the period to 2050 then CO_2 emissions would be lower than the central case shown here.

3.43 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 which are on order such as the Boeing 787 and Airbus A350) 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 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.

3.44 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[51].

3.45 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'[52]:

"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

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[51] 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)

[52] *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."

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

3.47 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.

3.48 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[53]. Of the aircraft types that are currently known and are to be introduced shortly, none is assumed to be ACARE compliant at launch. However, future variants introduced from 2020 may be. We have assumed a proportion of the new types of aircraft introduced from 2020 would be ACARE compliant.
- The share of new aircraft entering service drawn from an ACARE-consistent aircraft type is assumed to rise from 5% in 2020 to 25% in 2030.

3.49 Table 3.4 shows that these assumptions result in fleet fuel efficiency improving by 31% over 2005 to 2030, equivalent to 1.1% per annum[54]. The assumptions about the ACARE target and fleet turnover imply less than 1% of aircraft-kilometres performed by aircraft meeting the ACARE target in 2020. This rises to 11% in 2030. The resulting fuel efficiency is towards the lower end of the historic range quoted by the IPCC (1-2%), and is broadly similar 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[55] of 0.7-1.3% per annum.

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[53] 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.

[54] The assumptions about the ACARE target and fleet turnover imply less than 1% of aircraft kilometres performed by aircraft meeting the ACARE target in 2020. This rises to 11% in 2030.

[55] 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 2008	IPCC 1999	Historic average
2005-2010	1.1%	1.3%	1-2%
2010-2020	1.6%	1.0%	
2020-2030	0.6%	0.5%	
2005-2030	1.1%	0.9%	
Aggregate 2005-2030	31.0%	32.9%[57]	

Alternative fuels

3.50 As previously noted, we have assumed constant fuel composition during the period of the forecasts, i.e. no introduction of alternative fuels. In practice the industry is investigating keenly the potential for alternative fuels. In 2008 Virgin and Air New Zealand have both undertaken test flights with biofuels. Significant further work is needed to develop a sustainable biofuel which can be blended successfully with kerosene. In order to ensure that the forecasts remain reasonable and cautious, given the current lack of firm evidence on the potential impacts of these developments in the long term, we have not made any assumption about development and adoption of lower CO_2 fuels, although it might be reasonable to assume that the industry will make progress over the time frame covered by the forecasts.

Carbon dioxide

3.51 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[57].

Sensitivity tests

3.52 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.

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[56] This figure differs from the equivalent figure published in the 2007 document by 0.01% due to the removal of rounding. These annual improvements however do not include efficiency gains from improvements to air traffic management; in line with the IPCC assessment of this potential (see paragraph 3.39) 9% has therefore been included.

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

3.53 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.

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

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

3.54 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 projections to 2050

3.55 The Committee on Climate Change has advised Government that the UK should aim for a target to reduce greenhouse gas emissions by 80% below 1990 levels by 2050. This has been accepted by Government, and is now in the Climate Change Act. As explained above, the Government believes that international aviation and shipping emissions should be included in the UK's climate change strategy. This could mean that in due course these emissions are included in some separate framework, or it could mean they are included within the UK's domestic framework – these matters are the subject of ongoing international discussions.

3.56 But in any case, it is clear that the process of policy development and monitoring progress against this target requires a longer term view of aviation carbon dioxide emissions.

Methodology and assumptions

3.57 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.

3.58 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.

3.59 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.

3.60 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.

3.61 This results in a forecast fleet efficiency improvement of 31% over 2005-2030 (1.1% pa), as shown in Table 3.4 and 16.1% 2030-2050 (0.75% pa).

Sensitivity tests

3.62 There is 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. To generate the CO_2 emissions projection range between 2030 and 2050, we have therefore varied the fleet fuel efficiency assumptions by +/- 0.25% per annum.

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

Aviation CO_2 emissions forecasts to 2030 and projections to 2050

UK Aviation Emissions Forecast

3.64 The above section set out the methodology and assumptions used to forecast aviation carbon dioxide emissions to 2030, and to project further to 2050. This section sets out the results of applying these methods.

3.65 Table 3.6 reports our central forecast and range for CO_2 emissions from UK aviation to 2030, and the projection to 2050. 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.

3.66 The range assumes the demand range (explained in chapter 2), and the fuel efficiency range (explained above). Table 3.6 shows that the central case aviation emissions are forecast to rise from 37.5 $MtCO_2$ in 2005 to 58.4 $MtCO_2$ in 2030, after which their growth is projected to slow and stabilise between 2040 and 2050. We saw in Chapter 2 that post-2030, market maturity and capacity constraints cause the growth in passenger demand to slow. 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 stabilise.

Table 3.6: Aviation carbon emission forecasts to 2050, $MtCO_2$

	Low	Central	High	Total UK CO_2 emissions[58]
2005	37.5	37.5	37.5	590 - 691
2010	39.4	41.0	41.7	544 - 666
2020	45.1	50.3	52.9	450 - 618
2030	51.8	58.4	61.6	341 - 481
2040	53.8	61.1	65.0	231 - 345
2050	53.0	59.9	65.0	122 - 209

3.67 As explained earlier in this chapter, it is important to interpret the aviation CO_2 emission forecasts within the context of overall UK CO_2 emissions and broader UK climate change policy.

3.68 The action on overall UK CO_2 emissions in the Climate Change Act means that national emissions are expected to fall substantially to 2050. Figure 3.3 illustrates the forecast of aviation CO_2 emissions alongside the projected domestic greenhouse gas emissions consistent with the Climate Change Act 2050 target. The aviation line and the domestic economy line are shown independently in this figure, reflecting that no decision has yet been taken on how international aviation relates to any UK targets in the long term[59]. Nevertheless, it can be seen that falling overall UK emissions mean – even with aviation emissions stabilising after 2030 – aviation's share of UK greenhouse gas emissions rises to 2050. The share of aviation emissions depends on

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[58] Range shown reflects the different policy outcomes as described in detail in Annex K, and illustrate projected emissions assuming UK domestic targets for emission reductions to 2050 are met.

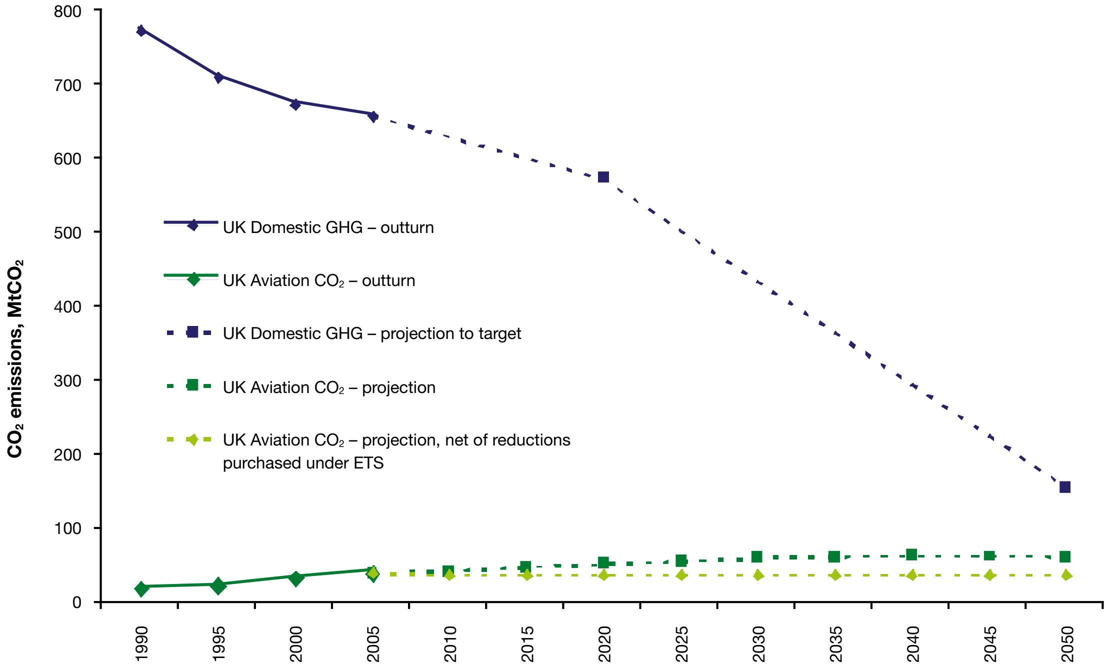
[59] UK domestic GHG emissions include domestic aviation because these emissions are included in the UK target for 2050. The UK aviation CO_2 emissions include both the domestic and international aviation emissions. Annex K contains further information on estimating aviation's future share of emissions.

the particular policy outcome, of which no one outcome is more likely than another, and could be in the range 19 – 54%. Further information on estimating aviation's share of emissions is provided in Annex K.

3.69 Figure 3.3 shows the forecast profile of emissions from UK aviation under the assumptions of fuel efficiency described earlier. As explained in this chapter, because aviation will be joining the EU ETS from 2012, any emissions growth above the aviation cap will be matched one-for-one by reductions in other sectors, through the purchase of allowances. There would therefore be no overall increase in emissions.

3.70 Furthermore, as shown in Box 3.2 the industry has suggested that fuel efficiency will exceed the gains assumed here due to major technological developments in aircraft and the introduction of lower-carbon fuels. Such developments have not been assumed in our forecasts in this chapter due to the uncertainties surrounding these developments, but if realised, aviation emissions would be lower. Therefore, under the ETS, again overall emissions would not be higher than the ETS cap, but aviation's contribution to CO_2 emission would be lower.

Figure 3.3: UK national and aviation CO_2 forecasts 2005-2050[60]



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[60] UK domestic GHG emissions include domestic aviation because these emissions are included in the UK target for 2050. It does not include international aviation CO_2 emissions. The UK aviation CO_2 emissions include both the domestic and international aviation emissions. Annex K contains further information on estimating aviation's future share of total emissions.

Airport Forecasts to 2030

3.71 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.

3.72 Table 3.7 presents the central case CO_2 emissions forecast to 2030, for the largest of the UK's airports. Again, the wider climate change policy context should be noted.

Table 3.7: Carbon dioxide emissions from airports (central demand and efficiency)[61]

	Emissions million tonnes CO_2		Share of Total UK Departure CO_2	
	2005	2030	2005	2030
		Central		Central
Heathrow	17.1	23.6	46%	41%
Gatwick	4.4	4.3	12%	7%
Stansted	1.3	2.6	4%	4%
Luton	0.6	0.8	2%	1%
London City	0.1	0.5	0%	1%
London Total	23.5	31.6	63%	54%
Other UK Airports	7.8	15.9	21%	27%
Freight	0.7	2.2	2%	4%
Residual	5.5	8.7	15%	15%
Total	37.5	58.4	100%	100%

3.73 Table 3.7 shows that in 2005 London airports accounted for a little over two thirds of total UK aviation carbon dioxide emissions. This is forecast to decline to 62% 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 were at Heathrow in 2007), which combine to give it a large share of seat-kilometres (just over a half).

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[61] 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 +5 $MtCO_2$ to ensure consistency with DEFRA 2005 outturn estimate.

Further analysis

3.74 These CO_2 forecasts and projections have been used for further analysis, showing:

- The value of aviation's climate change impact – see annex J;
- Aviation's estimated share of UK climate change emissions – see annex K; and
- International aviation emissions and carbon dioxide budgets – see annex L.

4. Monetised Net Benefits of Airport Development Scenarios

- We have updated our assessment of the net benefits of airport development scenarios in the South East, following new economic forecasts and oil price projections, and incremental improvements delivered by our process of continual improvement.
- The development of a second runway and associated terminal infrastructure at Stansted would deliver a net benefit of £10.0bn. A third runway and sixth terminal at Heathrow would deliver a net benefit of £5.5bn. Together, they would deliver a net benefit of £15.5bn.

Introduction

4.1 As outlined in Chapter 2, we have updated our modelling assumptions to account for recent developments. For example, we have adopted the latest forecasts of oil prices from BERR and updated our economic growth assumptions. We have also updated our airport capacity assumptions in line with the latest plans indicated by airport operators. Additionally, we have made a number of incremental improvements to our forecasting methodology. In light of these developments, we have refreshed our assessment of the net benefits of key developments supported in the 2003 ATWP.

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 estimate the monetised costs and benefits of airport development is consistent with that Guidance. It is also consistent with HMT guidance on appraisal in government, known as 'The Green Book'[62]

4.3 Benefits are defined as those to airport users, producers and society, net of the cost of extra carbon emissions. These net benefits are compared with capital and additional operating costs (including an appropriate share

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[62] *The Green Book, Appraisal and Evaluation in Central Government*, HM Treasury, http://www.hm-treasury.gov.uk/data_greenbook_index.htm

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 method captures the following forms of economic benefits to air transport users, producers and society, from additional airport capacity:

- benefits to passengers who are able to make more journeys, at lower cost and via more preferred airports;
- reduction in costs to passengers who enjoy higher frequencies;
- producer benefits to airport operators from additional air traffic;
- benefits captured in the form of additional Air Passenger Duty revenue; and,
- 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 90% since 1995, from 10.3 minutes on average to 19.6 minutes in 2007.

4.7 Extra runway capacity and better use of existing capacity would help to reduce airport delays. Airport delays impose costs on society in terms of increased costs for airlines, passengers and the environment. These delay reduction benefits have been incorporated into the net benefit estimates where possible.

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 Aviation Emissions Cost Assessment[63]. The resulting uplifted carbon dioxide emissions have then been valued using the current guidance on the shadow price of carbon (see Chapter 3).

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[63] *Aviation Emissions Cost Assessment 2008*, Department for Transport, 2008, available at: http://www.dft.gov.uk/pgr/aviation/environmentalissues/aviationemissionscostassess/aviationemissionscost.pdf

Surface access CO_2 emissions disbenefits

4.10 Chapter 3 explained that CO_2 emissions from surface access to and from UK airports are not included in the UK aviation inventory of CO_2 emissions, as they are counted in other parts of the UK inventory. However, to feed into the net benefits of additional airport capacity, we also estimate the change in CO_2 emissions from road, rail and bus/coach journeys to and from UK airports. Details of the method and results are shown in Annex I.

Air noise disbenefits

4.11 Additional capacity would lead to an increase in the number of air transport movements. This would lead to additional air and road noise. We have quantified the air noise impacts for additional capacity at Heathrow, using data generated for the 2007 *Adding Capacity at Heathrow Airport* consultation. No assessment has been made for the road noise since this would depend on the surface access strategy that accompanied possible development options.

4.12 The valuing of air noise impacts has relied on noise modelling conducted by CAA ERCD for the *Project for the Sustainable Development of Heathrow*. This gave results for: 2015 mixed mode within existing capacity (480,000 ATMs); 2015 mixed mode operations with additional capacity (540,000 ATMs); and, 2030 for Heathrow with a third runway (702,000 ATMs). A number of assumptions have been made:

- The quantification of air noise for Heathrow's third runway relies on the 2030 noise modelling position. It assumes that the difference in the number of households affected between the base (480,000 ATMs in segregated mode) and third runway scenario (702,000 ATMs) is indicative for the period between 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 2029 we have therefore slightly overestimated the noise impacts since capacity would be lower than the assumed 702,000 ATMs;
- In response to the ANASE[64] study, pending specific Government recommended values for airport noise, we have relied on the DfT WebTAG values for road and rail noise to provide an appropriate range of air noise costs; and,
- Similar assumptions are made for valuing the impact of mixed mode options. In particular, we have relied on the 2015 noise modelling positions to value the impacts on noise changes before 2020.

Air quality disbenefits

4.13 Additional capacity would also lead to changes in air quality around airports, both from increased ATMs and also the associated increase in surface access requirements. As with noise, we have estimated the air quality impact of Heathrow developments using data generated for the 2007 *Adding Capacity at Heathrow Airport* consultation.

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[64] http://www.dft.gov.uk/pgr/aviation/environmentalissues/Anase/

4.14 Projected levels of pollutants around Heathrow were modelled by CERC[65] ADMS, primarily to test that the proposals met European air quality limits around the airport for nitrogen dioxide (NO_2), the most critical local pollutant around Heathrow.

4.15 However, this modelling also allowed the Department to appraise the monetary impacts of local air quality changes around Heathrow from proposed developments. In line with DEFRA guidance, the assessment focuses on NO_x and PM_{10} damage, valued by the impact of each pollutant multiplied by the unit value of each impact, as recommended by the IGCB[66].

Infrastructure costs

4.16 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, £bn
s05	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	£7.8
s07	Stansted second runway (480,000 in 2015)	s02	Maximum Use	£4.8
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£7.8
s12s2mm1	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 in 2010-2019) then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£8.0
s12s2mm2	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£8.1
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	£12.6
s12s2_2015	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	s07	Stansted R2 2015	£8.5

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[65] Cambridge Environmental Research Consultants

[66] Defra-led Interdepartmental Group on Costs and Benefits (IGCB), a group of government economists and other experts that provides economic analysis and advice relating to the development and achievement of the Air Quality Strategy – 2007.

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

s12s2_ 2025	Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 2025, rising to 702,000 in 2030)	s07	Stansted R2 2015	£6.6
s12s2_ 605/122	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)	s07	Stansted R2 2015	£8.3
s12s2_ 605/129	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)	s07	Stansted R2 2015	£8.4

Notes:

2006 prices, discounted to present value year of 2006.

Figures in parentheses refer to the opening date and annual ATM capacity of the developed airport.

Non-monetised costs and benefits

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

- delay reduction benefits, other than at Heathrow for mixed mode scenarios;
- wider economic benefits, as identified in the Eddington Report, through raising productivity and improving competitiveness; and,
- benefits to international-to-international interliner passengers

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

- additional local air quality emissions and noise at airports other than Heathrow;
- land use impacts in the form of lost greenfield and agricultural land;
- impacts on heritage and any community severence effects; and,
- biodiversity and water related impacts.

Key Assumptions for Cost Benefit Analysis

Airport capacity development

4.19 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 London Luton Airport has announced scaled-down plans for greater capacity. Also, Stansted has received planning permission for an increase in capacity to 35 mppa from 25 mppa, and London City has received planning permission to raise capacity to 120,000 ATMs per year. Chapter 2 explained how these revised plans have been included in our updated forecasts.

4.20 As in the forecasts supporting the ATWP, it has been assumed that sufficient terminal capacity (subject to local planning restrictions) would be provided to meet local demand at airports outside the South East.

Appraisal period, discount rates, and optimism bias

4.21 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 an uplift of at least 44% in capital cost assumptions.

Projections beyond 2030 for appraisal purposes

4.22 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.

4.23 Key drivers of the benefits of airport development are passenger demand, ATM demand, and shadow costs. Our method for projecting passenger and ATM demand is set out in Chapter 2. The shadow cost for each South East airport exhibiting such a shadow cost before 2030 is projected beyond 2030 by combining (by year and capacity scenario):

- projections of demand at each airport in the absence of a capacity constraint (but retaining any constraints at all others); and,
- estimates of the relationship implicit in the forecasting model (before 2030) between each airport's demand and the cost passengers face in using it (and their trend).

4.24 At some airports a shadow cost may be incurred in the base case, but not in the option case, before 2030. To ensure the benefits of extra capacity are not overstated, it is necessary that such an airport incurs a shadow cost upon reaching capacity in the option case after 2030. In these cases we introduce the shadow cost in the year when the option reaches capacity. The starting level of the shadow cost is set to the average shadow cost increment over the final four years (pre-2030) in the base case. The post-2030 shadow cost is then grown on the same gradient as in the base case. If no shadow cost is incurred in either the base or the option case at an airport prior to 2030, then no shadow costs are projected post 2030. This necessary simplification could result in a minor underestimate of option benefits.

4.25 The cost of extra climate change emissions from airport development is found by applying the methods outlined above to the projections of CO_2 emissions outlined in Chapter 3.

Results

Central case

4.26 The updated net 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.

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

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
s05	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	£17.5	£7.8	£9.7	2.2
s07	Stansted second runway (480,000 in 2015)	s02	Maximum Use	£14.8	£4.8	£10.0	3.1
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£13.3	£7.8	£5.5	1.7
s12s2mm1	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 in 2010-2019) then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£14.2	£8.0	£6.2	1.8
s12s2mm2	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£14.2	£8.1	£6.1	1.8
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	£28.1	£12.6	£15.5	2.2

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

Scenario		Base case		Benefits	Infrastructure Costs	Net Benefit	Benefit-Cost Ratio
s12s2_ 2015	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	s07	Stansted R2 2015	£13.7	£8.5	£5.1	1.6
s12s2_ 2025	Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 2025, rising to 702,000 in 2030)	s07	Stansted R2 2015	£13.2	£6.6	£6.7	2.0
s12s2_ 605/122	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)	s07	Stansted R2 2015	£9.2	£8.3	£0.9	1.1
s12s2_ 605/129	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)	s07	Stansted R2 2015	£11.7	£8.4	£3.3	1.4

Notes:

1. 2006 prices, NPVs discounted to 2006.

2. Figures in parentheses refer to the opening date and annual ATM capacity of the developed airport.

3. ‘Benefits’ equals transport user benefits net of climate change disbenefits. At Heathrow, it additionally includes noise and air quality costs, and (for mixed mode) the effect of delay reductions on users and carbon emissions.

4. ‘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 DfT NATA BCRs reported for road and rail schemes, which divide the net benefits by the net effect on government spending.

Table 4.3: Breakdown of transport user benefits, £bn, NPV, 2006 prices

Scenario		Base case		Generated Users	Existing Users	Freight	Producers	Government	Delay Reduction Benefits	Aviation Carbon + other GHG disbenefits	Noise Disbenefit	Air Quality Disbenefit	Surface Access Carbon Disbenefit	Accident Disbenefit	Total Benefits
s05	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	13	neg	neg	7	4	–	-5	neg	neg	neg	neg	18
s07	Stansted second runway (480,000 in 2015)	s02	Maximum Use	11	neg	neg	2	4	–	-2	neg	neg	neg	neg	15
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	9	neg	neg	6	4	–	-5	neg	neg	neg	neg	13
s12s2mm1	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 in 2010-2019) then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	9	neg	neg	6	4	1	-5	neg	neg	neg	neg	14
s12s2mm2	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	10	neg	neg	6	4	1	-5	neg	neg	neg	neg	14
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	20	neg	neg	8	8	–	-8	neg	neg	neg	neg	28

Table 4.3: Breakdown of transport user benefits, £bn, NPV, 2006 prices *(Continued)*

Scenario		Base case		Generated Users	Existing Users	Freight	Producers	Government	Delay Reduction Benefits	Aviation Carbon + other GHG disbenefits	Noise Disbenefit	Air Quality Disbenefit	Surface Access Carbon Disbenefit	Accident Disbenefit	Total Benefits
s12s2_ 2015	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	s07	Stansted R2 2015	10	neg	neg	6	4	–	-5	neg	neg	neg	neg	14
s12s2_ 2025	Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 in 2025, rising to 702,000 in 2030)	s07	Stansted R2 2015	9	neg	neg	6	4	–	-5	neg	neg	neg	neg	13
s12s2_ 605/122	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)	s07	Stansted R2 2015	6	neg	neg	5	3	–	-4	neg	neg	neg	neg	9
s12s2_ 605/129	Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)	s07	Stansted R2 2015	7	neg	neg	5	4	–	-4	neg	neg	neg	neg	12

Notes:

2006 prices, NPVs discounted to 2006
'neg' means impact is estimated and non-zero, but rounds to zero at 0dp
'–' means impact is not estimated

Sensitivity tests

4.28 Table 4.4 below shows that the economic case for the ATWP-supported developments at Stansted and Heathrow is robust to the full range of sensitivity tests.

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

	Stansted second runway		**Heathrow third runway**		**Both**	
Sensitivity test	NPV (£bn)	BCR	NPV (£bn)	BCR	NPV (£bn)	BCR
Central case	£10.0	3.1	£5.5	1.7	£15.5	2.2
Low end of demand range	£7.1	2.5	£5.0	1.7	£12.1	2.0
High end of demand range	£11.3	3.4	£6.0	1.8	£17.3	2.4
Low GDP	£8.2	2.7	£5.3	1.7	£13.5	2.1
High GDP	£10.8	3.3	£6.7	1.9	£17.5	2.4
PBR Nov 2008 GDP forecast	£8.7	2.8	£5.4	1.7	£14.0	2.1
Lower shadow price of CO_2	£10.5	3.2	£5.7	1.7	£16.2	2.3
Higher shadow price of CO_2	£9.1	2.9	£4.2	1.6	£13.4	2.1
EU ETS	£9.6	3.0	£8.2	2.1	£17.8	2.4
Lower radiative forcing factor	£11.0	3.3	£7.8	2.0	£18.8	2.5
Higher radiative forcing factor	£4.3	1.9	£2.0	1.3	£6.3	1.5
BERR low oil price	£10.3	3.2	£6.1	1.8	£16.4	2.3
BERR high high oil price	£7.5	2.6	£5.3	1.7	£12.8	2.0
Low fuel efficiency	£9.5	3.0	£5.0	1.6	£14.5	2.2
High fuel efficiency	£10.1	3.1	£6.1	1.8	£16.2	2.3
PBR Nov 2008 APD bands and rates	£11.1	3.3	£6.4	1.8	£17.5	2.4

Notes:

1. 2006 prices, NPVs discounted to 2006.

2. '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 DfT NATA BCRs reported for road and rail schemes, which divide the net benefits by the net effect on government spending.

Annex A: Unconstrained Passenger Demand Econometric Models

Introduction

A.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

A.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.

A.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.

A.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

A.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[67], which allows us both to test for cointegration and efficiently to estimate the model's parameters while avoiding bias on the standard errors.

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[67] The exceptions are international to international interliner traffic, and some small, long haul, foreign leisure markets, where OLS in levels is used.

A.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.

A.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

A.8 The resulting parameter estimates, standard errors, and diagnostic test for the 21 markets are reported in Tables A1 to A3 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; and
- There is no evidence of autocorrelation or heteroscedasticity at the 5% level.

Table A1: Parameter estimates

Sector		Variable																												
	Dep Variable	**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-GDP**	**Lnt-GDP(-1)**	**Lnt-IMP**	**Lnt-IPS**	**Lnt-IPS(-1)**	**FGP**	**FGP(-1)**	**PFR**	**PFR(-1)**	**Tra(-1)**	**D-PFR**	**EXR**	**DUM01**
Charter Long Haul	D-Lnt-Tra	-7.42			-0.15						-0.95				0.30			2.24												
Charter Short Haul	D-Lnt-Tra	5.24									-0.74				-0.10						-0.29									
Domestic Business	D-Lnt-Tra	-3.82							-0.06		-0.84							1.66												
Domestic Leisure	D-Lnt-Tra	-1.82	1.37								-0.42		1.06									-0.24								
Foreign Business LDC	D-Lnt-Tra	-0.48									-0.23						0.32			0.03										
Foreign Business NIC	D-Lnt-Tra	0.00					4.10				-0.50						0.50													
Foreign Business OECD	D-Lnt-Tra	2.90			0.53			0.34			-1.31			0.59			1.71	-1.62												
Foreign Business W. Europe	D-Lnt-Tra	-1.03		-0.35	-0.35			0.37			-1.14			0.58				0.76												
Foreign Leisure LDC	Tra	97.33																					0.08		-0.09					
Foreign Leisure NIC	D-Lnt-Tra	0.00				-0.85				-0.06	-0.13						0.15													
Foreign Leisure OECD	Tra	63.15																					0.51		-0.12				0.03	-8.20

Table A1: Parameter estimates *(continued)*

Sector		Variable																												
	Dep Variable	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-GDP	Lnt-GDP(-1)	Lnt-IMP	Lnt-IPS	Lnt-IPS(-1)	FGP	FGP(-1)	PFR	PFR(-1)	Tra(-1)	D-PFR	EXR	DUM01
Foreign Leisure W. Europe	D-Tra	-0.32																						0.07		-0.01	-0.44	-0.02		
UK Business LDC	D-Lnt-Tra	-0.93					4.32				-0.66								0.84											
UK Business NIC	D-Lnt-Tra	1.27					1.15				-0.77						0.47													
UK Business OECD	D-Lnt-Tra	0.00				1.55					-0.40						1.51	-1.11												
UK Business W. Europe	D-Lnt-Tra	-1.99						0.54			-0.56			0.40				0.91		-0.32										
UK Leisure LDC	D-Lnt-Tra	-3.88					1.85				-1.02							2.45			-0.62									
UK Leisure NIC	D-Lnt-Tra	-5.48							0.27		-1.19	2.61			0.35						-0.58									
UK Leisure OECD	D-Lnt-Tra	9.51			-0.72		1.15				-0.45					-1.09						-0.51								
UK Leisure W. Europe	D-Lnt-Tra	3.40									-0.84		1.34			-0.33						-0.89								
Itol	Tra	0.55																					0.75		-0.33					-0.16

Table A2: Parameter t-statistics

Sector		Variable																												
	Dep Variable	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-GDP	Lnt-GDP(-1)	Lnt-IMP	Lnt-IPS	Lnt-IPS(-1)	FGP	FGP(-1)	PFR	PFR(-1)	Tra(-1)	D-PFR	EXR	DUM01
Charter Long Haul	D-Lnt-Tra	-4.32			-3.10						-5.66				5.34			4.55												
Charter Short Haul	D-Lnt-Tra	2.25									-2.52				-1.46						-1.24									
Domestic Business	D-Lnt-Tra	-4.32							-0.67		-3.80							4.13												
Domestic Leisure	D-Lnt-Tra	-0.60	1.48								-1.49		1.40									-0.93								
Foreign Business LDC	D-Lnt-Tra	-0.53									-1.06						3.02			0.23										
Foreign Business NIC	D-Lnt-Tra	0.00					1.51				-2.56						2.58													
Foreign Business OECD	D-Lnt-Tra	3.79			2.64			2.28			-7.52			4.16			3.01	-2.87												
Foreign Business W. Europe	D-Lnt-Tra	-1.92		-2.12	-2.45			2.71			-6.89			5.40				3.79												
Foreign Leisure LDC	Tra	4.10																					0.34		-2.45					
Foreign Leisure NIC	D-Lnt-Tra	0.00				-0.96				-0.48	-0.70						0.80													
Foreign Leisure OECD	Tra	3.05																					2.74		-2.77				0.32	-1.15
Foreign Leisure W. Europe	D-Tra	-0.12																						1.93		-1.82	-2.66	-1.33		

Table A2: Parameter t-statistics *(Continued)*

Sector		Variable																												
	Dep Variable	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-GDP	Lnt-GDP(-1)	Lnt-IMP	Lnt-IPS	Lnt-IPS(-1)	FGP	FGP(-1)	PFR	PFR(-1)	Tra(-1)	D-PFR	EXR	DUM01
UK Business LDC	D-Lnt-Tra	-1.55					3.29				-5.34								3.56											
UK Business NIC	D-Lnt-Tra	2.86					2.10				-4.04						4.20													
UK Business OECD	D-Lnt-Tra	0.00				3.04					-4.94						3.13	-2.66												
UK Business W. Europe	D-Lnt-Tra	-2.96						3.62			-4.02			4.80				3.28		-1.80										
UK Leisure LDC	D-Lnt-Tra	-2.79					3.80				-5.52							4.92			-5.31									
UK Leisure NIC	D-Lnt-Tra	-7.25							2.35		-9.72	10.77			4.95						-7.15									
UK Leisure OECD	D-Lnt-Tra	4.45			-3.65		3.53				-3.09					-4.97						-2.35								
UK Leisure W. Europe	D-Lnt-Tra	1.65									-5.58		5.01			-3.76						-3.24								
Itol	Tra	1.34																					2.34		-2.73					-4.53

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

LNT	Natural logarithm	FGP	Foreign GDP
D-	Differenced variable	IPS	UK Fares
[-1]	Offset one year	PFR	Foreign Fare
TRA	Traffic	IMP	Imports
GDP	UK GDP	EXP	Exports
CON	UK Consumer Expenditure	EXR	Exchange Rate
DUM01	Variable takes the value 1 in 2001, 0 in all other years		

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

Market sector	2005 share of modelled traffic	R^2	F	F sig	Durbin Watson d	RESET sig
Charter Long Haul	2%	0.75	10.96	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%	0.61	14.2	0.000	1.6	0.79
Foreign Leisure NIC	0%	0.22	0.4	0.833	2.7	0.70
Foreign Leisure OECD	3%	0.79	20.3	0.000	1.2	0.56
Foreign Leisure W. Europe	7%	0.78	7.2	0.002	*	*
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	1.4	0.93

* Updated ‘Foreign Leisure to W. Europe’ modelling replaced DW and RESET tests with Breusch-Pagan and Breusch-Godfrey tests for heteroscedasticity and autocorrelation. B-P test stat: χ^2=0.03, p=0.8545; B-G test stat: χ^2=1.547, p=0.2136. These imply no heteroscedasticity and no autocorrelation.

A.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

A.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, and the other income-related variables by a one-off step change of 10% in 2010.

A.11 Table A4 below summarises the resulting long run income and air fare elasticities. This shows that income is a strong driver in the UK scheduled markets, with the estimated income elasticity of demand ranging from 1.4 to 1.5. This falls to 0.6-0.7 for the foreign scheduled markets, and 0.4 for the charter market, but the overall average income elasticity is strong at 1.3. Air fare effects are more variable. The UK leisure sector showed a strong price elasticity of -1.0, while the foreign leisure market was found to be lower at -0.2. No air fare effect could be identified for the business sector. Charter and domestic travel showed some fare effects (-0.4 and -0.3 respectively). International to international interliner traffic was found to have a price elasticity of -0.3. The resulting overall air fare elasticity is -0.45.

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%	1.4	–
UK Leisure	29%	1.5	–1.0
UK Charter	16%	0.4	–0.4
Foreign Business	6%	0.6	–
Foreign Leisure	11%	0.7	–0.2
International to International Interliners	11%	0.7	–0.3
Domestic	17%	2.1	–0.3
Overall	100%	1.3	–0.5

Notes:

No significant price elasticity found for business

Income variable depends on sector

Price elasticities are point estimates, income elasticities are arc estimates.

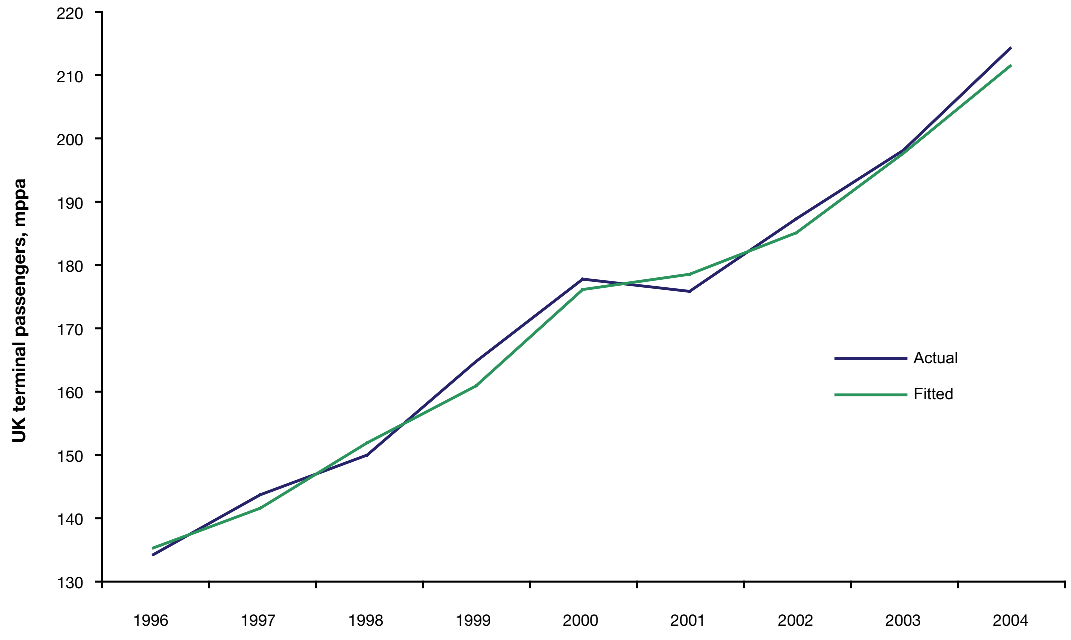
Results are elasticity of terminal passengers to income or fares; for trip elasticities, the domestic value should be halved.

A.12 It is intuitive that the overall price elasticity is some way below unity, given that passengers may have options for responding to, for example, an increase in price. In this case, passengers may have options available to reduce 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.

Model fit

A.13 The models resulting from this estimation process show a strong ability to fit the past data. Figure A1 shows that, when aggregated to the national level, the models accurately predict the trend in passenger demand, while also capturing shorter term movements.

Figure A1: Actual and fitted UK terminal passengers, 1996-2004



Note: not every model is fitted to data prior to 1996, so totals consistent with CAA outturn data can be presented from 1996 only.

Annex B: Unconstrained Demand Forecasting Assumptions

Introduction

B.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.

B.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 which form the basis of the forecast range, further require a 'low' and 'high' projection of each variable.

Economic Growth

B.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.

B.4 The central assumptions for near-term UK growth are based on the HM Treasury 2008 Budget Report[68]. Alongside the 2008 Budget Report HM Treasury also published long term fiscal forecasts taking account of new ONS demographic projections[69] [70]. In the long term – consumer expenditure is assumed to be a ¼ per cent lower than the GDP growth rate.

B.5 The Western Europe GDP assumptions to 2010 are taken from the 2007 HM Treasury *Pre-Budget Report*[71]. After 2010 the assumptions are based on the 2007 IMF *World Economic Outlook* (WEO) for the Euro area, and subject to the proviso that the rate of economic growth in this area will

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[68] Budget Report 2008, HM Treasury.

[69] *Long term public finance report: an analysis of fiscal sustainability*, HM Treasury, March 2008.

[70] 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.

[71] 2007 *Pre-Budget Report*, Annex A, Table A1.

not exceed the UK rate. Outside Europe, other OECD rates of growth are taken from the October 2008 IMF WEO with the average 1999-2008 rates being extended out to 2020 and short term forecasts used for 2008-2010. After 2020 this rate is reduced to halve the difference between the previous OECD rate and the prevailing European rate.

B.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. Latest forecasts from the October 2008 WEO are used for the short to medium term. The WEO now gives an average annual growth rate of 5.9% for developing Asia by 2013 (with lower rates for 2008-2012)[72] which we have adopted for the newly industrialising countries (NIC), principally China. We have adopted 5.9% between 2013-2015 after which it is dropped to 3.5% as in earlier forecasts. For the less developed countries (LDC) we have adopted the latest WEO 2008-2013 forecasts which after weighting by traffic are 5.8% per annum in 2013 and we then extend this rate onto 2015; thereafter it is reduced to 4% for the rest of the forecasting period as in previous forecasts.

B.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	1.88-2.97	1.50-2.60	0.50-2.75	4.38-7.40	5.80-7.20	1.63-3.04
2013-2017	2.20-2.86	2.00	2.51	3.50-5.89	4.00-5.81	1.95-2.61
2018-2020	2.14-2.19	2.00	2.51	3.50	4.00	1.89-1.94
2021-2030	2.11-2.23	2.00	2.25-2.51	3.50	4.00	1.86-1.98

B.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

B.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.

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[72] IMF *World Economic Outlook*, October 2008, Statistical Appendix, Tables A2 & A4.

Table B2: Visible Trade Growth Assumptions, % change pa

	W. Europe	OECD	NIC	LDC
2005-2012	1.53-2.65	0.50-2.79	4.30-7.27	5.53-6.87
2013-2017	2.04	2.54	3.44-5.79	3.81-5.54
2018-2020	2.04	2.54	3.44	3.81
2021-2030	2.04	2.28-2.54	3.44	3.81

Exchange Rates

B.10 We assume that future dollar exchange rates will equal the average of those over the previous twelve months[73].

Air Fares

B.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

B.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 (2007 prices) are assumed to move in line with BERR's central oil price projection, which falls from $73 per barrel in 2007 to $68 per barrel in 2015, then rises again to $75 per barrel in 2030[74]. This is illustrated in Table B3.

Table B3: Range of real oil price assumptions, $/barrel (2007 prices)

	Low	Central	High	High high
2007	73	73	73	73
2010	45	65	85	107
2015	45	68	90	150
2020	45	70	95	150
2025	45	73	100	150
2030	45	75	105	150

B.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 the resulting fuel efficiency growth rates for the fleet.

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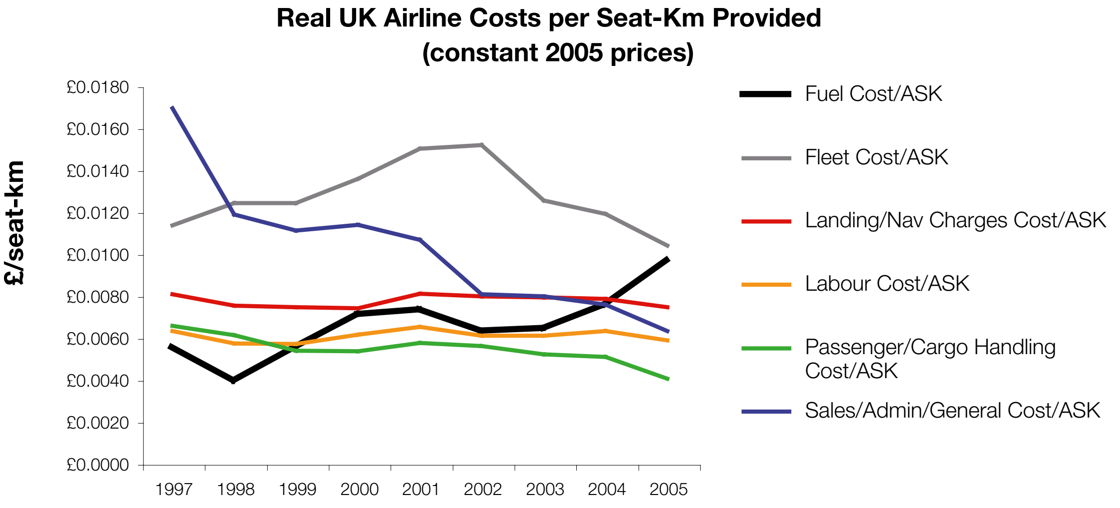
[73] For these forecasts, this means the dollar exchange rate reported by the Bank of England for the 12 months ending in September 2008.

[74] *Communication on BERR Fossil Fuel Price Assumptions*, BERR, May 2008.

Other Non-Fuel Costs

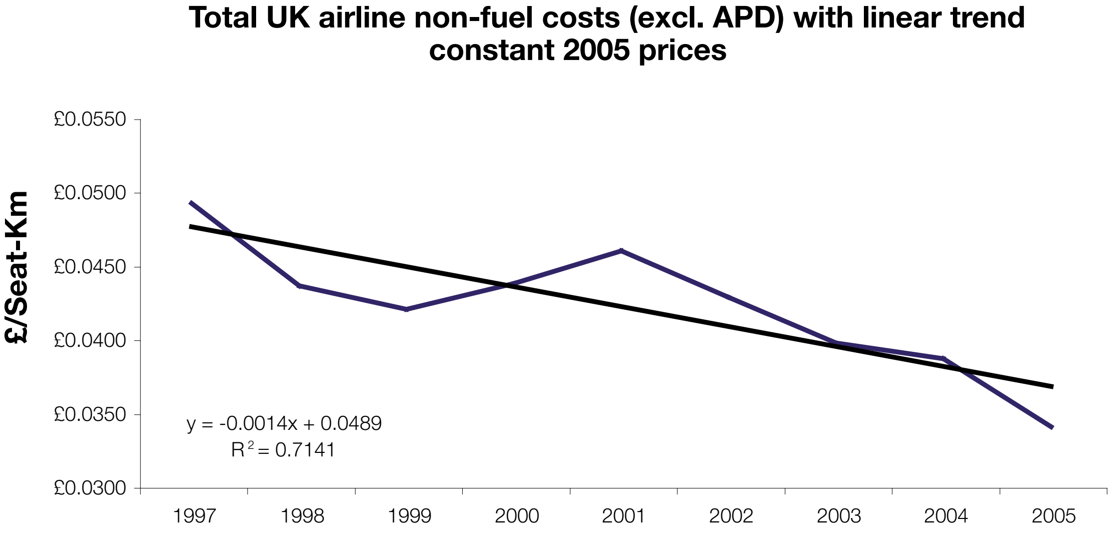
B.14 Figure B1 below shows the trend from 1997 to 2005 in the real costs per seat-kilometre for the four largest UK registered airlines (British Airways, bmi, easyJet and Virgin Atlantic), derived from CAA data[75]. These costs exclude APD and have been converted to 2005 prices. It shows that most non-fuel cost elements have trended down, with the exception of fleet costs where costs have fallen in only the more recent years.

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



B.15 Figure B2 shows that summing the non-fuel cost elements reveals an overall downward trend to 2005, for both short- and long-haul operations.

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



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[75] CAA ERG: UK Airline Financial Tables 1998-2006, *Table 2.6 Individual Airline Profit & Loss, Table 2.10 Operating and Traffic Statistics.*

B.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 by the 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

B.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.

B.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. In line with the *Aviation Emissions Cost Assessment 2008*[76] we count revenues from Air Passenger Duty (APD) as part of the aviation industry’s contribution to meeting its climate change costs.

B.19 Hence in these forecasts passengers are assumed to face charges to cover their climate change costs, comprising of APD and an additional cost equal to the difference between APD and aviation’s climate change costs per passenger journey (if positive) from 2007.

B.20 APD rates are assumed to remain constant in real terms. Table B5 sets out the current rates. As the HMT *Pre-Budget Report 2008* announcement revising the structure and rates of APD was made late in our forecasting process, the new version of APD has been included as a sensitivity test.

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[76] *Aviation Emissions Cost Assessment 2008*, Department for Transport, 2008, available at: http://www.dft.gov.uk/pgr/aviation/environmentalissues/aviationemissionscostassess/aviationemissionscost.pdf

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
Europe and the UK	£10	£20	97.4%
Other OECD	£40	£80	89.8%
NIC	£40	£80	85.3%
LDC	£40	£80	92.3%

Notes:

Passenger share derived from analysis of CAA Passenger Interview surveys at major UK airports

Europe defined by HM Revenue & Customs as passengers flying to: destinations in the European Economic Area (EEA); the European Common Aviation Area; countries applying to join the EU, and Switzerland.

B.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 DECC central value for the shadow price of carbon dioxide emissions (see Chapter 3); 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 released at altitude.

B.22 In the sensitivity tests, we follow DECC's guidance on the range around their shadow price of carbon dioxide, varying the 2000 shadow price of carbon dioxide by -10% and +20%. The radiative forcing factor is varied between 1 and 4.

B.23 We have also included a sensitivity test of aviation entering the EU Emissions Trading Scheme in 2012 (see Box 3.1). It is assumed that APD is retained as in the central case, but the additional cost to ensure fares reflect climate change costs is removed, as it is redundant under this test.

Typical Fares

B.24 Below we illustrate how the above assumptions combine to generate projections of how average single fares are expected to change over time[77] 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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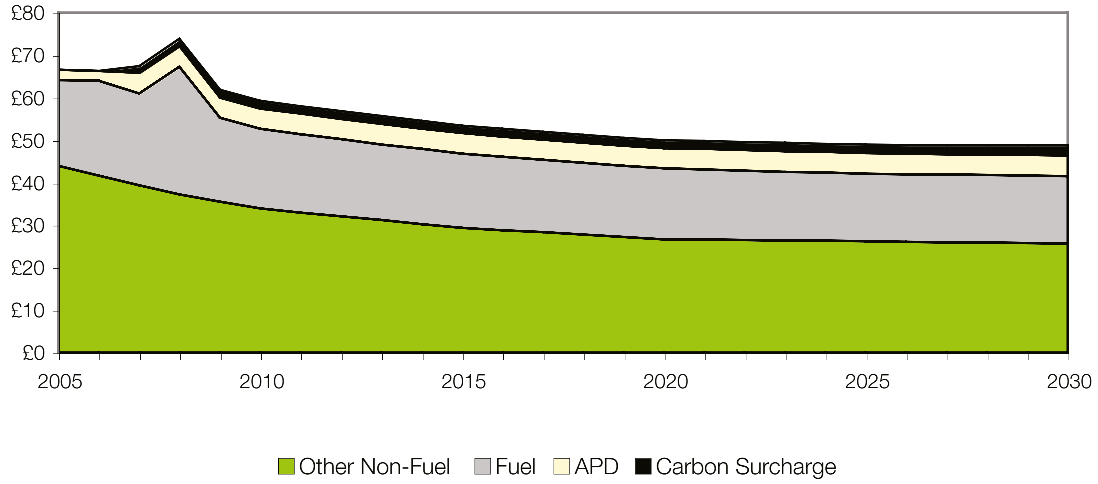
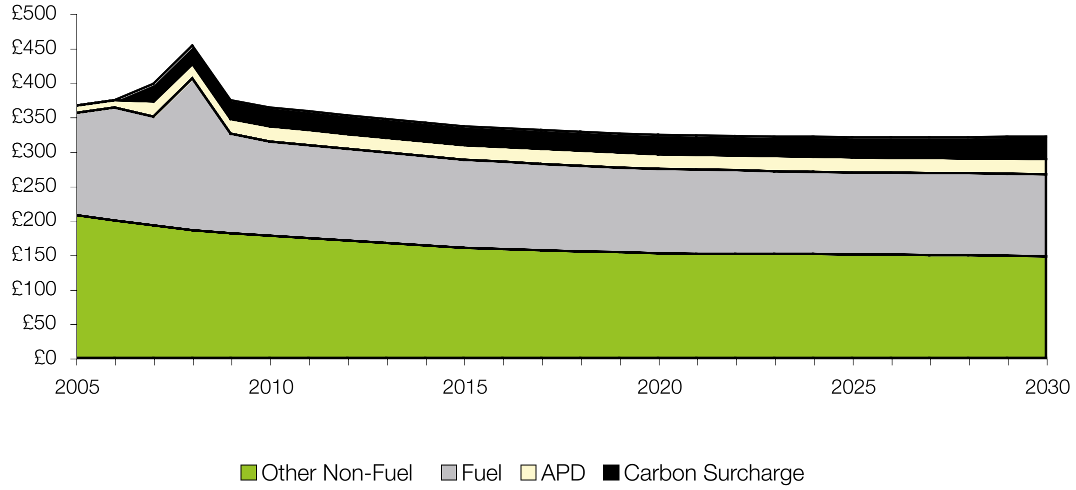
[77] The graphs assume that the APD charge is effectively collected over both legs of a journey and therefore is illustrated at 50% of the prevailing rate on a single fare. Oil prices, carbon costs and radiative forcing all use central assumptions

Figure B3: Composition of two typical projected single fares 2005-2030



Real Single Leisure Fare to Western Europe

Real Single Leisure Fare to the Far East



Market Maturity

B.25 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.

B.26 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.

B.27 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 y_0 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

B.28 The impact of these maturity exponents is to reduce the central national forecasts by 4 percent in 2015 and by 17 percent in 2030.

Annex C: Passenger Airport Choice Model – Detailed Methodology

Introduction

C.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.

C.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

C.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[78]:

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

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

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

C.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.

C.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[79]:

- international scheduled[80] 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[81];
- UK and foreign passengers; and,
- business and leisure passengers.

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[79] 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.

[80] 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).

[81] 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”).

C.6 Table C1 shows the 31 UK airports (by region) to which passengers can be allocated.

Table C1: UK Airports in National Air Passenger Allocation Model

London

Heathrow
Gatwick
Stansted
Luton
London City

Other East & SE

Southampton
Norwich

SW and Wales

Bristol
Cardiff Wales
Bournemouth
Exeter
Newquay
Plymouth

Midlands

Birmingham
Nottingham East Midlands
Coventry

North

Manchester
Newcastle
Liverpool
Leeds Bradford
Durham Tees Valley
Doncaster-Sheffield
Humberside
Blackpool

Scotland

Glasgow
Edinburgh
Aberdeen
Prestwick
Inverness

Northern Ireland

Belfast International
Belfast City

Annex D: Improvements to National Air Passenger Demand and CO_2 Forecasting Methods

Introduction

D.1 The models used to forecast UK air passenger demand and CO_2, and to estimate the monetised net benefits of additional airport capacity, have evolved over a number of years. It is our policy to continuously improve the models, taking on board latest data and methodological advances, and evolving to meet new policy analysis requirements.

D.2 *UK Air Passenger Demand and CO_2 Forecasts* 2007 (Annexes D and I) set out the improvements made to the passenger demand and CO_2 forecasting methods since the ATWP. This annex notes the incremental improvements made since *UK Air Passenger Demand and CO_2 Forecasts* 2007.

National Air Passenger Demand Model

D.3 The econometric models used previously to forecast unconstrained air passenger demand were set out in detail in annex A of *UK Air Passenger Demand and CO_2 Forecasts* 2007. Annex A of this report gives similar details of the latest models. The main changes are:

- Improved modelling of the Foreign Leisure travel market sectors (to Western Europe, OECD, and LDCs), to incorporate air fare elasticities; and
- Updated oil price, GDP, and exchange rate forecasts (see Annex B).

D.4 The improved modelling of the Foreign leisure market, and the higher oil price assumptions, reduced the national air passenger demand forecasts by a small amount. The higher long term growth rate assumptions caused a small increase. Overall, the effect was to reduce forecast demand.

National Air Passenger Allocation Model

D.5 The National Air Passenger Allocation Model which is used to convert unconstrained air passenger demand into constrained demand forecast, was set out in detail in chapter 2 of *UK Air Passenger Demand and CO_2 Forecasts* 2007. Chapter 2 of this report gives similar details of the latest version[82]. The main changes are summarised below.

- Projected capacity at London City increased from 73,000 to 120,000 ATMs after 2009 following granting of planning permission by the London Borough of Newham in October 2008.
- More comprehensive modelling of transferring passengers, by extending to low cost carrier passengers the option of transferring between international to international flights (including journey legs from the Republic of Ireland). This change acknowledges the existence of "do-it-yourself" or "informal" interlining on low cost airlines. This change has improved the model's detailed validation and the modelling of surface access demand at key South East airports. It had very little effect on the national demand forecasts, although it affected the distribution of some types of passenger demand between South East airports by a small amount.

CO_2 model

D.6 The CO_2 forecasting model used previously to convert constrained passenger demand into forecasts of the UK's inventory of aviation CO_2 emissions was set out in Chapter 3 of *UK Air Passenger Demand and CO_2 Forecasts 2007*. Chapter 3 of this report gives similar details of the latest version.

D.7 The main changes since the previous version are:

- Updated demand forecasts (as above);
- Updating the CO_2 emissions base year from 2005 to 2006;
- More accurate translation of domestic ATMs into domestic CO_2 emissions;
- More accurate forecasting of ground and auxiliary power unit emissions;
- Projecting the 'residual' CO_2 element (controlling our 2006 estimate to DECC's latest outturn) to grow proportionately with the forecast level of CO_2, rather than as a constant amount over time as in *UK Air Passenger Demand and CO_2 Forecasts* 2007; and
- Updating the base year data on the type and ages of aircraft for the fleet mix model from 2003 to 2007.

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[82] Even more details of the working of an earlier version of the model are set out in SPASM: *Rules & Modelling. See DfT/Scott Wilson Rules and Modelling: A Users Guide to SPASM, Edition 2*, April 2004.

D.8 Lower demand forecasts reduced the CO_2 forecast by a small amount. The change to the domestic CO_2 forecasts reduced the base year CO_2 emissions estimate, but as the forecasts are controlled to the DECC outturn estimate, this had little effect. The overall effect of the changes was to leave the CO_2 forecast relatively unchanged.

Transport User Benefits

D.9 The methodology for calculating the monetised net benefits of additional airport capacity was set out in Chapter 4 of *UK Air Passenger Demand and CO_2 Forecasts* 2007. Chapter 4 of this report gives similar details of the latest version. The main changes to the methods since the previous version are:

- Updated demand and CO_2 forecasts, as above;
- Revised estimate of the costs of constructing a third runway and sixth terminal (with or without prior mixed mode operations) at Heathrow;
- Revised noise cost estimates; inclusion of air quality cost estimates; and, revised delay reduction benefit estimates for the additional capacity scenarios at Heathrow;
- Updated estimate and inclusion of surface access CO_2 emission costs for all scenarios;
- Inclusion of accident risk impacts for all scenarios;
- Revised method for projecting shadow costs beyond 2030 for appraisal purposes, ensuring consistency with relationship between unconstrained demand, capacities, and shadow costs, prior to 2030; and
- More detailed projection of APD beyond 2030 (now at airport level), to ensure consistency with other post-2030 projections.

D.10 The overall effect of these changes was to increase the monetised net economic benefits of additional capacity at Heathrow slightly, and to reduce the monetised net economic benefits of additional capacity at Stansted.

Annex E: Detailed Validation Results

E.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 (passengers per ATM), split between international and domestic flights.

a) Airport level: validation results

Actual vs fitted passengers and ATMs, 2005

	Passengers (mppa)			ATMs (000 pa)		
	Actual	**Fitted**	**Difference**	**Actual**	**Fitted**	**Difference**
Heathrow	67.7	66.5	1.2	474	462	12
Gatwick	32.7	32.6	0.1	253	250	4
Manchester	22.1	21.7	0.3	218	206	12
Stansted	22.0	22.3	-0.3	180	184	-4
Birmingham	9.3	8.9	0.4	114	111	3
Luton	9.1	9.5	-0.4	79	86	-7
Glasgow	8.8	9.2	-0.4	100	97	2
Edinburgh	8.4	8.5	-0.1	119	119	0
Bristol	5.2	5.5	-0.3	64	64	0
Newcastle	5.2	5.2	0.0	57	54	3
Belfast International	4.8	4.9	-0.1	49	48	0
Liverpool	4.4	4.4	0.0	50	47	3
Nottingham East Midlands	4.2	3.7	0.4	54	50	4
Aberdeen	2.9	2.8	0.1	94	85	10
Leeds Bradford	2.6	2.9	-0.3	36	41	-5
Prestwick	2.4	2.3	0.1	21	19	2
Belfast City	2.2	2.2	0.1	39	36	3
London City	2.0	1.8	0.2	61	55	6
Southampton	1.8	1.8	0.0	44	43	1
Cardiff	1.8	1.8	-0.1	21	20	0
Durham Tees Valley	0.9	1.0	-0.1	12	21	-10
Exeter	0.8	0.9	0.0	13	13	0
Bournemouth	0.8	0.9	-0.1	12	11	1
Coventry	0.7	0.7	0.1	14	8	5
Doncaster Sheffield	0.6	0.6	0.0	5	6	0
Inverness	0.6	0.7	-0.1	20	14	7
Norwich	0.5	0.6	0.0	20	16	4
Humberside	0.5	0.4	0.0	12	11	0
Blackpool	0.4	0.4	0.0	14	3	11
Newquay	0.3	0.4	-0.1	8	10	-1
Plymouth	0.2	0.2	0.0	7	6	1

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%	33%	33%
5%-10%	22%	55%
10%-20%	22%	77%
20%-30%	14%	91%
30%-40%	5%	96%
40%-50%	2%	97%
50%+	3%	100%

International Flights

Error band	Proportion of routes	Cumulative proportion
0%-5%	24%	24%
5%-10%	22%	46%
10%-20%	26%	72%
20%-30%	17%	89%
30%-40%	6%	95%
40%-50%	2%	97%
50%+	3%	100%

Domestic Flights

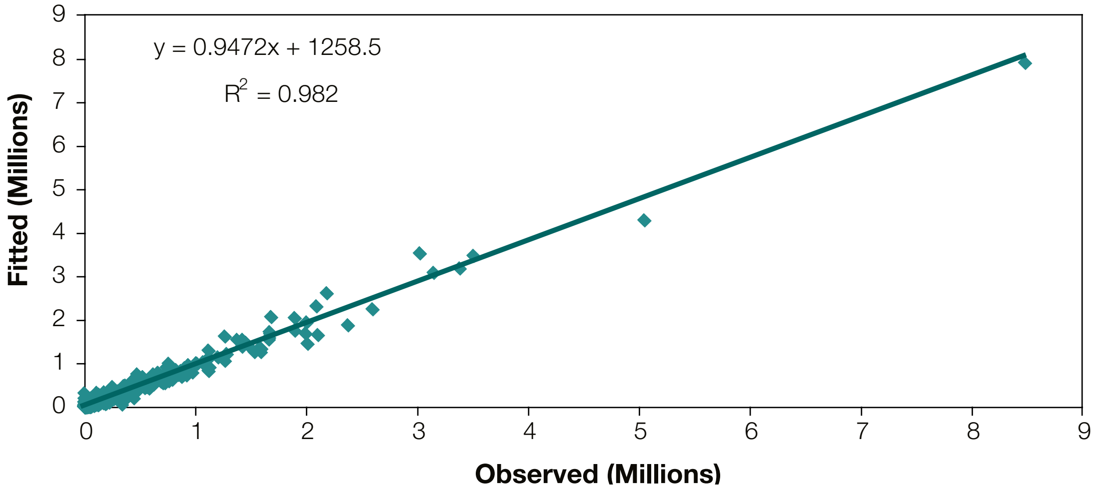
Error band	Proportion of routes	Cumulative proportion
0%-5%	59%	59%
5%-10%	20%	79%
10%-20%	10%	89%
20%-30%	7%	96%
30%-40%	1%	97%
40%-50%	1%	98%
50%+	2%	100%

c) Route level scatter plots

All flights (domestic and international)

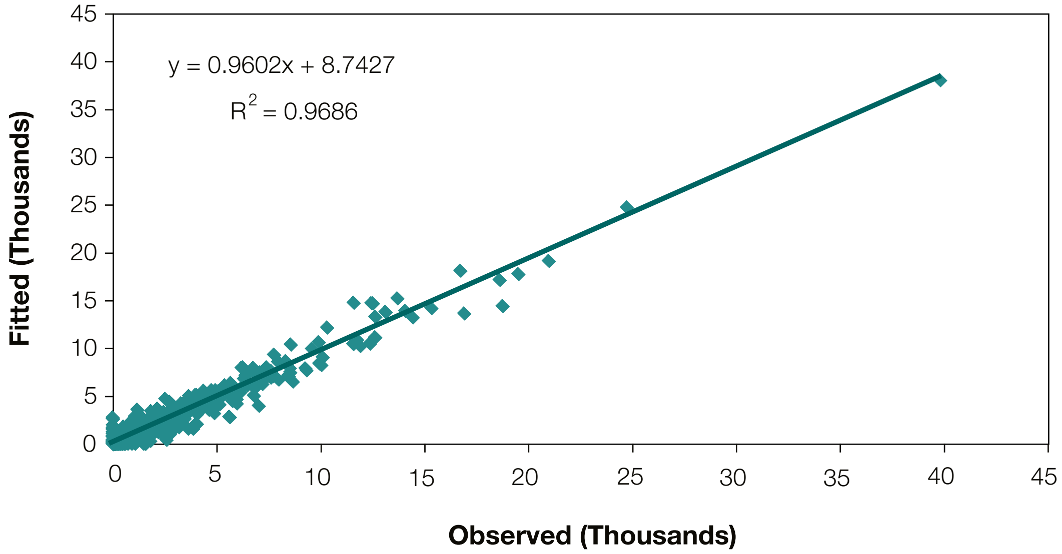
Passengers

2005 All Passenger Types



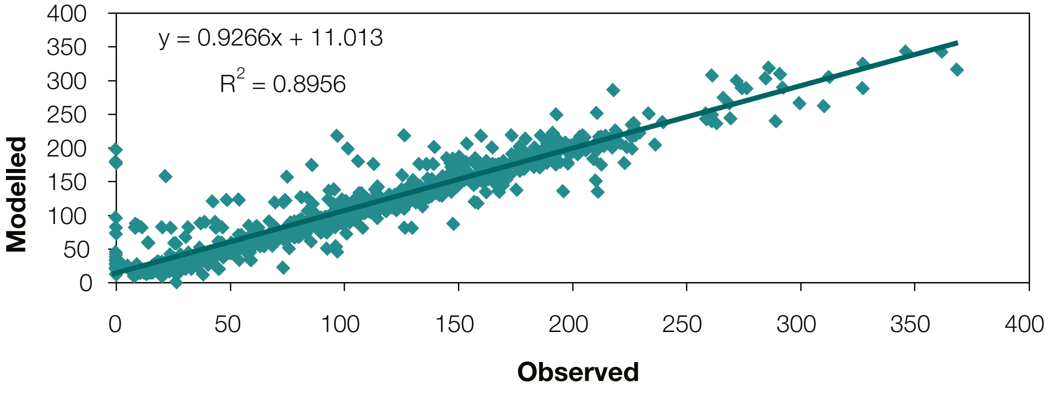
ATMs

2005 All ATMs



Loads

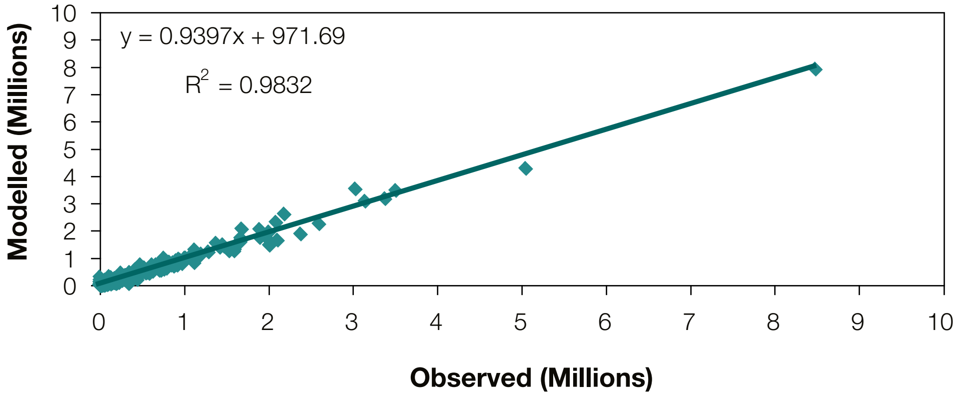
2005 All Aircraft Loads



International flights

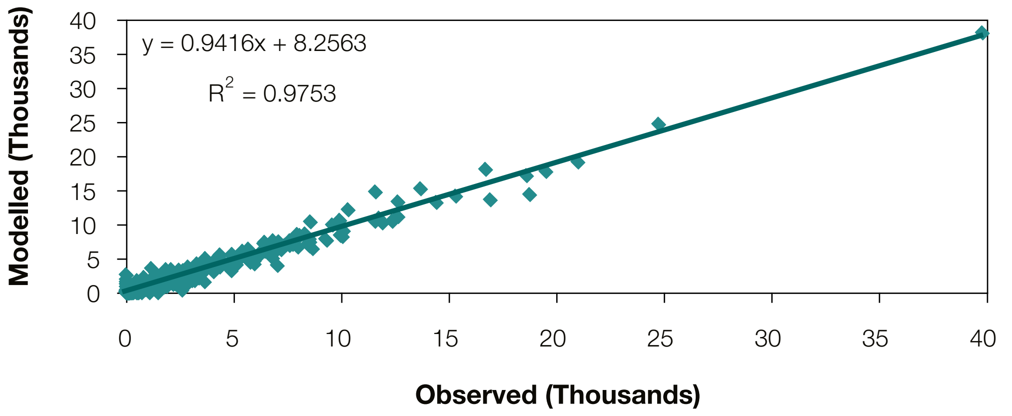
Passengers

2005 All International Passengers



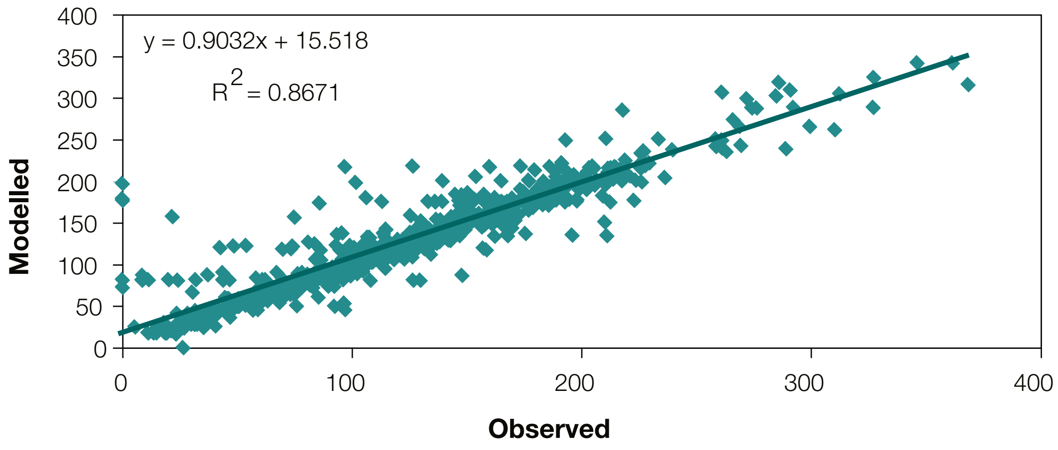
ATMs

2005 All International ATMs



Loads

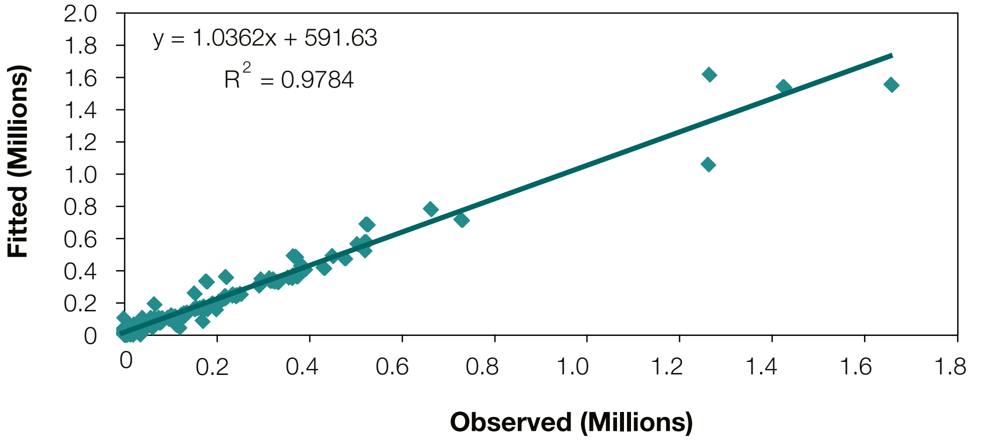
2005 All International Loads



Domestic flights (scheduled)

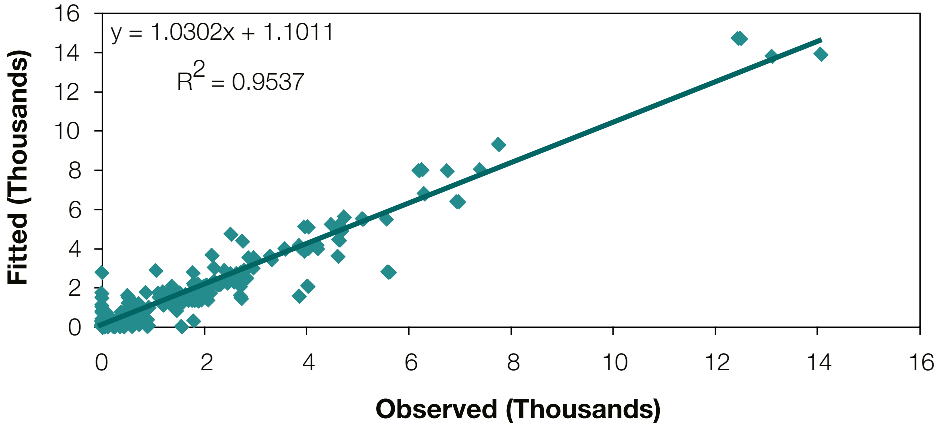
Passengers

2005 All Domestic Passengers



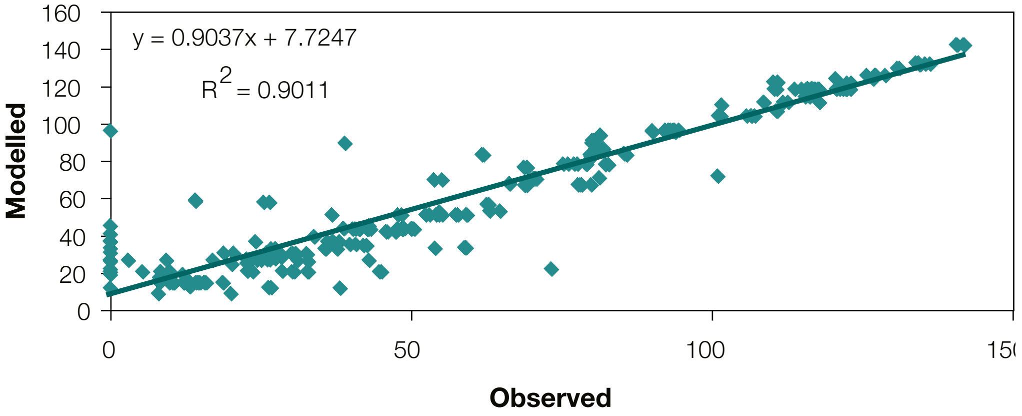
ATMs

2005 Domestic ATMs



Loads

2005 Domestic Aircraft Loads



Annex F: Airport Passenger Demand Forecasts

Introduction

F.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.

F.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 ATWP 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

F.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.

F.4 Table F2 shows the airport demand forecasts for 2030 for some of the largest airports, under the central demand forecasts and the capacity scenarios supported by the ATWP.

Table F1: Passenger demand forecasts at UK airports (mppa)

	Low			Central			High		
Airport	**2005**	2015	2030	**2005**	2015	2030	**2005**	2015	2030
Heathrow	**70**	75	130	**70**	80	135	**70**	80	135
Gatwick	**35**	35	40	**35**	35	40	**35**	35	40
Manchester	**20**	30	40	**20**	30	45	**20**	30	45
Stansted	**20**	25	40	**20**	35	55	**20**	35	65
Birmingham	**9**	14	20	**9**	15	25	**9**	20	25
Glasgow	**9**	11	15	**9**	11	15	**9**	11	20
Luton	**9**	14	15	**9**	15	15	**9**	15	15
Edinburgh	**8**	13	20	**8**	13	20	**8**	13	20
Bristol	**5**	7	10	**5**	8	12	**5**	8	12
Newcastle	**5**	7	10	**5**	7	11	**5**	8	12
Belfast International	**5**	7	11	**5**	7	12	**5**	7	11
Liverpool	**4**	3	7	**4**	4	8	**4**	5	8
Nottingham East Midlands	**4**	5	8	**4**	6	9	**4**	7	11
Leeds/Bradford	**3**	3	5	**3**	4	6	**3**	4	7
Aberdeen	**3**	4	6	**3**	4	6	**3**	4	7
Prestwick	**2**	3	5	**2**	4	5	**2**	4	6
Belfast City	**2**	3	4	**2**	3	4	**2**	3	5
London City	**2**	2	4	**2**	4	5	**2**	4	6
Southampton	**2**	2	3	**2**	3	4	**2**	3	6
Cardiff	**2**	2	3	**2**	2	3	**2**	2	3
Durham Tees Valley	**<1**	1	<1	**<1**	1	1	**<1**	<1	1
Bournemouth	**<1**	1	2	**<1**	2	3	**<1**	2	4
Exeter	**<1**	1	2	**<1**	1	2	**<1**	1	2
Inverness	**<1**	1	2	**<1**	1	2	**<1**	1	2
Coventry	**<1**	2	2	**<1**	3	2	**<1**	2	2
Doncaster Sheffield	**<1**	<1	<1	**<1**	<1	1	**<1**	<1	1
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	2	**<1**	2	3
Plymouth	**<1**	<1	<1	**<1**	<1	<1	**<1**	<1	<1
TOTAL	**230**	280	410	**230**	310	455	**230**	315	480

Table Notes

1. 2005 figures are CAA actuals.
2. Range is underlying demand scenarios, not runway constraint options.
3. If throughput is greater than 15m, throughput is rounded to the nearest 5 million.
4. National total throughputs are rounded to the nearest 5 million.
5. Modelled results Core s12s2 scenario (Stansted R2 in 2015, Heathrow R3 c. 2020).
6. ‘<1’ means non-zero, but rounds to zero at no decimal places.

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

Scenario		Heathrow	Gatwick	Stansted	Luton	London City	Total London	London Share	Regions	Total
s01	**Planning system in SE**	90	41	36	10	7	**185**	46%	216	**401**
s02	**Maximum use**	89	42	35	17	6	**190**	47%	215	**405**
s05	**Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	134	42	36	17	6	**235**	53%	206	**441**
s07	**Stansted second runway (480,000 in 2015)**	89	42	71	17	7	**225**	52%	207	**432**
s12s2	**Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	133	40	56	17	5	**251**	55%	202	**453**
s12s2mm1	**Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2019), then third runway (605,000 2020, rising to 702,000 in 2030)**	133	40	56	17	5	**251**	55%	202	**453**
s12s2mm2	**Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 2020, rising to 702,000 in 2030)**	133	40	55	17	5	**250**	55%	201	**451**
s12s2_2015	**Stansted second runway (480,000 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)**	133	40	55	17	5	**251**	56%	200	**451**
s12s2_2025	**Stansted second runway (480,000 2015), Heathrow third runway (opens 605,000 2025, rising to 702,000 in 2030)**	127	39	59	16	6	**248**	55%	203	**451**
s12s2_605/122	**Stansted second runway (480,000 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)**	117	40	60	17	6	**240**	54%	203	**443**
s12s2_605/129	**Stansted second runway (480,000 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)**	117	40	60	17	6	**240**	54%	203	**443**

Annex G: Detailed Demand and CO_2 Forecasts

Table G1: 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	30	30	32	35	35	39
OECD	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4
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	4	4	4
All Long Haul	5	6	6	6	6	6	6	7	7	7	8	8	8	9	9	9
All UK Business	19	22	22	22	27	27	27	32	32	32	37	37	40	44	44	48
UK Leisure																
Scheduled Short Haul	42	52	58	62	61	82	92	71	98	110	83	111	118	94	125	135
OECD	9	9	10	10	8	11	13	8	12	14	8	12	13	9	13	13
NIC	2	2	2	2	2	3	3	3	4	4	4	4	5	4	5	6
LDC	7	8	9	10	10	13	14	14	17	18	18	21	24	22	26	30
All Scheduled Long Haul	18	19	21	22	21	27	30	25	33	36	30	38	41	35	43	48
Short Haul Charter	32	32	33	34	30	33	33	30	32	33	29	31	31	28	30	30
Long Haul Charter	4	5	5	5	7	7	7	9	9	9	11	11	12	13	13	15
All Charter	36	37	38	39	37	39	40	39	41	42	40	42	43	42	44	45
All Short Haul	74	83	91	95	91	115	125	101	129	143	112	142	149	122	155	165
All Long Haul	22	24	26	27	28	34	37	34	42	45	41	49	53	48	57	63
All UK Leisure	95	108	118	123	119	149	162	135	171	188	152	191	202	170	212	228
Foreign Business																
Short Haul	10	11	11	11	13	13	13	14	14	14	16	16	17	18	18	19
OECD	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
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	8	8	8	10	10	11	13	13	13
All Foreign Business	14	16	16	16	19	19	19	23	23	23	26	26	27	30	30	32
Foreign Leisure																
Short Haul	17	14	15	15	16	17	17	17	18	18	19	20	21	21	21	22
OECD	6	6	7	7	7	7	7	7	8	8	8	8	8	8	8	9
NIC	1	1	1	1	2	2	2	3	3	3	3	3	4	4	4	4
LDC	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
All Long Haul	10	10	11	11	11	12	12	13	13	13	14	14	15	15	16	16
All Foreign Leisure	27	25	25	26	27	28	29	30	31	32	33	34	35	36	37	39
International to International Transfer	22	23	25	26	25	29	30	29	32	33	33	36	37	37	40	42
Total UK International	114	130	140	145	146	176	189	167	203	220	190	228	243	214	256	276
Total Foreign International	64	64	67	68	72	76	78	82	86	87	92	96	100	104	107	112
Total International	**177**	**194**	**207**	**213**	**218**	**252**	**267**	**249**	**289**	**307**	**282**	**324**	**343**	**318**	**363**	**388**
DOMESTIC (Internal 'end to end')																
Business	20	25	25	25	31	31	31	37	37	37	44	44	48	52	52	58
Leisure	17	25	25	25	29	30	31	34	35	36	39	40	43	44	46	50
Miscellaneous	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4
Total Domestic	**38**	**52**	**52**	**52**	**63**	**64**	**64**	**74**	**75**	**75**	**85**	**87**	**94**	**99**	**101**	**111**
GRAND TOTAL	**216**	**246**	**259**	**265**	**280**	**316**	**331**	**323**	**364**	**383**	**368**	**411**	**437**	**417**	**464**	**500**

Table G2: 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	12	24%	3	11%	3	14%	1	15%	1	36%	20	18%	20	22%	40	20%
UK Leisure	19	40%	20	68%	11	55%	5	58%	1	34%	57	51%	59	63%	116	57%
Foreign Business	7	15%	1	4%	1	7%	1	5%	0	11%	11	10%	4	4%	15	7%
Foreign Leisure	11	22%	5	17%	5	25%	2	22%	0	18%	23	21%	9	10%	33	16%
International-International Transfer	18		3		1		0		0		22		0		22	
Total	66		33		22		10		2		133		93		225	

2015	**Heathrow**		**Gatwick**		**Stansted**		**Luton**		**London City**		**Total London**		**Other Airports**		**National**	
UK Business	15	26%	4	11%	5	14%	2	13%	1	33%	26	18%	31	22%	57	20%
UK Leisure	24	43%	22	66%	19	55%	9	57%	2	41%	76	53%	86	63%	162	58%
Foreign Business	8	14%	2	5%	2	7%	1	7%	0	11%	14	9%	7	5%	20	7%
Foreign Leisure	10	17%	6	18%	8	25%	4	23%	1	15%	28	20%	14	10%	42	15%
International-International Transfer	21		3		2		0		0		26		0		26	
Total	78		37		36		16		4		170		138		308	

2030	**Heathrow**		**Gatwick**		**Stansted**		**Luton**		**London City**		**Total London**		**Other Airports**		**National**	
UK Business	26	26%	4	11%	7	13%	3	16%	2	37%	42	20%	49	24%	91	22%
UK Leisure	44	44%	26	68%	30	56%	9	57%	2	42%	111	52%	123	61%	234	56%
Foreign Business	14	15%	2	4%	3	6%	1	6%	1	10%	21	10%	10	5%	32	8%
Foreign Leisure	15	15%	7	17%	13	25%	4	21%	1	11%	39	18%	19	9%	57	14%
International-International Transfer	34		2		3		0		0		38		0		39	
Total	133		40		56		17		5		251		201		452	

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).

Table G3: Constrained terminal passengers, by international/domestic, scheduled/charter, and year

	Heathrow	Gatwick	Stansted	Luton	London City	London total	London share	Other Airports	Total
2005									
International Scheduled	62	20	18	7	1	109	73%	41	149
International Charter	0	10	1	1	0	11	32%	22	34
Domestic (excl. Transfers)	5	3	3	2	0	12	29%	30	42
Total	66	33	22	10	2	133	59%	93	225
2010									
International Scheduled	67	23	20	9	2	121	70%	51	172
International Charter	0	10	1	0	0	11	31%	23	35
Domestic (excl. Transfers)	6	3	3	2	1	15	29%	37	52
Total	73	36	24	11	2	147	57%	111	258
2015									
International Scheduled	71	24	30	14	3	142	67%	70	212
International Charter	0	9	2	0	0	11	31%	25	36
Domestic (excl. Transfers)	7	4	4	2	1	17	28%	43	60
Total	78	37	36	16	4	170	55%	138	308
2020									
International Scheduled	85	24	37	14	3	163	66%	83	246
International Charter	0	9	2	0	0	11	30%	26	37
Domestic (excl. Transfers)	9	4	5	2	1	20	28%	50	71
Total	93	37	44	17	5	195	55%	159	354
2025									
International Scheduled	106	25	41	13	4	188	67%	94	282
International Charter	0	10	2	0	0	12	32%	26	38
Domestic (excl. Transfers)	10	5	5	3	1	25	29%	60	85
Total	116	39	48	17	5	225	56%	180	405
2030									
International Scheduled	121	25	48	13	4	211	67%	107	317
International Charter	0	10	2	0	0	12	31%	27	39
Domestic (excl. Transfers)	12	5	6	3	2	28	29%	68	97
Total	133	40	56	17	5	251	55%	202	453

Table G4: Constrained terminal passengers, by domestic/short haul/long haul and year, South East airports only

mppa

2005	**Heathrow**	**Gatwick**	**Stansted**	**Luton**	**Total**
Long Haul	32	8	0	0	40
Short Haul	30	21	19	8	78
Domestic	5	3	3	2	13
Total	66	33	22	10	131
Long Haul Share	*48%*	*24%*	*0%*	*0%*	*31%*
2010					
Long Haul	34	10	0	0	44
Short Haul	33	23	21	9	86
Domestic	6	3	3	2	14
Total	73	36	24	11	144
Long Haul Share	*47%*	*28%*	*0%*	*0%*	*31%*
2015					
Long Haul	38	11	0	0	49
Short Haul	33	22	31	15	101
Domestic	7	4	4	2	17
Total	78	37	36	16	167
Long Haul Share	*49%*	*30%*	*0%*	*0%*	*29%*
2020					
Long Haul	45	12	0	0	57
Short Haul	40	21	39	14	114
Domestic	9	4	5	2	20
Total	93	37	44	17	191
Long Haul Share	*48%*	*32%*	*0%*	*0%*	*30%*
2025					
Long Haul	53	12	0	0	65
Short Haul	52	22	43	14	131
Domestic	10	5	5	3	23
Total	116	39	48	17	220
Long Haul Share	*46%*	*31%*	*0%*	*0%*	*30%*
2030					
Long Haul	61	12	0	0	73
Short Haul	60	23	50	13	146
Domestic	12	5	6	3	26
Total	133	40	56	17	246
Long Haul Share	*46%*	*30%*	*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 G5: Constrained terminal passengers, journey purpose and destination detail, main airports

2005	Domestic (Excl. int'l transfers)					Short Haul						Long Haul						
mppa	UKBus	UKLei	FoBus	FoLei	Total	UKBus	UKLei	FoBus	FoLei	I to I	Total	UKBus	UKLei	FoBus	FoLei	I to I	Total	Grand Total
Heathrow	3	2	0	0	5	5	8	4	5	8	30	4	9	3	6	10	32	66
Gatwick	1	1	0	0	3	2	14	1	3	2	21	1	5	0	2	1	8	33
Stansted	1	2	0	0	3	2	10	1	5	1	19	0	0	0	0	0	0	22
Luton	1	1	0	0	2	1	4	0	2	0	8	0	0	0	0	0	0	10
London City	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
London Total	6	6	0	1	12	10	37	7	15	11	80	4	14	4	8	11	40	133
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	5
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	4
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	20
Regional Total	15	14	0	1	30	5	40	3	7	0	55	1	5	0	1	0	8	93
National Total	21	20	1	1	42	15	77	10	23	11	135	5	19	4	9	11	48	225

Table G5: Constrained terminal passengers, journey purpose and destination detail, main airports *(continued)*

2015	Domestic (Excl. int'l transfers)					Short Haul						Long Haul						
mppa	UKBus	UKLei	FoBus	FoLei	Total	UKBus	UKLei	FoBus	FoLei	I to I	Total	UKBus	UKLei	FoBus	FoLei	I to I	Total	Grand Total
Heathrow	5	2	0	0	7	6	9	5	4	9	33	4	13	4	6	12	38	78
Gatwick	2	2	0	0	4	2	14	1	4	1	22	1	6	1	2	1	11	37
Stansted	1	2	0	0	4	3	16	2	8	2	31	0	0	0	0	0	0	36
Luton	1	1	0	0	2	1	8	1	3	0	15	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	9	8	0	1	17	13	49	9	20	13	103	5	19	4	8	13	50	170
Manchester	3	1	0	0	4	2	15	1	2	0	21	1	4	0	1	0	6	31
Birmingham	1	1	0	0	2	1	7	1	1	0	11	1	3	0	1	0	4	17
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	4	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	3	0	0	5	0	1	1	0	0	2	0	0	0	0	0	0	7
Liverpool	0	1	0	0	1	0	2	0	1	0	3	0	0	0	0	0	0	4
East Midlands	0	0	0	0	1	1	4	0	1	0	5	0	0	0	0	0	0	6
Other Airports in Model	5	6	0	0	12	2	14	1	3	0	20	0	0	0	0	0	1	33
Regional Total	21	20	1	1	43	8	57	5	10	0	81	2	9	1	2	0	14	138
National Total	30	27	1	2	60	21	106	14	30	13	184	6	28	5	10	13	63	308

Table G5: Constrained terminal passengers, journey purpose and destination detail, main airports *(continued)*

2030	Domestic (Excl. intl' transfers)					Short Haul						Long Haul						
mppa	**UKBus**	**UKLei**	**FoBus**	**FoLei**	**Total**	**UKBus**	**UKLei**	**FoBus**	**FoLei**	**I to I**	**Total**	**UKBus**	**UKLei**	**FoBus**	**FoLei**	**I to I**	**Total**	**Grand Total**
Heathrow	8	4	0	0	12	11	19	8	7	15	60	7	21	6	8	19	61	133
Gatwick	2	3	0	0	5	1	16	1	4	1	23	1	7	1	2	1	12	40
Stansted	2	4	0	1	6	5	26	3	13	3	50	0	0	0	0	0	0	56
Luton	1	2	0	0	3	1	8	1	3	0	13	0	0	0	0	0	0	17
London City	1	0	0	0	2	1	2	1	1	0	4	0	0	0	0	0	0	5
London Total	14	13	0	1	28	20	70	14	27	19	150	8	28	7	10	20	73	251
Manchester	5	2	0	0	7	3	20	2	3	0	27	1	7	1	1	0	9	44
Birmingham	2	2	0	0	3	2	10	1	1	0	15	1	4	1	1	0	6	24
Glasgow	5	3	0	0	9	1	5	0	1	0	6	0	1	0	0	0	2	17
Edinburgh	7	6	0	0	13	1	3	0	1	0	6	0	1	0	1	0	2	21
Bristol	1	2	0	0	3	1	6	0	1	0	8	0	0	0	0	0	0	12
Newcastle	2	2	0	0	4	1	5	0	1	0	6	0	0	0	0	0	0	11
Belfast International	3	4	0	1	8	0	2	1	0	0	3	0	0	0	0	0	0	11
Liverpool	1	1	0	0	2	1	3	1	1	0	6	0	0	0	0	0	0	8
East Midlands	1	1	0	0	1	1	5	1	1	0	8	0	0	0	0	0	0	9
Other Airports in Model	9	9	0	0	18	3	18	2	4	0	27	0	0	0	0	0	1	46
Regional Total	34	32	1	2	68	13	77	8	14	0	112	2	14	1	3	0	21	201
National Total	48	45	1	3	97	33	147	22	41	19	262	10	42	8	13	20	93	452

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 Middle East and North America.
4. UK to Channel Isles counted as short haul

Table G6: 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	1	1	1	1
Midlands	5	6	3	5	6	7
Wales	1	1	1	1	1	1
South West	5	6	5	5	5	8
Regional Total	12	13	10	12	14	18
SE Passengers	93	129	165	93	129	195
Total Surface Passengers at SE Airports	**105**	**143**	**175**	**105**	**143**	**213**
Other Airports						
Northern Ireland	7	10	15	7	10	16
Scotland	24	33	46	24	33	51
North	33	47	67	33	47	68
Midlands	14	21	35	14	21	32
Wales	3	5	8	3	5	7
South West	7	12	18	7	12	17
Regional Total	88	129	189	88	128	191
SE Passengers	2	4	14	2	4	5
Total Surface Passengers at Other Airports	**89**	**133**	**203**	**89**	**133**	**196**
I to I Interliners at SE Airports	22	26	24	22	26	38
I to I Interliners at Regional Airports	0	0	1	0	0	0
Domestic Interliners at SE Airports	8	5	1	8	5	5
Domestic Interliners at Regional Airports	0	0	0	0	0	0
Grand Total	**225**	**307**	**405**	**225**	**307**	**453**
Passengers with Regional O-Ds						
Northern Ireland	7	10	15	7	10	16
Scotland	24	33	46	24	33	51
North	34	48	68	34	48	69
Midlands	19	27	38	19	27	39
Wales	4	6	9	4	6	9
South West	12	17	24	12	17	25
South East	95	134	180	95	134	200
Total Surface Passengers	**195**	**276**	**379**	**195**	**276**	**409**

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 G7: Air Transport Movements, by domestic/international, scheduled/charter, passenger/freight, and year

ATM 000s	International Scheduled	International Charter	Domestic	Freight	Total
2005	1,190	170	770	70	2,200
2010	1,330	180	860	70	2,440
2015	1,650	180	920	70	2,810
2020	1,890	190	1,060	90	3,230
2025	2,070	190	1,150	100	3,520
2030	2,280	190	1,240	120	3,840

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 G8: 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	460	250	180	90	50	1,040	47%	1,160	2,200
2010	490	270	190	100	60	1,110	45%	1,320	2,440
2015	480	270	270	120	90	1,230	44%	1,580	2,810
2020	550	260	320	130	110	1,370	42%	1,860	3,230
2025	650	260	340	130	120	1,510	43%	2,010	3,520
2030	710	260	390	120	130	1,630	42%	2,220	3,840

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 G9: CO_2 emissions by UK airport, 2030/2050, central and range

million tonnes CO_2	2030			2050		
	Low	**Central**	High	Low	**Central**	High
Heathrow	21.4	**23.6**	24.4	19.0	**21.4**	23.3
Manchester	3.9	**4.6**	5.1	4.8	**5.4**	5.6
Gatwick	3.8	**4.2**	4.4	3.4	**3.9**	4.3
Birmingham	2.4	**2.8**	2.9	2.2	**2.6**	2.9
Stansted	1.7	**2.5**	2.9	2.7	**3.0**	3.2
Edinburgh	1.1	**1.3**	1.4	2.0	**2.3**	2.6
Glasgow	1.0	**1.2**	1.3	1.1	**1.2**	1.3
Luton	0.8	**0.8**	0.8	0.7	**0.7**	0.7
Bristol	0.5	**0.6**	0.6	0.5	**0.6**	0.6
Newcastle	0.5	**0.6**	0.6	0.6	**0.7**	0.8
Belfast International	0.4	**0.5**	0.5	0.7	**0.8**	0.8
East Midlands	0.4	**0.5**	0.6	0.6	**0.7**	0.9
London City	0.3	**0.5**	0.4	0.4	**0.4**	0.4
Liverpool	0.4	**0.4**	0.5	0.5	**0.5**	0.6
Aberdeen	0.4	**0.4**	0.4	0.5	**0.5**	0.5
Leeds/Bradford	0.3	**0.3**	0.4	0.4	**0.5**	0.6
Southampton	0.2	**0.3**	0.4	0.3	**0.4**	0.4
Bournemouth	0.2	**0.3**	0.3	0.3	**0.4**	0.4
Prestwick	0.2	**0.2**	0.2	0.2	**0.3**	0.3
Coventry	0.2	**0.2**	0.2	0.2	**0.2**	0.2
Cardiff	0.2	**0.2**	0.2	0.2	**0.2**	0.3
Belfast City	0.1	**0.1**	0.1	0.1	**0.1**	0.1
Doncaster Sheffield	0.1	**0.1**	0.1	0.2	**0.2**	0.2
Blackpool	0.1	**0.1**	0.1	0.1	**0.1**	0.2
Durham Tees Valley	0.1	**0.1**	0.1	0.2	**0.2**	0.2
Exeter	0.1	**0.1**	0.1	0.1	**0.1**	0.2
Inverness	0.1	**0.1**	0.1	0.1	**0.1**	0.1
Norwich	0.1	**0.1**	0.1	0.1	**0.1**	0.1
Humberside	–	**–**	0.1	–	**0.1**	0.1
Plymouth	–	**–**	–	–	**–**	–
Newquay	–	**–**	–	–	**–**	–
Ground (APU)	0.7	**0.8**	0.8	0.7	**0.8**	0.9
Freight	2.2	**2.2**	2.2	2.3	**2.4**	2.4
Residual	7.7	**8.7**	9.1	7.7	**8.8**	9.5
Total	51.8	**58.4**	61.6	53.0	**59.9**	65.0

Notes

1. Low CO_2 assumes low demand scenario and the high fuel efficiency case (e3a)
2. High CO_2 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. CO_2 emissions from UK departures only.
6. APU, freight and residual add-on not allocated to airports.
7. "-" means non-zero, but rounds to zero at no decimal places.

Table G10: CO_2 emissions at airport level 2005 and 2030 detailed

	Total CO_2 ($MtCO_2$) in 2005	Share of 2005 Total CO_2	Total CO_2 ($MtCO_2$) in 2030	Share of 2030 Total CO_2
Heathrow	17.1	45.6%	23.6	40.4%
Gatwick	4.4	11.7%	4.2	7.2%
Manchester	2.5	6.7%	4.6	7.9%
Stansted	1.3	3.5%	2.5	4.3%
Birmingham	0.8	2.2%	2.8	4.8%
Glasgow	0.8	2.1%	1.2	2.0%
Luton	0.6	1.6%	0.8	1.3%
Edinburgh	0.5	1.4%	1.3	2.2%
Bristol	0.4	1.0%	0.6	1.1%
Newcastle	0.3	0.9%	0.6	1.0%
Belfast International	0.3	0.7%	0.5	0.9%
Nottingham East Midlands	0.3	0.7%	0.5	0.8%
Liverpool	0.2	0.6%	0.4	0.7%
Leeds/Bradford	0.2	0.5%	0.3	0.6%
Cardiff	0.2	0.4%	0.2	0.3%
Aberdeen	0.1	0.4%	0.4	0.6%
London City	0.1	0.3%	0.5	0.8%
Prestwick	0.1	0.3%	0.2	0.4%
Southampton	0.1	0.3%	0.3	0.5%
Belfast City	0.1	0.2%	0.1	0.2%
Durham Tees Valley	0.1	0.2%	0.1	0.2%
Exeter	0.1	0.2%	0.1	0.2%
Bournemouth	0.1	0.2%	0.3	0.5%
Coventry	0.1	0.1%	0.2	0.3%
Doncaster Sheffield	–	0.1%	0.1	0.2%
Norwich	–	0.1%	0.1	0.1%
Inverness	–	0.1%	0.1	0.2%
Humberside	–	0.1%	–	0.1%
Blackpool	–	0.0%	0.1	0.2%
Newquay	–	0.0%	–	0.0%
Plymouth	–	0.0%	–	0.0%
Ground (APU)	0.4	1.2%	0.8	1.3%
Freight	0.7	1.9%	2.2	3.8%
Residual	5.5	14.6%	8.7	14.8%
Total	37.4		58.4	

Notes

1. Low CO_2 assumes low demand scenario and the high fuel efficiency case (e3a).
2. High CO_2 assumes high demand scenario and the low fuel efficiency 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. CO_2 emissions from UK departures only.
6. APU, freight and residual add-on not allocated to airports.
7. "-" means non-zero, but rounds to zero at no decimal places.

Table G11: ATMs (short vs long haul), available seat-kms, average flight length, and CO_2 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	325	136	409,991	2,837	2	15	17
Gatwick	210	37	121,106	2,019	2	3	4
Manchester	178	18	71,535	1,593	1	1	3
Stansted	172	1	38,935	1,157	1	0	1
Birmingham	104	4	21,603	1,160	1	0	1
Glasgow	81	5	20,850	1,172	0	0	1
Luton	77	0	16,813	1,184	1	0	1
Edinburgh	106	2	10,667	692	0	0	1
Bristol	61	0	9,595	959	0	0	0
Newcastle	52	0	9,475	988	0	0	0
Nottingham East Midlands	33	0	7,692	1,177	0	0	0
Liverpool	48	0	6,617	810	0	0	0
Belfast International	42	1	5,921	755	0	0	0
Cardiff	20	0	4,327	1,125	0	0	0
Leeds/Bradford	40	0	4,088	693	0	0	0
Prestwick	17	0	3,845	1,111	0	0	0
Aberdeen	41	0	2,938	690	0	0	0
London City	52	0	2,198	550	0	0	0
Durham Tees Valley	21	0	1,943	552	0	0	0
Southampton	42	0	1,865	493	0	0	0
Bournemouth	9	0	1,723	1,087	0	0	0
Coventry	7	0	1,457	1,217	0	0	0
Belfast City	35	0	1,443	355	0	0	0
Exeter	12	0	1,456	843	0	0	0
Doncaster Sheffield	5	0	1,352	1,498	0	0	0
Norwich	11	0	1,042	709	0	0	0
Humberside	6	0	808	858	0	0	0
Inverness	10	0	694	574	0	0	0
Blackpool	4	0	476	774	0	0	0
Newquay	8	0	229	306	0	0	0
Plymouth	6	0	110	365	0	0	0
Total	1,834	205	782,794	1,551	11	20	31
Total CO_2 including freight, ground delay emissions and residual adjustment to DECC 2006 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. Airport level CO_2 emissions exclude freight and ground (delay) emissions.
5. Airports sorted on descending available seat-kms (2005).
6. "0" means non-zero, but rounds to zero at no decimal places.

Table G12: ATMs (short vs long haul), available seat-kms, average flight length, and CO$_2$ emissions (short vs long haul), by UK airport, 2030

Airport	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	509	202	729,191	2,860	3	20	24
Gatwick	206	52	149,035	2,191	1	3	4
Manchester	315	40	157,640	1,753	2	3	5
Stansted	371	0	89,867	1,200	3	0	3
Birmingham	191	37	89,148	1,740	1	2	3
Glasgow	128	9	40,127	1,253	1	1	1
Luton	117	0	26,209	1,152	1	0	1
Edinburgh	197	11	33,359	949	1	0	1
Bristol	120	0	17,531	902	1	0	1
Newcastle	100	0	17,448	981	1	0	1
Nottingham East Midlands	76	1	14,755	1,109	0	0	0
Liverpool	97	0	9,318	848	0	0	0
Belfast International	97	2	14,367	823	0	0	1
Cardiff	34	1	5,832	962	0	0	0
Leeds/Bradford	73	0	8,498	827	0	0	0
Prestwick	33	0	7,463	1,157	0	0	0
Aberdeen	80	1	7,370	850	0	0	0
London City	121	0	9,604	746	0	0	0
Durham Tees Valley	40	0	2,787	734	0	0	0
Southampton	77	0	5,236	667	0	0	0
Bournemouth	40	0	7,131	1,388	0	0	0
Coventry	25	0	6,104	1,486	0	0	0
Belfast City	56	0	2,533	346	0	0	0
Exeter	22	0	2,792	921	0	0	0
Doncaster Sheffield	13	0	4,000	1,920	0	0	0
Norwich	17	0	1,323	743	0	0	0
Humberside	7	0	1,105	1,005	0	0	0
Inverness	22	0	1,892	601	0	0	0
Blackpool	16	0	4,753	1,449	0	0	0
Newquay	7	0	263	387	0	0	0
Plymouth	9	0	206	367	0	0	0
Total	3,216	356	1,466,887	1,572	18	29	47
Total CO$_2$ including freight, ground delay emissions and residual adjustment to DECC 2006 estimate							58.4

Notes

1. Seat-Kms and average distances are next stop only.
2. Distances are Great Circle, uprated by 9% for indirect routeing.
3. CO$_2$ emissions from UK departures only.
4. Airport level CO$_2$ emissions exclude freight and ground (delay) emissions.
5. Airports sorted on descending available seat-kms.
6. “0” means non-zero, but rounds to zero at no decimal places.

Table G13: Carbon dioxide emissions by South East Airport, by development scenario, 2030, $MtCO_2$

Code	Scenario	Heathrow	Gatwick	Stansted	Luton	London City	Total South East	Other Airports	Passenger ATM APU ground emissions	Freight Aircraft	Residual	Total CO_2
s01	**Planning system in SE**	18	4	2	–	–	25	18	1	2	8	54
s02	**Maximum use**	18	5	2	1	–	25	17	1	2	8	53
s05	**Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	23	4	2	1	–	30	16	1	2	9	57
s07	**Stansted second runway (480,000 in 2015)**	18	5	3	1	–	28	16	1	2	8	55
s12s2	**Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	24	4	3	1	–	32	15	1	2	9	58
s12s2mm1	**Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 in 2010-2019), then third runway (605,000 in 2020, rising to 702,000 in 2030)**	24	4	3	1	–	32	15	1	2	9	58
s12s2mm2	**Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 in 2010-2015 & 540,000 in 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)**	24	4	2	1	–	32	15	1	2	9	58
s12s2_2015	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)**	24	4	2	1	–	32	15	1	2	9	58
s12s2_2025	**Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 in 2025, rising to 702,000 in 2030)**	23	4	3	1	–	31	15	1	2	9	58
s12s2_605/122	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)**	22	5	3	1	–	30	16	1	2	9	58
s12s2_605/129	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)**	22	5	3	1	–	30	16	1	2	9	58

Notes
1. APU, Freight and Residual not allocated to airports.
2. CO_2 counted for UK departures only.
3. South East is main London Airports only.
4. '–' means: non-zero, but rounds to zero at no decimal places

Table G14: Carbon dioxide emissions by South East Airport, by development scenario, 2050, $MtCO_2$

Code	Scenario	Heathrow	Gatwick	Stansted	Luton	London City	Total South East	Other Airports	Passenger ATM APU ground emissions	Freight Aircraft	Residual	Total CO_2
s01	**Planning System in SE**	16	4	2	–	1	23	20	1	2	8	53
s02	**Maximum Use**	16	4	1	1	1	23	20	1	2	8	54
s05	**Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	21	4	1	1	1	28	18	1	2	8	58
s07	**Stansted second runway (480,000 in 2015)**	16	5	3	1	1	26	19	1	2	8	56
s12s2	**Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	21	4	3	1	1	30	18	1	2	9	60
s12s2mm1	**Stansted second runway (480,000 in 2015), Heathrow Mixed Mode (480,000 2010-2019), then third runway (605,000 2020, rising to 702,000 in 2030)**	21	4	3	1	1	30	18	1	2	9	60
s12s2mm2	**Stansted second runway (480,000 in 2015), Heathrow Mixed Mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 2020, rising to 702,000 in 2030)**	21	4	3	1	1	30	18	1	2	9	60
s12s2_2015	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)**	21	4	3	1	1	30	18	1	2	9	60
s12s2_2025	**Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 2025, rising to 702,000 in 2030)**	21	4	3	1	1	30	18	1	2	9	60
s12s2_605/122	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)**	20	4	3	1	1	28	19	1	2	9	59
s12s2_605/129	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)**	20	4	3	1	1	29	19	1	2	9	59

Table Notes

1. APU, Freight and Residual not allocated to airports.
2. CO_2 counted for UK departures only.
3. South East is main London Airports only.
4. '–' means: non-zero, but rounds to zero at no decimal places

Table G15: UK aviation carbon dioxide emissions, by capacity scenario and year, $MtCO_2$

Code	Scenario	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
s01	**Planning System in SE**	37	41	46	49	50	54	54	55	54	53
s02	**Maximum Use**	37	41	46	49	50	53	55	55	54	54
s05	**Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	37	41	46	50	53	57	59	59	59	58
s07	**Stansted second runway (480,000 in 2015)**	37	41	46	50	52	55	57	57	57	56
s12s2	**Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)**	37	41	46	50	54	58	60	61	61	60
s12s2mm1	**Stansted second runway (480,000 in 2015), Heathrow Mixed Mode (480,000 2010-2019), then third runway (605,000 in 2020, rising to 702,000 in 2030)**	37	41	46	50	54	58	60	61	61	60
s12s2mm2	**Stansted second runway (480,000 in 2015), Heathrow Mixed Mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 2020, rising to 702,000 in 2030)**	37	41	47	50	54	58	60	61	61	60
s12s2_2015	**Stansted second runway (480,00 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)**	37	41	46	51	54	58	60	61	60	60
s12s2_2025	**Stansted second runway (480,000 in 2015), Heathrow third runway (opens 605,000 2025, rising to 702,000 in 2030)**	37	41	46	50	52	58	61	61	61	60
s12s2_605/122	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity)**	37	41	46	51	53	58	59	60	60	59
s12s2_605/129	**Stansted second runway (480,000 in 2015), Heathrow third runway (487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity)**	37	41	46	51	53	58	60	60	60	59

Notes

1.Total includes around freight, APU and residual to match DECC bunker return

2. CO_2 counted for UK departures only.

Table G16: CO_2 emissions by demand sensitivity case 2030/2050

Scenario	Difference from central case assumptions	Total CO_2 ($MtCO_2$) in 2030	Total CO_2 ($MtCO_2$) in 2050
Central case	-	**58**	**60**
Low GDP	GDP grows ¼% pa slower	**55**	**58**
High GDP	GDP grows ¼% pa faster	**62**	**62**
PBR Nov 2008 GDP forecast	Pre-Budget Report 2008 GDP Forecasts	**56**	**59**
BERR High High oil price	Increase from $38 to $136 per barrel by 2030 (2004 price base)	**52**	**55**
BERR High oil price	Increase from $38 to $95 per barrel by 2030 (2004 price base)	**56**	**58**
BERR Low oil price	Increase from $38 to $41 per barrel by 2030 (2004 price base)	**62**	**62**
EU ETS	Aviation enters EU ETS scheme (central case APD retained)	**56**	**58**
Higher shadow price of CO_2	Shadow price of carbon raised by 20%	**58**	**59**
Lower shadow price of CO_2	Shadow price of carbon lowered by 10%	**59**	**60**
Higher radiative forcing factor	Radiative forcing factor raised from 1.9 to 4.0	**55**	**58**
Lower radiative forcing factor	Radiative forcing factor dropped from 1.9 to 1.0	**59**	**61**
Higher Airline Non-Fuel Costs	Airline non-fuel costs increased by 0.5% pa 2005-2020	**57**	**59**
Lower Airline Non-Fuel Costs	Airline non-fuel costs reduced by 0.5% pa 2005-2020	**59**	**61**
Lower Fuel Efficiency	5% ACARE replacement stock 2020-2030	**58**	**63**
Higher Fuel Efficiency	5% ACARE replacement stock 2020, 50% ACARE by 2030	**59**	**57**
PBR Nov 2008 APD bands and rates	Pre-Budget Report 2008 Four Band APD in 2010	**58**	**60**

1.Total includes residual adjustment to ensure consistency with DECC outturn estimate.

2. CO_2 counted for UK departures only.

3. Option ‘s12s2’: Stansted second runway in 2015, Heathrow R3 around 2020.

Annex H: Monetised Net Benefits Methodology

Introduction

H.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 monetised net benefits of key development options in the South East was reported in *Passenger Forecasts: Additional Analysis* in 2004. These were updated in *UK Air Passenger Demand and* CO_2 *Forecasts 2007*, reflecting the 2006 Stern Review, and Eddington Study.

H.2 We have since updated our demand and CO_2 forecasting method and 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. 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 (see Annex D for more detail). In light of these developments, we have refreshed our appraisal of key development options supported in the 2003 ATWP.

H.3 This annex provides a detailed description of the current methodology for estimating the monetised net benefits of additional airport capacity. This is a cost-benefit analysis that compares the monetised benefits of airport developments, net of the cost of extra carbon dioxide emissions (and noise and air quality emissions costs at Heathrow), with the associated capital costs.

H.4 Additionally, we record the costs and benefits which are currently non-monetised.

Benefits

Monetised Benefits

H.5 The monetised benefits from additional airport capacity are intrinsically linked with the process for forecasting the redistribution of demand between constrained airports.

H.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.

H.7 Figure H1 and Figure H2 represent the two (interlinked yet conceptually separate) markets which jointly determine the volume and price of air travel from a hypothetical airport[83].

H.8 Figure H1 shows the interaction of airlines, who supply 'seats' on flights, and passengers who demand them. Figure H2 shows the interaction between an airport, which supplies air transport movements (ATMs), and airlines who demand them. The airlines' demand for ATMs (at a given airport charge) in Figure H2 is determined by the interaction of supply and demand in Figure H1. At the same time, their supply of seats (at a given air fare) in Figure H1 is influenced by the airport charge, which is determined by the interaction of supply and demand in Figure H2.

H.9 In Figure H1, the airlines' supply curve (S) depends on airport capacity (either R1 or R2, where R2>R1), air passenger duty (APD), and other costs. Hence without APD, and with lower airport capacity, the airline supply curve is S(R1). With APD and higher airport capacity, it is S^t(R2). Also, environmental costs (such as CO_2 emissions) are shown by the marginal social cost (MSC) curve laying above the (without tax) supply curve by the value of the marginal external cost (MEC)[84].

H.10 From Figure H1, it is apparent that APD raises fares, and reduces passenger demand. The effect of this is to reduce airlines' demand for ATMs at a given airport charge, moving the demand curve in Figure H2 leftwards, from $D_{airport}$ to $D^t_{airport}$.

H.11 With these external costs and duty in place, many of the monetised benefits of additional airport capacity can be identified in these two figures. Additional capacity causes the airport supply curve to move from SRMC(R1) to SRMC(R2) in Figure H2, reducing airport charges (from P^t_1 to P^t_2) and increasing ATMs (from ATM^t_1 to ATM^t_2). This provides a benefit of area A (initially to airlines, but assumed to pass through to passengers under competitive airline conditions). Also, the airport operator gains area B[85].

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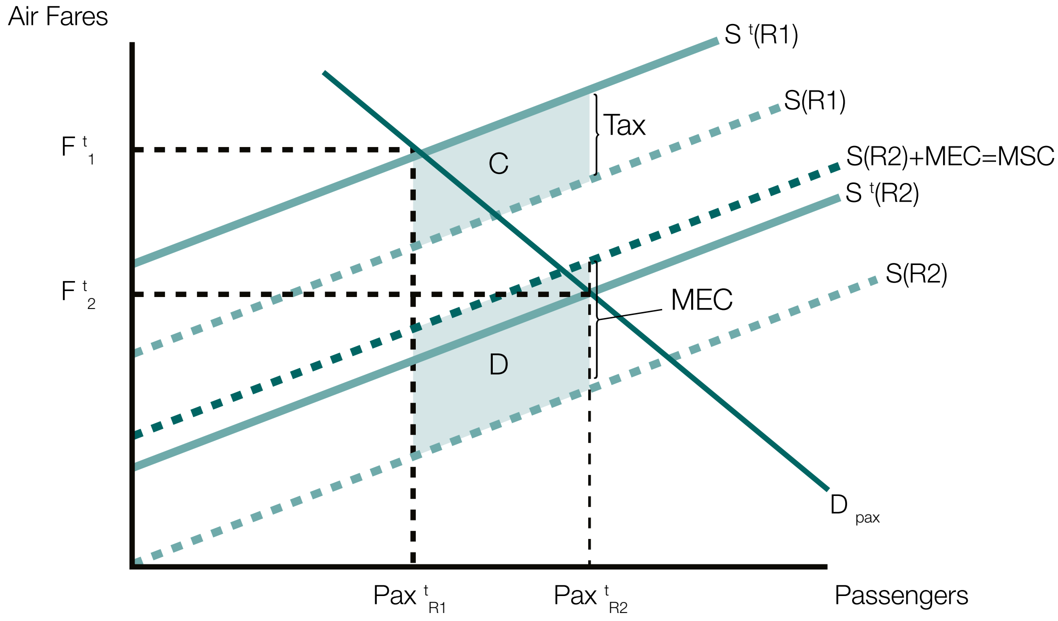
[83] For simplicity of presentation, the analysis here assumes that airport charges are set at the market clearing level. In practice, a number of UK airports are designated for the purpose of airport charge regulation, meaning that their charges may be capped below this level. In such circumstances, part of the benefit to airport operators could instead accrue to passengers and/or airlines.

[84] This is shown for the higher capacity (R2) case only, for simplicity. The duty rate is shown as being below MEC for illustrative purposes only.

[85] It was noted above that the effects of airport charge regulation on the distribution of benefits between passengers (via airlines) and airports is not shown here. The actual calculations performed (see para. H.15) capture the (reducing) effect of this regulation on operator benefit, but not the (increasing) impact on passenger benefits. Hence the monetised benefits are underestimated to some degree in the central case.

H.12 Figure H1 shows that APD causes the marginal private benefit of travel (equal to the demand curve, D_{pax}) to exceed the marginal private cost (S(R1)) at any level of passenger demand. Hence the increase in travel due to extra airport capacity generates a net (private) benefit, which takes the form of APD revenue on the extra passenger travel (area C)[86]. However, in Figure H1 there is also an increase in the external costs of aviation, shown by area D[87].

Figure H1: Airline supply and passenger demand, with external cost and internalising tax



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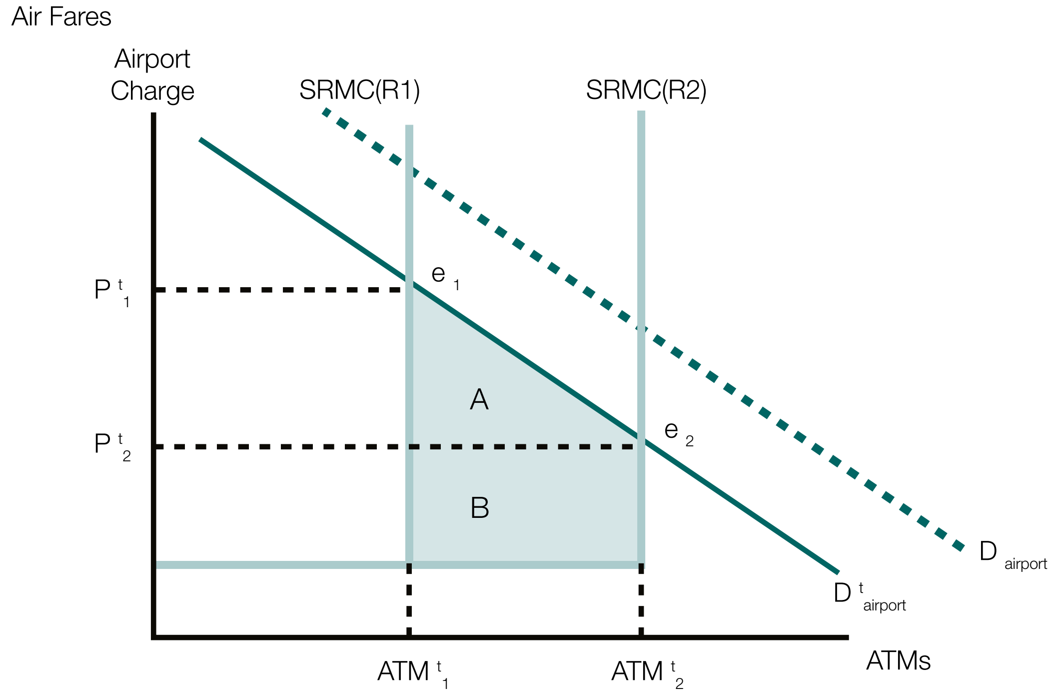
[86] If there were such a gap between marginal private cost and marginal private benefit other than due to a tax, this benefit would still arise, but would accrue to passengers; hence the APD benefit may be seen as capturing passenger benefits.

[87] It would be equivalent to calculate the value of the extra uninternalised external costs (C-D); and, if APD exactly internalised the external costs, C-D=0 and there would be no need to measure either, other than for reporting the distribution of benefits.

Figure H2: Airport supply and airline demand, with impact of internalising tax



H.13 In our appraisal methodology we measure these benefits in the following categories:

- Generated user benefits: A
- Producer benefits: B
- APD revenue: C
- Carbon costs: -D

H.14 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).

H.15 The exact formulae used are as follows:

Generated Users Benefit

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

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

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

Producer Benefit

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

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

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

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

External cost disbenefits

H.16 Aviation contributes to climate change through emissions of carbon dioxide, and the warming effects of non-carbon emissions released at altitude. The increase in UK aviation's carbon dioxide emissions under each airport development scenario has been assessed using the CO_2 forecasting model outlined in Chapter 3.

H.17 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[88]. The resulting uplifted carbon dioxide emissions have then been valued using the new DECC guidance on the shadow price of carbon dioxide (see Chapter 3). The formula used is:

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

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 dioxide, in year t

H.18 Emissions of CO_2 from surface access journeys to and from UK airports are not part of the UK aviation CO_2 emissions inventory, and are therefore not covered by the forecasts reported in Chapter 3. However, for the purposes of estimating the net benefits of additional airport capacity, the impact of airport development on these emissions has been estimated and monetised using the shadow price of carbon dioxide. Annex I explains the method and reports the impacts of the ATWP-supported developments on surface access CO_2 emissions.

H.19 For the Heathrow additional capacity scenarios, independent data is available on noise and air quality impacts, making it possible to monetise these effects. The exact process is set out later in this annex.

Existing Users Benefit

H.20 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

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[88] *Aviation Emissions Cost Assessment 2008*, Department for Transport, 2008, available at: http://www.dft.gov.uk/pgr/aviation/environmentalissues/aviationemissionscostassess/aviationemissionscost.pdf

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.

H.21 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}

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

Generated Freight Users Benefit

H.22 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

H.23 Airport delays impose costs on society through increased costs for airlines, passengers and the wider community. Airlines bear additional costs on the fleet as well as flying and ground personnel, users of airports suffer through delays, as measured by their value of time. Delays also impose costs on the wider community through environmental costs from increased emissions and noise, for example.

H.24 At Heathrow, average delay has increased from 10.3 to 19.6 minutes between 1995 and 2007 and the percentage of flights suffering serious delays of more than 30 minutes rose from 15.2% in 2002, to 18.4% in 2006[89].

H.25 The White Paper 2003 and Progress Report 2006 stressed the importance of making better use of the current runways and suggested that this could 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 a reduction in delay and hence bring some economic benefits.

H.26 The appraisal methodology has quantified the benefit of reducing delay through mixed mode operations at Heathrow. This assessment has relied on the following set of assumptions.

- NATS modelling has been used to provide estimates for the delay reductions from mixed mode with additional capacity in 2015 (540,000 ATMs). The results show that average delay could be reduced by 3 minutes. Currently, no formal analysis has been performed 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 largest benefits are reduced travel time for passengers and lower operating costs for airlines. Information for airline delay costs per minute was obtained from a study conducted by the University of Westminster (2004)[90] on behalf of EUROCONTROL[91]. Business passenger value of time is airport specific and obtained from the CAA International Passenger Survey (2006).

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[89] CAA Airport Statistics (2006).

[90] University of Westminster, “Evaluating the true cost to airlines of one minute airbourne or ground delay”, Performance Review Commission, Eurocontrol (2004).

[91] European Organisation for the Safety of Air Navigation, “Standard Inputs for EUROCONTROL Cost Benefit Analyses” (2005).

- There are also some small environmental benefits from reduced flight times leading to reductions in carbon dioxide emissions. The calculation of environmental benefits has relied on assumptions on fuel burn from CORINAIR data for the fleet mix assumed in the DfT's Air Passenger Model, and emissions valued at DECC's shadow price of carbon.

H.27 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). Hence the current estimates are likely to understate the overall benefits from reduced delays.

Air noise disbenefits

H.28 Pending specific Government recommended values for aircraft noise, the appraisal methodology uses standard DfT TAG methodology[92] for road and rail noise quantification as far as possible.

H.29 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 (480,000 ATMs), 2015 mixed with additional capacity (540,000 ATMs) and 2030 for Heathrow third runway (702,000 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 (480,000 ATMs in segregated mode) and third runway scenario (702,000 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 702,000 ATMs.
- The ERCD noise modelling can only measure noise with a sufficient degree of confidence to the 54dBA level, whereas TAG specifies valuation to the 45dBA noise contour level. The Department has used the more accurate 54dBA level in its appraisal, but presented the less accurate 45dBA level as a sensitivity, for transparency.

H.30 Similar assumptions are made for quantifying the impact of mixed mode options. In particular, we have relied on the 2015 noise modelling positions to quantify the impacts on noise changes before 2020.

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[92] TAG unit 3.2.2, available at: http://www.webtag.org.uk/webdocuments/3_Expert/3_Environment_Objective/3.3.2.htm

Air Quality disbenefits

H.31 The air quality disbenefits of additional capacity have been monetised in the course of appraising proposals for a third runway at Heathrow. These disbenefits would occur both from additional ATMs and from additional surface access emissions from passengers getting to and from the airport.

H.32 CERC[93] ADMS modelling is used to estimate expected air quality resulting from different proposals, using an impact pathway approach as used by the IGCB[94] to inform the review of the Air Quality Strategy (IGCB, 2007).

H.33 Using the damage cost guidance values from the AQS 2007[95], the impacts of both NO_x and PM_{10} particulates on chronic morbidity and acute mortality and building soiling are assessed. The value of impacts are presented on a PV basis for consistency with the appraisal.

Non-monetised benefits

H.34 The following are currently not taken into account when valuing the benefits of airport development:

- delay reduction benefits, other than at Heathrow for mixed mode scenarios;
- benefits to international-to-international interliner passengers;
- wider economic benefits, as identified in the Eddington Report, through raising productivity and improving competitiveness; and
- local environmental impacts (e.g. noise and local air pollution other than at Heathrow, landscape and biodiversity impacts).

H.35 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.

H.36 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)[96] paper. The Eddington study also noted the potential contribution of

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[93] Cambridge Environmental Research Consultants.

[94] Interdepartmental Group on Costs and Benefits (IGCB), a group of government economists and other experts that provides economic analysis and advice relating to the development and achievement of the Air Quality Strategy – 2007.

[95] http://www.defra.gov.uk/environment/airquality/panels/igcb/guidance/index.htm

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

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.

H.37 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.

H.38 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.

H.39 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% 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[97] 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.

H.40 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

H.41 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.

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[97] 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 (Central Surface Access)
s05	Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	£7.8
s07	Stansted second runway (480,000 in 2015)	s02	Maximum Use	£4.8
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£7.8
s12s2mm1	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 in 2010-2019) then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£8.0
s12s2mm2	Stansted second runway (480,000 in 2015), Heathrow mixed mode (480,000 2010-2015 & 540,000 2015-2020), then third runway (605,000 in 2020, rising to 702,000 in 2030)	s07	Stansted R2 2015	£8.1
s12s2	Stansted second runway (480,000 in 2015), Heathrow third runway (605,000 in 2020, rising to 702,000 in 2030)	s02	Maximum Use	£12.6
s12s2_ 2015	Stansted second runway (480,000 in 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020 and rising to 702,000 in 2030)	s07	Stansted R2 2015	£8.5
s12s2_ 2025	Stansted second runway (480,000 in 2015), Heathrow third runway opens 605,000 2025, rising to 702,000 in 2030)	s07	Stansted R2 2015	£6.6
12s2_ 605/122	Stansted second runway (480,000 in 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 122mppa final terminal capacity	s07	Stansted R2 2015	£8.3
12s2_ 605/129	Stansted second runway (480,000 in 2015), Heathrow third runway 487,000 in 2015, rising to 605,000 in 2020, 605,000 thereafter, 129mppa final terminal capacity	s07	Stansted R2 2015	£8.4

Non-monetised costs

H.42 The following costs from additional capacity are currently not monetised:

- additional local air quality emissions (other than at Heathrow);
- land use impacts in the form of lost greenfield and agricultural land;
- impacts on heritage and any community severence effects; and
- biodiversity and water related impacts.

Annex I: Surface Access CO_2 Emissions

Introduction

I.1 Air travel inevitably involves passengers making trips to and from airports by surface modes to begin or complete their journeys, and these trips generate CO_2 emissions. Estimates of the impact of additional airport capacity on these surface access CO_2 emissions were previously reported in Annex E of *The Future Development of Air Transport in the United Kingdom: South East* (February 2003), and Annex D of *Aviation and the Environment – Using Economic Instruments* (March 2003).

I.2 Surface access journeys by passengers to and from UK airports are not included in the UK aviation bunker CO_2 inventory because they are recorded elsewhere in the UK transport inventory. However, we have updated the estimates of the CO_2 emissions from all road, rail and bus/coach journeys made by passengers to and from UK airports, and included these in the monetised net benefits of airport capacity changes (see Chapter 4, and Annex H).

I.3 This annex sets out our method for estimating surface access CO_2 emissions, and reports the results.

Method

I.4 To forecast surface access CO_2 emissions for journeys to and from each airport, we take each year's forecast of demand to travel between each modelled airport and each UK zone, by mode, resulting from the demand forecasting process[98], and apply CO_2 emission rates by mode. This takes account of the forecast changes in the level of demand to use each airport, the average journey length, and (where appropriate) changes in the fuel efficiency of these journeys. The split of journeys by mode (road, rail or bus/coach) is that reported in the most recent CAA passenger interview survey[99] for each airport and each zone.

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[98] See Chapter 2 for the demand forecasting process, Annex C for full list of airports, Figure 2.6 for the UK zones, and Figure 2.7 for the surface access network

[99] CAA Passenger Survey Report 2007, www.caa.co.uk

I.5 The rate of emissions for car and taxi journeys is calculated taking account of the vehicle occupancies, splits of parking and drop-off and taxi trips observed in the annual CAA passenger interview survey. The emissions rate per vehicle is based on the DfT Webtag standard average car CO_2 emissions for each modelled year, which depends on vehicle speeds[100].

I.6 The airport passenger allocation model described in section 2.2 forecasts how passengers will choose between the different airports available to them, using a representation of the surface access network linking passengers' origins/destinations with airports. To find the base year emissions rate (166gCO_2/km), the passenger-weighted modelled speed of road trips to each mainland UK airport was calculated from the travel times in this surface access network model.

I.7 Car fuel efficiencies are assumed to grow in line with the latest DfT projections of fleet fuel efficiency. Rail and bus/coach CO_2 emissions are calculated on a passenger-km basis and are much smaller components of the total surface access inventory. The rail and bus/coach emissions rates are taken from DECC company reporting guidelines and are not assumed to change over time[101] [102]. Table I1 shows the surface access emissions rates used in the detailed modelling up to 2030.

Table I1 Airport surface access CO_2 emission rates

	Road g/vehicle-km	Rail g/passenger-km	Bus/Coach g/passenger-km
2005	166	60	29
2010	160	60	29
2015	147	60	29
2020	135	60	29
2025	129	60	29
2030	128	60	29

Results

I.8 Table I2 shows the modelled surface access emissions for journeys to all airports, assuming the ATWP-supported airport capacity developments, by surface mode. In 2005, road-based journeys contribute 91% of airport access emissions. This drops marginally to 89% by 2030, principally due to efficiencies in the vehicle fleet. The forecasts do not make allowance for policies successfully achieving higher public transport mode shares for airport access journeys.

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[100] Webtag Unit 3.5.6: Values of Time and Operating Costs.

[101] *Guidelines to Defra's GHG conversion factors for company reporting*, Annexes updated April 2008, Annex 6 Table 10. Rail emissions rates are based on national rail and take account of grid electricity generation. The bus/coach rate is based on National Express reporting.

[102] In estimating the net benefits of airport development beyond 2030, no further surface access CO_2 efficiency growth is assumed, and emissions are assumed to grow in line with the increase in passengers requiring surface access.

Table I2: Airport surface access CO_2 emissions, $MtCO_2$, s12s2

	Road	Rail	Bus/coach	Total
2005	2.1	0.2	0.0	2.3
2010	2.4	0.2	0.1	2.6
2015	2.7	0.2	0.1	3.0
2020	2.8	0.3	0.1	3.1
2025	3.0	0.3	0.1	3.4
2030	3.3	0.3	0.1	3.7

I.9 Table I3 and Table I4 show the total surface access CO_2 emissions for the Stansted second runway only option and the 'maximum use' base case calculated on a similar basis to the above table. The difference between the capacity options and the base case is relatively small and is shown in Table I5. The maximum modelled increase in surface CO_2 is $0.055MtCO_2$ in 2030 for the s12s2 scenario.

Table I3: Airport surface access CO_2 emissions, $MtCO_2$, s07

	Road	Rail	Bus/coach	Total
2005	2.1	0.2	0.0	2.3
2010	2.4	0.2	0.1	2.6
2015	2.7	0.2	0.1	3.0
2020	2.8	0.3	0.1	3.1
2025	2.9	0.3	0.1	3.3
2030	3.2	0.3	0.1	3.7

Table I4: Airport surface access CO_2 emissions, $MtCO_2$, s02

	Road	Rail	Bus/coach	Total
2005	2.1	0.2	0.0	2.3
2010	2.4	0.2	0.1	2.6
2015	2.7	0.2	0.1	3.0
2020	2.8	0.3	0.1	3.1
2025	2.9	0.3	0.1	3.3
2030	3.2	0.3	0.1	3.6

Table I5: Airport surface access CO_2 emissions, $MtCO_2$, difference from s02

	Total $MtCO_2$	**Total $MtCO_2$**
	Stansted second runway	**Stansted second runway and Heathrow third runway**
	s07	**s12s2**
2005	0.000	0.000
2010	0.000	0.000
2015	0.004	0.006
2020	0.027	0.022
2025	0.019	0.046
2030	0.038	0.055

I.10 The effect of the airport developments on surface access CO_2 emissions is relatively small because additional airport capacity has two offsetting effects: (i) an increase in the number of passengers travelling to/from airports; and (ii) reduced surface journey distance due to more passengers being able to fly from their preferred (often nearer) airport.

Annex J: The Estimated Value of UK Aviation's Climate Change Impact

Introduction

J.1 The 2004 report supporting the Air Transport White Paper, *Aviation and Global Warming*, presented the estimated value of UK aviation's climate change impact, using:

- DECC actual aviation CO_2 emissions in 2000 and DfT forecast aviation CO_2 emissions in 2030;
- DECC 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 illustratively account for the climate change effects of non-carbon emissions at altitude).

J.2 It found that, using a radiative forcing factor of 2.5 to account for the non-CO_2 impact of aviation (based on evidence at the time), the value (in 2000 prices) of emissions in 2000 was estimated at £1.4bn, rising to £4.8bn for emissions in 2030.

J.3 These estimates can now be updated using the latest CO_2 forecasts reported in this document, the current DECC guidance on the shadow price of carbon dioxide emissions, and the latest scientific evidence on the radiative forcing factor.

Method and Results

Method

J.4 Figure J1 below illustrates the method that can be used to estimate the value of UK aviation's climate change impact. In a given year, emissions would be split between 'ground' and 'in air' emissions. 'In air' emissions are uprated by the radiative forcing factor[103], added to 'ground' emissions, and multiplied by the shadow price of carbon dioxide appropriate to the year in question.

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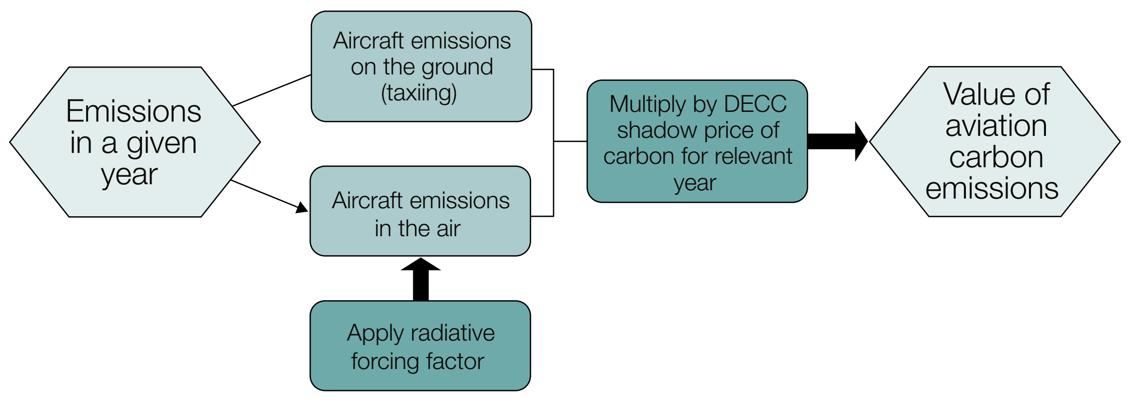
[103] This is because the factor is intended to capture the impact of emissions at altitude.

Figure J1: Estimating the value of aviation's climate change impact



Carbon dioxide forecasts

J.5 Chapter 3 explained that the official UK inventory of carbon dioxide emissions includes only domestic, not international, aviation CO_2 emissions[104]. 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[105], DECC 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 58.4MtCO$_2$.

Radiative forcing factor

J.6 In our analysis, a 'radiative forcing factor' is used to inflate CO_2 emissions from aircraft in the air to illustratively 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

J.7 DECC's current guidance on the value of carbon dioxide emissions (published in 2007[106]) suggested the appropriate way to value those 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 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.

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[104] This is actual CO_2 so does not include a radiative forcing index to account for the non-CO_2 effects of aviation.

[105] Currently recorded as a memo item in the DECC statistics.

[106] 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).

J.8 DECC'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[107]. 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 dioxide in future years, we also present a sensitivity range of the shadow price of carbon dioxide 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, DECC shadow price (2006 prices)

	2005	2030
- Central	23.80	39.10
- High (central + 20%)	28.60	47.00
- Low (central - 10%)	21.40	35.20

Results

J.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 £1.6bn in 2005, and is expected to rise to £4.1bn in 2030 (in 2006 prices[108]).

J.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	1.6	4.1
	4	3.3	8.0
SPC	Central +20%	2.0	5.2
	Central	1.6	4.1
	Central -10%	1.5	3.9

* Figures may differ slightly from those published in *UK Air Passenger Demand and CO_2 Forecasts 2007* due to an improvement to the approach used for accounting for radiative forcing effects.

J.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 to the year 2008, again in 2006 prices). Table J3 presents the discounted costs of carbon.

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[107] This is equivalent to £70 per tonne of carbon in 2000 at 2000 prices.

[108] Figures are presented in 2006 values to be consistent with our other modelling results.

Table J3: The value of aviation’s climate change impacts (2006 prices), discounted

		2005 (£bn)	**2030 (£bn)**
Radiative forcing factor	1	0.9	1.1
	1.9 – central	1.6	1.9
	4	3.3	3.8
SPC	Central +20%	2.0	2.4
	Central	1.6	1.9
	Central -10%	1.5	1.8

J.12 Table J3 presents the central case estimated costs of carbon dioxide emissions to be £1.6bn in 2005 rising to £1.9bn when discounted to 2008. The central estimates are very similar to those in *UK Air Passenger Demand and* CO_2 *Forecasts*, 2007.

Annex K: Aviation's Estimated Share of UK Climate Change Emissions

Introduction

K.1 The Environmental Audit Committee (EAC) 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. They were updated in November 2007. The forecasts and projections of aviation CO_2 emissions in Chapter 3 have been used to update this analysis.

Method and Results

K.2 The position has been updated since November 2007 in a number of respects.

i) The Climate Change Act 2008 has received Royal assent, setting a target to reduce UK domestic greenhouse gas emissions by 80% below 1990 levels by 2050.

ii) An agreement has been reached in Europe such that aviation will be included in the EU Emissions Trading Scheme (ETS) from 2012, which covers carbon dioxide emissions. Under the Emissions Trading Scheme, aviation emissions of carbon dioxide are capped. In 2012 this cap will be 97% of average annual CO_2 emissions for the 2004-06 period, tightening to 95% of those emissions from 2013. Under the ETS, aviation emissions would not be able to grow above the cap except by securing emissions allowances from other sectors. Therefore, this ensures that abatement takes place in other sectors equivalent to aviation's CO_2 emissions above the cap.

iii) The Committee on Climate Change recommended on 1 December 2008 that the scope of the targets and budgets in the Climate Change Act should not be extended to include international aviation and shipping. However, like the Government, the Committee on Climate Change also believes that international aviation and shipping emissions should be included in the UK's climate change strategy. This could mean that in due course these emissions are included in some separate framework, or it could mean they are included within the UK's domestic framework – these matters are the subject of ongoing international discussions.

K.3 The 2007 edition of this report presented an estimate of aviation's share of emissions in the future. These recent policy developments mean that this is now not so straightforward. Each of the policy developments above would be expected to influence both the level of UK emissions and how they should be accounted for in UK climate change strategy. It would therefore be misleading to give a single figure for aviation's estimated share of CO_2 emissions, given the range of potential policy outcomes. Moreover it will be important to draw a distinction between aviation's "allowed" emissions – i.e. the amount of emissions permitted within the ETS cap – and aviation's "total" emissions – which include emissions for which allowances are purchased from other sectors across the EU to ensure other sectors (for whom abatement is cheaper) abate the equivalent amount.

K.4 In the tables below, we have therefore presented aviation's estimated share of emissions in a range which reflects different possible policy outcomes whilst attempting to follow as far as possible the original format used in the EAC's report. The options reflected should not be taken to be the Government's preferred policy outcomes; they are merely indicative of the range that is currently possible, avoiding the use of too many assumptions about future international treatment of international aviation emissions. This range recognises the equal validity of using both "allowed" and "total" emissions as described above. It should also be noted that the forecast of aviation emissions in scenarios i) and ii) below is as presented in Chapter 3 (but the treatment of aviation emissions vis-a-vis the UK emissions target differs).

K.5 As Chapter 3 explained, although fuel efficiency improvements are assumed, the aviation emissions forecast is cautious because no major technological changes are assumed and in that sense, abatement from the aviation sector is relatively limited. This is not the implicit assumption for other UK sectors in the following tables because there, the achievement of the UK's 80% reduction target by 2050 is treated as a given and therefore action is taken in UK sectors to meet the 2050 target.

K.6 The policy outcomes subsumed within the range are:

i) Scenario 1: **international aviation is additional to UK domestic obligations**. The UK adopts a target to reduce domestic emissions by 80% below 1990 levels by 2050, which is achieved predominantly through the rest of the economy with no further abatement in aviation other than is already included in the forecasts (e.g. through fuel efficiency improvements, improved air traffic management etc);

ii) Scenario 2: **international aviation is within the UK domestic target**. Here, the UK target of an 80% reduction relative to 1990 levels is adopted but international aviation is included such that international aviation and other sectors combined meet the UK target (i.e. a greater level of effort is implicitly made in the rest of the economy while allowing aviation emissions to grow as forecast in Chapter 3); and,

iii) Scenario 3: **aviation CO_2 emissions are capped under the EU Emissions Trading Scheme**. Here, considering CO_2 emissions only, aviation is included in the EU ETS and therefore allowed emissions from aviation do not exceed the cap. Emissions above the cap are matched by an equivalent reduction in other sectors of the EU ETS through the purchase of allowances. Aviation's share of emissions is therefore estimated on the basis that its CO_2 emissions are at the level of the cap[109].

K.7 The range for total CO_2 and GHG emissions therefore reflects the fact that the precise way in which international aviation might relate to the UK's 2050 target has not yet been determined. For example, in the event of a sector-level agreement – i.e. emissions allocated to airlines and other operators as in the EU ETS, rather than to states – such emissions could remain additional to UK domestic obligations, or in the event of agreement to allocate emissions to individual states, they could be incorporated directly in the UK target. In the latter case the precise nature of the UK target would need to be considered.

K.8 In addition, the methodology to be used in allocating international aviation emissions to individual states is a further uncertainty. For the purposes of this analysis, it is assumed that international aviation is estimated in line with bunker fuel sales, consistent with our current UNFCCC reporting requirements.

K.9 In referring to the tables below, it is important to understand the range of policy assumptions which lies behind the range of figures.

K.10 A further complication should also be noted. The Climate Change Act commits the Government to an 80% reduction target for the UK covering six different greenhouse gases (this so-called "Kyoto basket" includes carbon dioxide CO_2, nitrous oxide N_2O, methane CH_4, sulphur hexafluoride SF_6, perfluorocarbons PFCs, hydrofluorocarbons HFCs). The three scenarios are therefore shown based on both an 80% reduction of CO_2 only and of all six greenhouse gases.

K.11 Yet further complication arises when accounting for the fact that aviation's climate change effects also go beyond CO_2[110] and indeed the basket of six greenhouse gases referred to above. The non-CO_2 effects of aviation – arising from NO_X emissions, contrails and potential generation of cirrus, for example – are not greenhouse gases for the purpose of the UK target; they are not part of the Kyoto basket. But, it is important that we record these aviation effects to provide a complete picture, while recognising the extent of scientific uncertainty over their precise effects as described in Chapter 3.[111]

K.12 Aviation's non-CO_2 climate change effects are accounted for using an illustrative radiative forcing factor. The nature of this factor and context within which it has been used are described in detail in Chapter 3. Results using this factor should therefore be interpreted appropriately. It should be noted that the UK greenhouse gas targets will not apply to the non-CO_2 effects of aviation. Therefore, these have been counted as part of UK total climate change emissions in Table K2, but not as part of the targets.

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[109] For illustration, it is here artificially assumed that UK's aviation emissions are capped whereas actually, the cap is at the EU, and not national, level. In addition, for this representation, only departing flights have been considered but the EU ETS scheme will cover both arriving and departing flights. The results should therefore be considered illustrative.

[110] The emissions of non-CO_2 Kyoto Greenhouse Gases from aviation are insignificant, constituting only 1.07% of total emissions from domestic and international aviation in 2005.

[111] The non-CO_2 climate change effects from other sectors has not been accounted for in this annex.

K.13 The relationship between total aviation emissions (i.e. both CO_2 and non-CO_2 effects) and total UK emissions has to be calculated on a different basis from that in Table K1 (and K1a-f), as it would not be practicable nor consistent with the Climate Change Act to incorporate aviation's non-CO_2 effects directly within the UK target. Tables K2, and K2a-c, have therefore also been displayed.

K.14 Tables K1 and K2 show that with no radiative forcing factor, UK aviation emissions are projected to rise from 6.3% of the UK total CO_2 emissions in 2005[112] to between a range of 24% to 49% in 2050. Considering all greenhouse gases to which the UK target applies (but without taking account of the non-CO_2 effects from aviation) suggests aviation's share in 2005 was 5.4% and in 2050 is estimated to be in the range of 19% to 38%. When aviation's non-CO_2 effects are also included in the calculation, the share of emissions accounted for by aviation in 2050 rises to a figure in the estimated range of 37% to around 54%.

K.15 Tables K1 and K2 summarise the results and their dependency on policy outcomes. Tables K1a to K1f set out the underlying information for K1; Tables K2a-c underpin Table K2 and include the radiative forcing factor for aviation.

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[112] This figure differs from that quoted in Chapter 3 for aviation's share because in this annex, we have explicitly not accounted for international shipping in the UK total.

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

Year	Summary of illustrated policy outcome scenarios			
	Aviation (domestic and international) actual & central forecast	Total UK CO_2 emissions including international aviation $MtCO_2$	Total UK greenhouse gas emissions including international aviation CO_2 $MtCO_2e$	Aviation's share of emissions from all scenarios
1990	16.9	608.2 to 608.2	786.6 to 786.6	2.2% to 2.8%
2005	37.5	590.3 to 590.3	690.5 to 690.5	5.4% to 6.3%
2020	50.3	450.0 to 485.5	582.1 to 617.5	5.9% to 11.2%
2050	59.9	121.6 to 173.6	157.3 to 209.3	19.0% to 49.2%

Table K2: Aviation's share of climate change emissions (including a radiative forcing factor on aviation's CO_2 emissions)

Year	Summary of illustrated policy outcome scenarios $MtCO_2e$, with radiative forcing	
	Total UK climate change emissions with aviation included	Aviation's share of UK climate change emissions
1990	801.8 to 801.8	4.0% to 4.0%
2005	724.3 to 724.3	9.8% to 9.8%
2020	627.4 to 662.9	12.5% to 15.2%
2050	211.2 to 263.1	37.1% to 53.9%

Table K1a: Scenario 1: International aviation is additional to UK obligations

Year	UK aviation and total emissions, $MtCO_2$			
	Aviation (domestic and international) actual* & central forecast	UK CO_2 emissions actual* and target (domestic only)	UK CO_2 emissions plus UK international aviation CO_2	Aviation as % of combined total
1990	16.9	592.4	608.2	2.8%
2005	37.5	555.2	590.3	6.3%
2020**	50.3	438.4	485.5	10.4%
2050***	59.9	118.5	173.6	34.5%

* UK CO_2 emissions as reported to the UNFCCC in the UK inventory

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.16 In this scenario the UK meets its target to reduce domestic CO_2 emissions by 80% below 1990 levels by 2050. International aviation CO_2 emissions are not included in that target but are shown as a proportion of a combined total i.e. the rest of UK domestic emissions are reduced by 80% relative to 1990 levels but international aviation emissions (as estimated in Chapter 3) continue to grow as forecast and are added to produce a combined total. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K1b: Scenario 1: International aviation is additional to UK obligations, all GHGs

Year		UK aviation and total GHG emissions, $MtCO_2e$		
	Aviation (domestic and international) actual* & central forecast	**UK all GHGs actual* and target (domestic emissions only)**	**UK total GHG emissions including international aviation CO_2**	**Aviation as % of combined total**
1990	16.9	770.8	786.6	2.2%
2005	37.5	655.5	690.5	5.4%
2020**	50.3	570.4	617.5	8.2%
2050***	59.9	154.2	209.3	28.6%

* UK GHG emissions as reported by DECC

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.17 Similar to K1a above, in this scenario the UK meets its 80% domestic greenhouse gas reduction target in 2050. International aviation emissions are not included in that target but are shown as a proportion of a combined total. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K1c: Scenario 2: International aviation included in the UK domestic targets

Year	UK aviation and total emissions, $MtCO_2$		
	Aviation (domestic and international) actual* & central forecast	**UK CO_2 emissions actual* and target including domestic and international aviation**	**Aviation as % of total**
1990	16.9	608.2	2.8%
2005	37.5	590.3	6.3%
2020**	50.3	450.0	11.2%
2050***	59.9	121.6	49.2%

* UK CO_2 emissions as reported to the UNFCCC in the UK inventory

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.18 In this scenario the UK meets its 80% domestic CO_2 reduction target in 2050. International aviation CO_2 emissions are subject to the same target and are therefore shown as a proportion of a total based on a combined reduction target of 80% in 2050. The combined total UK emissions including international aviation emissions are 80% lower in 2050 than in 1990. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K1d: Scenario 2: International aviation included in the UK domestic targets – all GHGs

Year	UK aviation and total GHG emissions, $MtCO_2e$		
	Aviation (domestic and international) actual* & central forecast	**UK GHG emissions actual* and target including domestic and international aviation**	**Aviation as % of combined total**
1990	16.9	786.6	2.2%
2005	37.5	690.5	5.4%
2020**	50.3	582.1	8.6%
2050***	59.9	157.3	38.1%

* UK GHG emissions as reported by DECC

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.19 Similar to K1c, in this scenario the UK meets its 80% domestic greenhouse gas reduction target in 2050. International aviation emissions are subject to the same target and are therefore shown as a proportion of a total based on a combined reduction target of 80% in 2050 i.e. domestic UK emissions including international aviation are, combined, 80% lower in 2050 than their 1990 levels. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K1e: Scenario 3: International aviation emissions capped in line with the EU ETS

Year	UK aviation and total emissions, $MtCO_2$			
	Aviation (domestic + international) actual* & future cap	UK CO_2 emissions actual and target (domestic only)	UK CO_2 emissions actual and target including capped domestic and international aviation	Aviation as % of combined total
1990	16.9	592.4	608.2	2.8%
2005	37.5	555.2	590.3	6.3%
2020**	35.6	438.4	471.7	7.5%
2050***	35.6	118.5	151.8	23.5%

* UK CO_2 emissions as reported to the UNFCCC in the UK inventory

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.20 In this scenario the UK meets its 80% domestic CO_2 reduction target in 2050. UK aviation CO_2 emissions are shown as capped under the EU Emissions Trading Scheme. The "capped" level of aviation emissions represents the aviation proportion of combined emissions. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K1f: Scenario 3: International aviation emissions capped in line with the EU ETS – all GHGs

Year	UK aviation and total GHG emissions, $MtCO_2e$			
	Aviation (domestic + international) actual* & future cap	**UK GHG emissions actual and target (domestic only)**	**UK GHG emissions actual and target including capped domestic and international aviation**	**Aviation as % of combined total**
1990	16.9	770.8	786.6	2.2%
2005	37.5	655.5	690.5	5.4%
2020**	35.6	570.4	603.7	5.9%
2050***	35.6	154.2	187.5	19.0%

* UK GHG emissions as reported by DECC

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.21 In this scenario the UK meets its 80% domestic greenhouse gas reduction target in 2050. International aviation CO_2 emissions are shown as capped under the EU Emissions Trading Scheme. The “capped” level of aviation emissions represents the aviation proportion of combined emissions. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K2a: Scenario 1: International aviation is additional to UK obligations using a radiative forcing factor on aviation emissions

Year	UK and aviation emissions, $MtCO_2e$			
	Aviation (domestic + international) actual* & central forecast – CO_2 emissions with radiative forcing factor applied $MtCO_2e$	**UK actual greenhouse gas emissions and target for the domestic economy $MtCO_2e$**	**UK target plus domestic and international aviation non-CO_2 emissions plus international aviation CO_2**	**Aviation as % of combined total**
1990	32.2	770.8	801.8	4.0%
2005	71.2	655.5	724.3	9.8%
2020**	95.6	570.4	662.9	14.4%
2050***	113.8	154.2	263.1	43.2%

* UK CO_2 emissions as reported by DECC

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.22 In this scenario the UK meets its 80% domestic greenhouse gas reduction target in 2050. A radiative forcing factor has been applied to aviation's CO_2 emissions. International aviation emissions, covering the range of climate change effects, are not included in that target but are shown as a proportion of a combined total which includes the UK target and aviation's non-CO_2 climate change emissions. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K2b: Scenario 2: International aviation included in the UK domestic targets using radiative forcing factor on aviation emissions

Year	UK aviation and total emissions, $MtCO_2$			
	Aviation (domestic + international) actual* & central forecast – CO_2 emissions with radiative forcing factor applied $MtCO_2e$	Total UK climate change emissions with aviation included – actual* and target $MtCO_2e$	UK target plus domestic and international non-CO_2 emissions and international aviation CO_2	Aviation as % of total
1990	32.2	786.6	801.8	4.0%
2005	71.2	690.5	724.3	9.8%
2020**	95.6	582.1	627.4	15.2%
2050***	113.8	157.3	211.2	53.9%

* UK CO_2 emissions as reported by DECC

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

K.23 In this scenario the UK meets its 80% domestic greenhouse gas reduction target in 2050. UK international aviation CO_2 emissions are subject to the same target and are therefore shown as a proportion of a total based on a combined reduction target of 80% in 2050. International aviation's non-CO_2 effects are also included but are additional to the UK target as they are not greenhouse gases within the classification of the UK target. Aviation is shown as a proportion of this total (UK target plus aviation's CO_2 and non-CO_2 climate change effects). This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Table K2c: Scenario 3: International aviation emissions capped in line with EU ETS using radiative forcing factor on aviation emissions

Year	UK aviation and total emissions, $MtCO_2e$				
	Aviation (domestic + international) actual* & central forecast with CO_2 cap and non-CO_2 included	Aviation actual* CO_2 emissions and future cap $MtCO_2e$****	UK target emissions $MtCO_2e$	UK target plus capped domestic and international aviation non-CO_2 emissions and international aviation CO_2	Aviation as % of total
1990	32.2	16.9	770.8	801.8	4.0%
2005	71.2	37.5	655.5	724.3	9.8%
2020**	80.9	35.6	570.4	649.0	12.5%
2050***	89.5	35.6	154.2	241.4	37.1%

* UK GHG emissions as reported by DECC

** Assumes a target for 2020 of 26% below 1990 levels

*** Assumes a target for 2050 of 80% below 1990 levels

**** The cap shown here is only illustrative for departing flights. The ETS will cover all departing and arriving flights and sets a cap at the EU level for the sector, not at at the national level.

K.24 In this scenario the UK meets its 80% domestic greenhouse gas reduction target in 2050. International aviation emissions are shown as capped under the EU Emissions Trading Scheme. The "capped" level of aviation emissions represents the aviation proportion of combined emissions which includes non-CO_2 emissions from aviation. This is one of a number of scenarios as set out in this report, and contributes to the range of possible outcomes. No one outcome is more likely than any other. Therefore undue weight should not be attributed to this table.

Annex L: UK International Aviation CO_2 Emissions and Budgets

L.1 Table L1 shows how these forecasts relate to the carbon budgets to be established under the Climate Change Act 2008. The table sets out the emissions of carbon dioxide which the Secretary of State expects the UK will report under obligations to the United Nations Framework Convention on Climate Change over the first three carbon budget periods. The figures therefore represent an estimate of the carbon dioxide emissions from UK sales of international aviation bunker fuels.

Table L1: International Aviation Emissions and Carbon Budgets – Carbon Dioxide Emissions $MtCO_2$

Budget Period 2008-2012	**2008**	**2009**	**2010**	**2011**	**2012**	**Aggregate for Budget Period 2008-12**
	36.1	36.7	38.4	39.8	40.8	191.8
Budget Period 2013-2017	**2013**	**2014**	**2015**	**2016**	**2017**	**Aggregate for Budget Period 2013-2017**
	41.7	42.4	43.3	44.1	44.5	216.2
Budget Period 2018-2022	**2018**	**2019**	**2020**	**2021**	**2022**	**Aggregate for Budget Period 2018-2022**
	45.4	46.1	47.1	47.8	48.0	234.4

Annex M: Glossary

ACARE	Advisory Council for Aeronautics Research in Europe
APD	Air Passenger Duty
ATM	Air Traffic Movement
ATWP	The Future of Air Transport White Paper (2003)
APU	Auxillary Power Unit
BCR	Benefit Cost Ratio
BERR	Department for Business, Energy and Regulatory Reform (formerly DTI)
CO_2	Carbon Dioxide
CAA	Civil Aviation Authority
CORINAIR	Part of the European Environment Agency (EEA) Corine programme (Co-ordination of information on the environment) tasked with creating an inventory of European air pollutant emissions – in effect a methodology and databank for calculating aviation emissions by aircraft type.
DECC	Department for Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of Environment Transport & Regions (predecessor of DfT in 2000 when a previous set of forecasts were produced.)
DfT	Department for Transport
EU ETS	European Union Emissions Trading Scheme
FMM	Fleet Mix Model
GDP	Gross Domestic Product (National Income)
HMT	Her Majesty's Treasury
IATA	International Air Transport Association (Airline trade body)
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change

IPS	International Passenger Survey (ONS)
LDC	Less Developed Countries
MDS-T	MDS Transmodal (Freight Consultants)
mppa	Million Passengers Per Annum
$MtCO_2$	Million Tonnes of Carbon Dioxide
NATS	National Air Traffic Services
NIC	Newly Industrialised Countries
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development (used in this report to refer to members outside the European Union)
OEF	Oxford Economic Forecasting
OLS	Ordinary Least Squares (a method of regression analysis in statistics)
ONS	Office of National Statistics
RASCO	Regional Air Services Co-ordination Study DfT (2002)
RF or RFI	Radiative Forcing Index - a factor applied to CO_2 to account for other climate change impacts of aviation emissions
SERAS	South East Region Air Services Study DfT (2002)
SPASM	Alternative, earlier name for DfT National Air Passenger Allocation Model
UNFCC	United Nations Framework Convention on Climate Change
WEO	World Economic Outlook (produced by the International Monetary Fund)