Airports Commission: Interim Report

# Appendix 3: Technical Appendix

December 2013

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# Contents

# Section 1:
# Introduction

**1.1** **Part A** of this appendix summarises the Commission's research into the costs of aviation capacity constraints to the economy. **Section 2** sets out the Commission's findings on the costs of aviation capacity constraints in four areas:

- provider and user impacts;
- delay impacts;
- direct economy impacts; and,
- wider economic impacts.

**1.2** **Part B** of this appendix sets out the Commission's aviation forecasts, which have been produced using an updated version of the Department for Transport's (DfT) aviation forecasting model. Technical advice and support, including undertaking model runs, has been provided by DfT modellers. This appendix sets out forecasts of passenger numbers, air transport movements (ATMs) and aviation carbon emissions at UK airports.

**1.3** Over the past year the Commission has built on the existing DfT aviation forecasting model, undertaking model developments and adopting new and alternative input assumptions. Uncertainty around many forecasting assumptions are tested and two overriding constraints on demand are considered – carbon constraints and capacity constraints – resulting in four core demand scenarios which are the focus of much of **Part B** of this appendix. These are:

- carbon traded and capacity unconstrained demand ($CO_2$ emissions are part of an ETS, but not limited to any target);
- carbon capped, capacity unconstrained (carbon limited to emissions level in 2005);
- carbon traded, capacity constrained; and,
- carbon capped and capacity constrained.

1.4 **Section 3** summarises the responses the Commission received to its discussion paper on aviation demand forecasting and discusses the model developments that have been made.

1.5 **Section 4** presents the changes to input assumptions that have been adopted since the last DfT forecasts were published in January 2013.

1.6 **Section 5** sets out how the forecasts deal with $CO_2$ emissions from aviation and **Section 6** sets out demand forecasts in the four core scenarios of:

- capacity constrained/carbon capped;
- capacity unconstrained/carbon capped;
- capacity constrained/carbon traded; and,
- capacity unconstrained/carbon traded.

1.7 **Section 7** considers a number of alternative scenarios.

## Summary of findings

### Part A: Economic analysis

1.8 The Commission's research into the effect of aviation capacity constraints on the economy found that:

- costs to providers and users of the UK airport system could be £18 billion to £20 billion in present value terms and including delay costs, between 2021 and 2080;
- there is good evidence to suggest that there are costs associated with lost trade, foreign direct investment (FDI) and tourism, and that these are likely to affect wider UK economic performance; and,
- these whole economy impacts of capacity constraints on GDP could cost £30 billion to £45 billion, in present value terms, between 2021 and 2080.

## Part B: Modelling and forecasts

**1.9** The Commission's forecasts show that:

- with unconstrained capacity the median forecast is for passenger numbers at the larger UK airports[1] to increase from 217 million passengers in 2011 to 297 million passengers by 2030 and 448 million by 2050 in a carbon traded scenario;[2]
- with capacity constraints and carbon traded, passenger numbers are forecast to increase to 299 million by 2030 and 400 million by 2050;
- in a scenario with unconstrained capacity and carbon capped (i.e. assuming UK departing flights carbon emissions in 2050 are limited to 2005 levels by increased carbon prices being incorporated in fares) passenger numbers are forecast to rise to 295 million by 2030 and 377 million by 2050;
- carbon capping leads to broadly similar demand between scenarios and with constrained capacity and carbon capped, passenger numbers at UK airports are forecast to increase to 295 million by 2030 and 389 million by 2050;
- the London airport system is forecast to be full by around 2041 in a carbon capped scenario. With carbon traded there is a range around the median forecast which shows the London airport system could be full as soon as 2030 or as late as 2049;
- Heathrow remains full across all the demand cases considered, while Gatwick fills up between 2014 and 2035 depending on the scenario;
- with a carbon cap excess demand in the London airport system is between 170,000 and 200,000 ATMs by 2050, equivalent to one net additional runway;
- all four scenarios see significant growth across most market segments, with the exception of UK and international transfer passengers, which are forecast to decline significantly by 2050 when capacity is constrained; and,
- a congestion charge on the busiest airports to re-distribute demand would have a negative effect on overall UK connectivity and capacity.

1 The 29 largest UK airports and four foreign hub airports are included in the model. These airports are listed in Table 3.1.
2 CAA statistics show a higher number of 219 million for 2011 as they include smaller airports and some miscellaneous movements not included in this modelling. 2011 is the modelling base year used in this analysis. The 2012 CAA figure for UK terminal passengers is 221 million

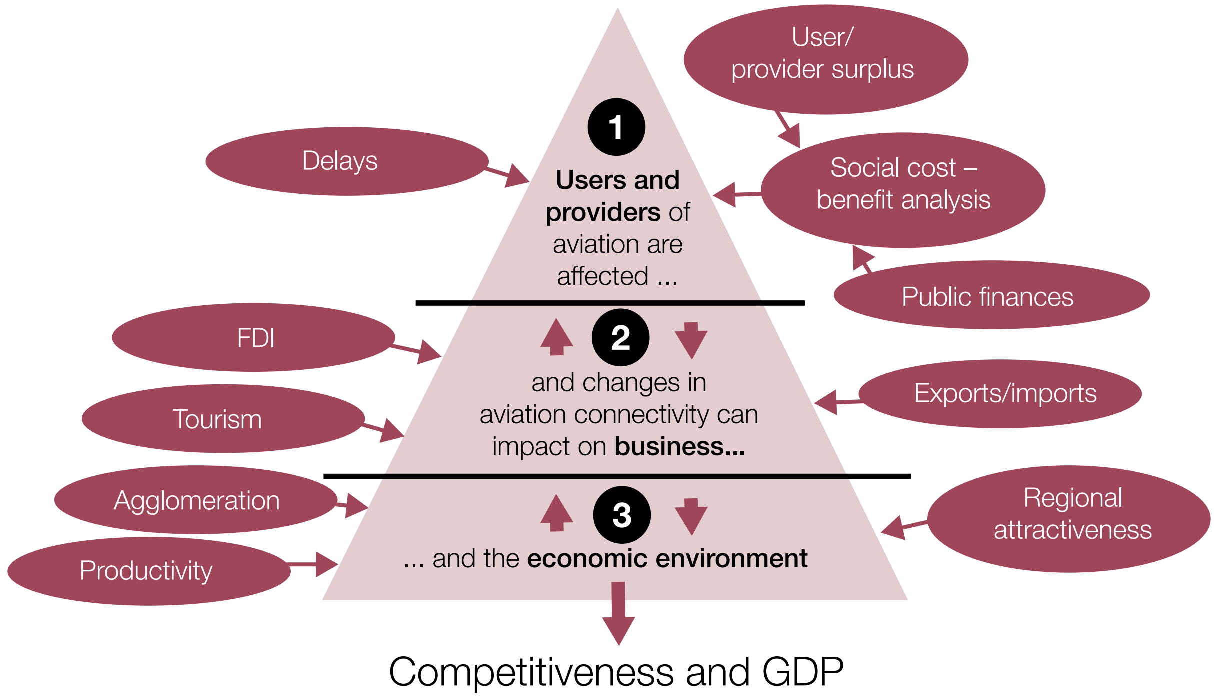
# Part A: Economic analysis

## Section 2:

## Summary of Commission's research into the economic costs of aviation capacity constraints

**2.1** The Commission has investigated the economic costs of constraining aviation capacity through a programme of research and analysis over the past nine months. The responses to the Commission's March 2013 discussion paper *Aviation Connectivity and the Economy* have informed the work to estimate these potential impacts, focusing on three levels.[3] As a change in airport capacity transmits through the economy the overall impact becomes harder to measure, as depicted in **Figure 2.1** below.

**Figure 2.1: How a change in airport capacity/aviation connectivity transmits through the economy**




3 Airports Commission, Aviation Connectivity and the Economy Discussion Paper, March 2013, https://www.gov.uk/government/publications/discussion-paper-on-aviation-connectivity-and-the-economy

**2.2** In order to better understand each impact in detail the Commission have undertaken a demanding work programme, outlined in **Table 2.1**.

**Table 2.1: Economy research work programme**

| | Impact | Description | Work commissioned from |
|---|---|---|---|
| **(1) Provider and user impacts** | a) Passengers, airports, airlines and Government | Provider and user impacts are assessed in the DfT model by applying an increase in the shadow cost to limit demand to capacity. In reality there will be a mixture of responses, causing some passengers to pay more, some to transfer to other airports and some not to fly. | DfT aviation model |
| | b) Delays | Once an airport reaches capacity delays can start to build. This causes both costs to the passenger (increased travel times and unreliability) and airlines (maintenance, fuel and staffing). | Leigh Fisher |
| **(2) Business** | Direct economy impacts | A reduction in aviation connectivity may impact upon the level of trade, FDI and tourism, which then transmits through the economy and affects the level of GDP. | PwC |
| **(3) Economic environment** | Wider economic impacts | Changes in trade, FDI and tourism can all have wider impacts, such as changes in productivity, as they transmit further through the economy. | SDG |

**2.3** Previous Government studies looking at the case for additional airport capacity have focused primarily on impacts on passengers, airports and airlines, those found under (1). The Commission recognises the importance of these impacts but is of the view is that it is important to also take a wider perspective which considers not only the immediate effects on airlines and passengers of capacity constraints, but also the broader economic effects on business (2) and the economic environment (3).

**2.4** In addition to the individual work streams mentioned above, 'top down' analysis of the possible impact on GDP has been undertaken using computable general equilibrium (CGE) models. Though the GDP impacts are broadly encompassed under impacts on business (2) and the economic environment (3), it is likely that impacts on passengers, airports and airlines will also be included to some degree within these figures, so these should not be considered completely additional to one another.

**2.5** The Commission's work to date is not intended to be used to undertake cost-benefit analysis of specific capacity options and outcomes should not be considered in this way. All the analysis undertaken is based on changes at an aggregate airport system level, considering the differences between a constrained and unconstrained airport system, and is not related to specific options. The costs of capacity constraints presented here are indicative of the likely benefit of releasing capacity, however, the size of the benefit will vary by scheme, and could be higher or lower than found by the Commission's early work.

**2.6** In addition, the UK aviation sector is largely privately owned and financed, so the financing of infrastructure investment will require a commercial case for any proportion privately financed and this is likely to involve a number of other factors which are not included in this preliminary analysis.

**2.7** The rest of this section summarises all the work undertaken in more detail; outlining the methods, results and caveats.

## Provider and user impacts

**2.8** An appraisal of the costs of congestion premia at UK airports has been undertaken following DfT guidance on the appraisal of aviation schemes published in WebTAG as far as it is possible at this preliminary stage.[4] As part of demand forecasting the National Air Passenger Allocation Model (NAPAM) applies a 'shadow cost' to passengers travelling from a constrained airport. This has the effect of restricting demand at an airport to its capacity. These shadow costs can be used to estimate the value of relieving a capacity constraint, and likewise indicate the cost of a capacity constraint.

**2.9** Comparing the shadow cost under capacity unconstrained and capacity constrained systems allows a comparison of the difference in prices that passengers would hypothetically have to pay under a constrained system. This has been quantified for both the carbon capped and carbon traded policy scenarios.

**2.10** This appraisal includes the latest WebTAG parameters and values of time, where relevant.[5] The approach to the extrapolation of passenger demand and shadow costs in the period after 2050 is under review; yet in this appraisal it is assumed that passenger demand continues to rise until each airport reaches capacity and that

4 TAG unit 3.18 *Aviation Appraisal* at http://www.dft.gov.uk/webtag/documents/expert/unit3.18c.php

5 There are no 'official' published UK air passenger VoTs. Resource leisure times for appraisal are WebTAG compliant, but behavioural leisure times for passenger airport choice remain based on the previous versions (in turn based on CAA research) and updated in line with WebTAG growth in VoT. Business VoTs, both resource and behavioural, are based on the latest data collected by the CAA in the latest passenger interview surveys

shadow costs are extrapolated in line with the trend growth at the end of the modelled period.

**2.11** The appraisal concentrates on the costs to passengers of incurring shadow costs and the benefits to airports and airlines who collect this 'rent'. The impacts on public finances are also quantified. Environmental costs (non carbon greenhouse gas emissions, noise, air quality, accidents and surface access carbon), which tend to be scheme specific, have been omitted from the analysis.

**2.12** All the results are quoted with a 2012 present value year and price base for a 2021 to 2080 appraisal period.

**Table 2.2: Preliminary quantification of costs of capacity constraints**

| £billion, 2012 present values | Carbon capped | Carbon traded |
|---|---|---|
| User (passengers) | -58.4 | -72.4 |
| Provider (airports and airlines) | 51.2 | 58.7 |
| Public finances (Government) | -7.9 | -3.8 |
| Net cost | -15.1 | -17.6 |

**2.13** **Table 2.2** demonstrates that, consistent with the aviation WebTAG methodology, most of the cost arises in the transfer from users (air passengers) to providers (airlines). Costs to the public finances comprise Air Passenger Duty (APD) foregone, and indirect taxation receipts from goods consumed across the rest of the economy from UK leisure passengers.[6]

**2.14** The modelled shadow cost is lower in the Commission's latest forecasts than it would have been in the previous DfT model because of the introduction of foreign hubs. Therefore, as a sensitivity test a second appraisal has been undertaken to assess the costs without the foreign hub modelling, shown below in **Table 2.3.**

**Table 2.3: Preliminary quantification of costs of capacity constraints (no foreign hubs)**

| £billion, 2012 present values | Carbon capped | Carbon traded |
|---|---|---|
| User (passengers) | -67.1 | -120.9 |
| Provider (airports and airlines) | 55.4 | 101.1 |
| Public finances (Government) | -4.8 | -5.9 |
| Net cost | -16.6 | -25.8 |

6 The net Government revenue is higher in the carbon capped case than carbon traded because the increase in the share of short-haul passengers and lower APD receipts is more than offset by the indirect taxation received on alternative expenditure by leisure passengers who no longer travel

**2.15** There are a number of uncertainties associated with this preliminary appraisal which will be resolved in advance of appraising site specific options. Within the DfT appraisal framework, planned development work includes completing a review of the approach to the extrapolation of passenger demand and shadow costs beyond 2050, and extending the 2021 to 2080 appraisal period to allow for modelling a 60 year appraisal where the opening year is later than 2021.

**2.16** The appraisal framework is highly stylised and in practice the cost of the constraint would be experienced partly in less attractive travel options such as less convenient schedules, less competition between different airlines and more limited choice of destinations. These effects cannot be fully captured by this welfare analysis approach.

**2.17** In addition, this framework excludes some important factors which would be considered when appraising specific options. For example, environmental impacts such as noise and air quality have not been considered and impacts on the air freight industry and its customers have not been monetised. Surface access and other costs are also not assessed here.

**2.18** A particular difficulty is faced in estimating the benefits to UK plc. Aviation is an international industry; with airlines and airports in international ownership and passengers of foreign origin using the UK airport system. The analysis presented here concerns the market as a whole and does not split the impacts into UK and foreign effects.

**2.19** Finally, wider international economic benefits have not been estimated – details of the research that has been undertaken by the Commission in this area to date follows from paragraph 2.39.

## Delay costs

**2.20** Leigh Fisher, on behalf of the Commission, have undertaken some preliminary work to estimate the delay costs to airlines and passengers of capacity constraints. Delay costs have been modelled from 2021 to 2080 for the London airport system and are applied to every passenger.

**2.21** For the purposes of this indicative analysis it is assumed that every airport which experiences a terminal or runway capacity constraint between 2021 and 2080 will have the same level of delay. Various other assumptions underpin this analysis:

- arrival delays are assumed to be five minutes per passenger and departure delays are seven minutes, at every capacity constrained airport. This is based on estimates of expected delays at Heathrow after the short-term measures to improve airspace and runway operations (set out in **Chapter 5** of the *Interim Report*) have been applied;

- it is assumed that the delays build up linearly from a level of one minute delay in the baseline to five or seven minutes once capacity is reached. From this point they are held constant. Heathrow starts the modelling period with the full delay as it is already very close to capacity;
- next generation aircraft are assumed to be 10% more fuel efficient than current aircraft, and next but one generation aircraft are assumed to be 50% more efficient, in line with EU objectives;[7]
- maintenance costs are decreased by 20% with each new generation of aircraft. A conservative approach is taken to all the other parameters which remain the same over time as new aircraft enter the fleet; and,
- the fleet mix is based on the categories of aircraft type used in the DfT's Fleet Mix Model. These categories are used to derive broad averages for costs from the University of Westminster European airline delay cost reference values.[8]

**2.22** Further work is required to develop a methodology for assessing the value of reducing delays when the Commission considers specific airport expansion options in Phase 2. Nonetheless the results of this preliminary analysis show that there could be at least a £1.8 billion cost associated with delays in the London airport system over the period from 2021 to 2080.[9]

**2.23** The figure presented here does not include the value of noise respite (for example, if less stacking occurs) and lower $CO_2$ emissions. Therefore the Commission's calculation is likely to be an underestimate of the potential value of reducing delays. Using standard DfT methodology to value reliability would also most likely produce a higher figure.

## Direct economy impacts

**2.24** PwC has carried out analysis, on behalf of the Commission, to quantitatively assess the link between aviation activity and the economy,[10] specifically how changes in aviation connectivity can impact upon:

- trade;

7 Flightpath (2050) http://ec.europa.eu/transport/modes/air/doc/flightpath2050.pdf
8 European airline delay cost reference values: Final report V3.2 (March 2011), Department of Transport Studies University of Westminster, London
9 2012 present value and price base
10 PwC, "Econometric analysis to develop evidence on the impact of aviation interventions on international business", available on the Airports Commission website

- FDI;
- tourism; and,
- cross-border migration.

**2.25** The study was undertaken using econometric analysis of panel datasets to investigate historical relationships and associations on a cross-section of countries.

**2.26** Before undertaking this analysis the Commission asked PwC to consider how difficulties experienced in previous studies could be resolved, in order to provide a better understanding of the links between aviation interventions and the impacts on the economy. Two major issues associated with previous studies are those relating to endogeneity and finding a suitable proxy for aviation connectivity.

**2.27** The main challenge of estimating an empirical relationship of this sort is the issue of endogeneity.[11] Reverse causality presents itself when two variables have a bi-directional impact, so a change in one variable affects the other and vice-versa. For example, if a country invests heavily in tourist infrastructure and experiences more tourist arrivals it may be that the provision of infrastructure encouraged tourists to visit but it is equally plausible that the need for such investment was driven by an increase in tourist arrivals. Therefore investment in tourist infrastructure could both explain and be explained by tourist arrivals.

**2.28** An omitted variable could be a problem if the variable that is omitted becomes part of the error term, thereby creating a bias in the analysis. The presence of this bias would cause the model to appear to explain more or less than it would without the bias so the outputs are not reliable.

**2.29** Undertaking an econometric analysis required PwC to find a suitable proxy for aviation connectivity. Aviation connectivity is a broad term and the proxy needed to meet these various definitions and have a good panel dataset available. PwC found direct seat capacity to be the best proxy for aviation connectivity, reflecting actual UK airport capacity, operational constraints and accounting for changing plane size. Scheduled seat capacity data was obtained from Sabre Airport Data Intelligence and the UK CAA, and was constructed at the regional level.

**2.30** As with any measure there are a number of drawbacks, including a dataset with only a ten year time series and the exclusion of onward connections from the data.

11 Endogeneity occurs when the independence between the errors in the independent variables is violated, and this prevents the use of an Ordinary Least Square (OLS) method. Endogeneity can present itself as: measurement error; simultaneity also known as reverse causality; or omitted variable bias

In addition, it does not reflect the way in which seat capacity is distributed among airports.

**2.31** PwC also considered alternative connectivity measures used in other studies, such as number of destinations served, frequency of services, cost of travel, and other connectivity indices. Direct flight frequency was tested as an alternative measure to connectivity and a 96% correlation was found between direct seat capacity and direct flight frequency, with similar regression coefficients for these two proxies. In addition, indirect seat capacity and indirect flight frequency were also tested as proxies for aviation connectivity but the coefficients were found to be statistically insignificant in the early stages of work.

### Methodology and results

**2.32** PwC first undertook a review of the literature, focusing on previous studies that have attempted to tackle similar research questions, and used recent statistical articles to ensure their methods and techniques were up-to-date and following best practice.

**2.33** Using the results of the literature review, PwC developed a number of regression models to analyse the relationship between seat capacity and FDI, trade, cross-border migration and tourism, in addition to other explanatory variables. A variety of econometric techniques are used on panel data to address endogeneity issues in the relationships. A summary of the regression models are presented in **Table 2.4**.

**Table 2.4: Summary of PwC econometrics variables and specification**

| Regression | Dataset | Independent variables | Literature[12] | Approach to endogeneity |
|---|---|---|---|---|
| Tourism (inbound and outbound) | 11 years, (2002-12)<br>44 countries | • GDP in the origin country<br>• Relative prices<br>• Hotel rooms available in destination country (proxy for tourism infrastructure)<br>• Distance between London and destination capital<br>• Whether English is the official language spoken<br>• Seat capacity | The model specification is a classical demand function for international tourism (Witt and Witt, 1995; Naudee and Saayman, 2005)<br>Seat capacity and a language dummy are added as additional variables | Dynamic panel model, System GMM<br>Lagged tourist arrivals and tourism infrastructure are treated as endogenous in the inbound model. UK GDP is treated as endogenous in the outbound model<br>Higher-order lagged values of the endogeous variables are always used as instruments |
| Trade (UK imports and exports) | 11 years, (2001-11)<br>164 countries (UK trading partners) | • UK GDP<br>• Trading partner GDP<br>• Exchange rates<br>• Distance between London and destination capital<br>• Previous colonial links<br>• Whether English is the official language spoken<br>• Whether the country traded with was landlocked<br>• Seat capacity | Uses a gravity model widely applied in international trade literature (Arvis and Shepherd, 2013)<br>Seat capacity is added as additional variable | Gravity model, Pseudo-Poisson Maximum Likelihood (PPML) estimator (Fally, 2012)<br>Goods exports: PPML<br>Goods imports: PPML<br>Services exports: PPML<br>Services imports: IVPPML (seat capacity is treated as endogenous) |

12 References for this literature can be found in PwC's report, available on the Airports Commission website

**Table 2.4: Summary of PwC econometrics variables and specification**

| Regression | Dataset | Independent variables | Literature | Approach to endogeneity |
|---|---|---|---|---|
| FDI<br><br>Regional manufacturing FDI inflows | 9 years, (2003-2012)<br><br>11 UK regions | • GVA in the manufacturing sector<br>• Wages<br>• Unemployment<br>• Migration<br>• Infrastructure<br>• Connectivity index | Following Arromdee et al. (1989), this model is augmented with migration and aviation connectivity | MM Robust Regression with Fixed Effects |
| National FDI inflows | 7 years (2005-11) | • FDI-origin country's GDP<br>• Productivity<br>• Distance between London and destination capital<br>• Openness<br>• Patents applications in FDI-origin country<br>• UK interest rates<br>• UK tax rates<br>• Whether English is the official language spoken<br>• Seat capacity | Following Coughlin and Eran (1999), this model is augmented with patents, interest rates, tax rates and seat capacity | PPML |

| Table 2.4: Summary of PwC econometrics variables and specification | | | | |
|---|---|---|---|---|
| Regression | Dataset | Independent variables | Literature | Approach to endogeneity |
| National FDI outflows | 7 years (2005-11) | • UK GDP<br>• Purchasing power of FDI-recipient country<br>• Population<br>• GDP of destination country<br>• Distance<br>• Inflation<br>• Productivity<br>• Openness of recipient country<br>• Transport costs<br>• Corruption<br>• Seat capacity | As above | Instrumental Variable PPML<br>GDP of destination and corruption are treated as endogenous |

**2.34** Using seat capacity as a proxy for aviation connectivity the econometric analysis found that a 10% increase in seat capacity is associated with:

- **tourism**: a 4% increase in tourist arrivals in the UK and around a 3% increase in UK tourists abroad;
- **trade**: a 1.7% increase in UK goods imports and a 3.3% increase in UK goods exports; and a 6.6% increase in UK imports of services and a 2.5% increase in UK exports of services;
- **FDI**: a 4.7% increase in UK FDI inflows and a 1.9% increase in UK FDI outflows. In the regional FDI model a 1% increase in connectivity is associated with approximately a 1.1% increase in manufacturing related FDI inflows; and,
- **cross-border migration**: a robust relationship between aviation connectivity and migration was not established due to poor quality data so this was omitted from the econometrics work.

**2.35** The results should be treated with caution and read not as representing causality but association, given the short time period of the data which was available. For example, this could indicate that an increase in seat capacity provides more scope for trade or that an increase in trade increases the need for seat capacity, or some combination of the two.

**2.36** The relationships found in the PwC research indicate that connectivity by air may play an important role in enabling trade and tourism, and facilitating foreign investment in the UK.

**2.37** The econometric study found positive and statistically significant links between aviation connectivity and trade, FDI and tourism. Overall the results indicate that a 10% increase in seat capacity between the UK and any other given country is associated with an increase in activity of between 1% and 7% across the various areas. However, the Commission's peer reviewers noted a number of caveats which mean that these numbers should be interpreted with caution, and considered qualitatively as indications from emerging research.

**Reviewers' comments**

**2.38** Three peer reviewers (Professor Peter Mackie, David Starkie and Professor Daniel Graham) have provided a critique of this work. A summary of this is available on the Commission's website. They concluded that the results of this work were a positive step forward and represent a good starting point for future analysis in this field. Specifically, their view was that these results should be interpreted with caution for the following reasons:

- the approach taken has been data driven rather than hypothesis driven;
- preference for model specification has been driven by statistical performance rather than what might be expected in principle;
- the data for some variables has a limited time series, therefore association between the variables and results could have been affected;
- the study is not location or country specific and the effects will in reality differ between destinations. For example, an increase in short-haul leisure services to destinations such as Ibiza or Crete may have no noticeable impact on trade or FDI, whereas an increase in seat capacity to other destinations will be likely to increase trade by a much larger extent;
- the study took direct seat capacity as a proxy for connectivity in assessing the effects of capacity constraints, whereas in practice the cost of a constraint would manifest itself in many different ways which aren't accounted for in the analysis; and,

- indirect seat capacity is not captured, hence, any substitution effects between direct and indirect flights could overestimate the direct effects.

## Wider economy impacts

**2.39** The PwC project considered the direct impacts of a change in connectivity on some key economic variables and in order to investigate how these impacts can contribute to the UK economy, SDG undertook a study on behalf of the Commission of the wider economy impacts.

**2.40** This study consisted of a literature review and the development of a conceptual framework to help understand both the transmission mechanism through which the direct impacts can affect productivity, and the likely magnitude. Such productivity gains are, if measured correctly, additional to benefits captured elsewhere and are often termed wider economic impacts.

**2.41** SDG's work investigated the strength and nature of the links between the direct impacts of connectivity and the transmission through to the wider economy; considering impacts such as productivity gains, economies of scale, agglomeration economies and spillovers.

**2.42** The study found a significant body of literature on the economic impacts of aviation, but also that much of the evidence lacks robustness. For the same reasons as discussed under the direct impacts, the relationship between aviation and the economy is fraught with endogeneity problems. Very little of the literature on the economic impacts of aviation have addressed these issues adequately.

**2.43** The study also found a widespread confounding of what are, on one hand, the impacts on economic flows, such as on trade, tourism and FDI, and, on the other, economic benefits. Increasing an economic flow such as trade does not deliver benefits unless doing so increases productive capacity or well-being after allowing for the opportunity cost of resources used. This could be in the form of productivity gains through spillovers or economies of scale, or in the form of economic welfare through lower prices and increased variety.

**2.44** The study found, however, a much better body of evidence on the links between economic flows and wider productivity impacts. A significant amount of research has focused on investigating the economic benefits of trade, FDI, agglomeration and tourism. With recent developments in econometric techniques allowing endogeneity problems to be successfully dealt with, there is now a sufficiently robust evidence base to allow such relationships to be quantified.

**2.45** With the parallel PwC study focusing on identifying the direct impacts of aviation connectivity on economic flows, SDG's research therefore focused on building the evidence base on the wider economic impacts of the change in such flows. **Table 2.5** summarises the key findings of the wider impacts on the economy resulting from the direct impacts of improved aviation connectivity. They identified a strong link between increased inward and outward FDI and productivity, and increases in trade and productivity.

**2.46** It should be noted that some studies present findings relating to the wider impacts of trade, FDI and tourism in general, rather than specifically related to aviation. Also, some analysis is based on data and work from elsewhere in the world so may not be directly applicable to the UK.

**Table 2.5: Key findings of SDG literature review**[13]

| Wider impact – theory of transmission | Evidence |
|---|---|
| **Trade** | |
| Wider benefits from trade include:<br>• comparative advantage;<br>• productivity benefits from specialisation, such as division of labour and economies of scale, or from increased variety and quality of inputs;<br>• increased competition in import and export markets; and,<br>• firms learning from importing and exporting by acquiring technology, knowledge and information.<br>However, exporters may be likely to be more productive because of self-selection, i.e. the more productive firms export – studies need to correct for this (Wagner, 2012). | The positive links between trade and productivity are well researched. Early work finds that a 10% increase in trade raises domestic GDP per capita by between 5% (Frankel and Romer, 1999) and 12% (Alcala and Ciccone, 2004).[14]<br>However, these studies compare trade and GDP across a wide range of countries and may not be representative of the marginal impacts on GDP in a developed and open economy such as the UK. |
| | Micro level studies find strong links between trade and productivity, finding firms can become between 10% and 50% more productive once they start exporting (see for instance Wagner, 2012).<br>UK production and service sector firms can achieve long term productivity gains from exporting, 11% and 37% respectively (Harris and Li, 2011).<br>Smeets and Warzynski (2011) find that increased imports raises the productivity of manufacturing firms, with an elasticity of 0.18. |
| | Other micro studies find evidence to suggest that trade can increase competition, the variety of inputs and learning by importing and can reduce prices and mark-ups, leading to productivity gains (Armiti and Wei, 2006; Chen, 2009; Ge, Lai and Zhu, 2011; Wagner, 2012). |

13 References for this literature can be found in SDG's report, available on the Airports Commission website
14 These studies do not consider trade by aviation or aviation connectivity specifically

| Table 2.5: Key findings of SDG literature review | |
|---|---|
| **Wider impact – theory of transmission** | **Evidence** |
| **FDI** | |
| Increased economic opportunities or competition, such as from a new source of imports or inward FDI, can have wider implications for the domestic economy, particularly on increasing the productivity of domestic firms.<br><br>Gorg and Greenaway (2004) suggest productivity spillovers arise from FDI through:<br>• imitation or adopting production methods and managements from foreign firms;<br>• competition;<br>• human capital; and,<br>• exports.[15]<br><br>Those firms currently operating will need to respond by reducing costs, increasing productivity, adopting their processes and technology. Alternatively, they could forgo profits, face lower market shares, or go out of businesses. These negative impacts generate a positive creative process, by replacing existing activity by a more efficient use of resources, termed 'creative destruction'.<br><br>Outward FDI could also lead to productivity gains from a learning process similar to that described for trade above. | Girma and Wakelind (2000) find that productivity gains tend to be within the same industry and region – with a 0.14% increase in productivity per 1% increase in stock of FDI in the UK.<br><br>Barrel and Pain (1997) find that a 1% increase in stock of FDI within manufacturing in the UK raises long-run productivity of incumbent firms by 0.26%. They find no effects in service sectors.<br><br>Liu et al. (2000) find labour productivity in domestic firms increase by 0.1% for a 1% increase in FDI stock.<br><br>Haskel (2007) finds the impact on Total Factor Productivity of a 1% increase in the stock of FDI within the same sector to be 0.05%.<br><br>Driffield et al. (2008) suggest that different types of FDI have varying impacts on productivity; and the labour costs and technology of the host and source countries are important determinants of the impact. They also find outward FDI has a positive effect on source-country productivity.[16] |
| **Tourism** | |
| Net changes in aggregate tourism do not, in itself, represent an economic gain. A change in tourism spending patterns will result in reallocation of resources between sectors (Frechtling, 1994). There may be a compositional impact on total GDP if the reallocation is between sectors with different labour productivity. | Differences in tax take (principally Value Added Tax) by sector may mean the compositional impacts lead to net welfare gains. Blake (2007) uses CGE modelling for the UK and finds that such welfare gains amount to 6% of net UK tourism spending. Forsyth (2006) finds 7% welfare gains for Australia.<br><br>It is important to consider that there could also be displacement of tourism activity. |

15 NERA, (2009) "Transport's Role in Facilitating International Business", Draft Consolidated Report for the Department for Transport
16 *Ibid*

<table>
<tr><th colspan="2">Table 2.5: Key findings of SDG literature review</th></tr>
<tr><th>Wider impact – theory of transmission</th><th>Evidence</th></tr>
<tr><td colspan="2">Agglomeration</td></tr>
<tr><td>Agglomeration and clusters of economic activity produce positive externalities (Graham, 2007, 2010). These productivity gains are enjoyed by some firms when located in proximity to:<br>• other firms, offering more opportunities for collaboration and exchange of knowledge;<br>• workers, enabling better matching of employees to firms;<br>• suppliers, increasing choice, competition, flexibility and resilience in the supply chain; and,<br>• customers, lowering transport and communication costs and increasing economies of scale.<br>If aviation connectivity increases the economic density of the region, or changes business composition, there may be additional agglomeration benefits. Firms enjoying agglomeration economies tend to be in high-value activities, and the activities attracted may therefore raise internal firm productivity levels.<br>However, it is important to also consider that there might be negative agglomeration effects from where activity may be displaced.</td><td>Evidence from the US finds a significant relationship between airport capacity and regional employment. A 10% increase in passengers at US airports leads to a 0.5%-1.5% increase in service employment with no or negative impacts on manufacturing and goods-related jobs (Brueckner, 2003; Percoco, 2010; Sheard, 2012)<br>Evidence suggests that a 10% increase in employment density raises productivity by around 1.3% for the economy as a whole, 0.7% for manufacturing and 2.0% for services (Graham, 2007).<br>More recent findings suggest a lower economy-wide elasticity of 0.04 (note this is not directly comparable to previous results) (Graham, 2010).</td></tr>
</table>

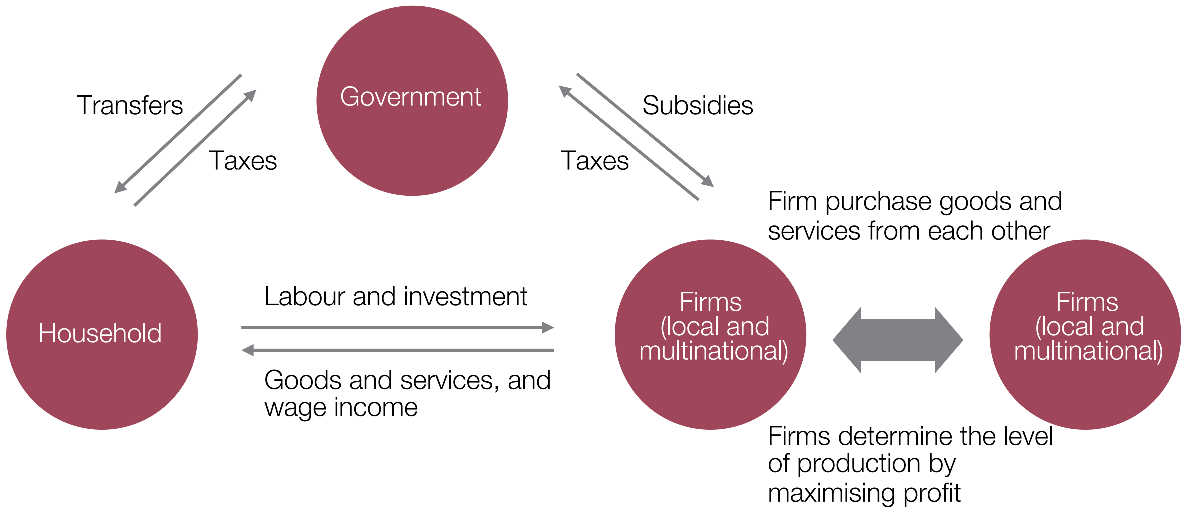
## CGE modelling

**2.47** In order to better understand how the national economy could be affected by capacity constraints the Commission have analysed the impact of a constrained airport system using computable general equilibrium (CGE) modelling. This type of model attempts to represent the entire economy so can be considered a 'top down' approach to examining the costs of capacity constraints.

**2.48** CGE models are well suited to evaluating the economic impact of a capacity constraint in the aviation sector. They are able to capture the economic behaviours of all agents (users, providers, Government, investors) in the economy, as **Figure 2.2** below shows. Each of these institutions is interlinked through either labour market flows, capital market flows, intermediate product demand, taxes or Government transfers.

**2.49** The model tracks the evolution of the economy over time as it reacts to changes, accounting for behavioural responses of firms and households and interdependencies between markets. This modelling allows the full effect of a change in the aviation sector as it transmits through the economy to be captured. This is in contrast to most transport models which are partial equilibrium; using standard supply and demand analysis to find equilibrium in one isolated market and ignoring interdependencies with the wider economy.

**Figure 2.2: Economic interactions between households, businesses and the Government are captured in the CGE model**




**2.50** Two different CGE models were used to test the impact of an aviation capacity constraint; the HMRC model and a model owned and operated by PwC. Both models have similar underpinnings but the way the capacity constraint has been modelled differs. In the HMRC model, the change in seat capacity is applied as a constraint on the aviation sector's output, which causes the price of aviation to increase and then impacts on the rest of the economy. In the PwC model, the constraint on seat capacity is modelled as lower productivity in the aviation sector, which impacts on the rest of the economy.

### HMRC CGE modelling

**2.51** The aviation capacity constraint is modelled as a constraint on the aviator sector's output, which forces prices of aviation up. The difference in trip numbers with a constrained and unconstrained airport system, at ten yearly intervals, was input into the CGE model. By 2050 the forecast showed there would be 7% fewer trips with a capacity constraint.[17] HMRC then calculated that there would need to be an 11.7%

17 Due to the timing of this analysis January 2013 DfT forecasts were used to provide numbers on change in trips with and without a capacity constrained system

increase in the price of aviation by 2050 to reduce aviation output to the level implied by the capacity constrained demand forecasts.

**2.52** By 2030 capacity constraints could be depressing GDP by around 0.03%. By 2050, as the London airport system becomes completely full, the contraction in GDP is much higher, around 0.09%. Assuming a 60 year appraisal period, the total cost of a capacity constraint could amount to £45 billion between 2021 and 2080, in present value terms. This estimate has formed the upper bound of the range presented in **Chapter 3** of the *Interim Report*.

**2.53** The biggest effect is within the aviation sector where a 7% reduction in demand due to the capacity constraint leads to a contraction of closer to 9%. However, the total effects of a capacity constraint on the economy are found to be larger because of the importance of aviation to other sectors of the economy.

**2.54** The increase in the price of aviation will reduce real household disposal incomes, in turn reducing demand for other goods and services consumers may have chosen to purchase. Companies which rely on aviation will face higher costs of production which may feed through to consumers as higher prices. The loss of aviation activity also affects businesses which supply inputs to the aviation industry.

**2.55** Foreign owned airlines experience the effects of the constraint through higher modelled airport slot prices but they don't suffer from the second round effects mentioned here like UK airlines do. Therefore, they become relatively more competitive compared to UK airlines, which has a negative impact on UK exports.

**2.56** A constrained aviation system could also affect productivity levels throughout the economy. The CGE model does not directly include these impacts but to ensure consistency of approach with the econometrics work a productivity effect has been imposed on firms which use aviation as an input, which increased the magnitude of the negative GDP effect.

**2.57** The Commission undertook some stylised modelling to incorporate productivity effects in the HMRC model. An exogenous productivity shock was applied on top of the capacity constraint to capture potential total factor productivity loss as a result of lower aviation demand. All sectors suffered a reduction in their productivity levels, depending on how much they used aviation as an input. The extent of the productivity shock is given as the product of elasticity between aviation demand and productivity multiplied by the percentage change in aviation demand as a result of the constraint. Given the uncertainty around scale a range of elasticities were tested and it was found an elasticity of 0.1 could lead to a reduction in GDP of 0.17% of GDP by 2050. The elasticity between productivity and aviation demand is hard to measure and hence the results should be interpreted with care. The CGE model cannot measure how much aviation demand will change productivity levels, but it can model how a given productivity shock will affect GDP.

### PwC CGE modelling

**2.58** The PwC CGE model is based on 2010 UK data and for this analysis covers 11 industries, 11 product markets, one household type, three types of labour (professional, skilled and unskilled) and differentiates capital provisions between debt and equity. It also incorporates the UK's tourism satellite account. A key difference between this model and the HMRC model is the separate inclusion of inbound and outbound tourism as a sector in PwC's model. This may account for some of the difference in the results.

**2.59** Seat capacity is taken as the measure of capacity constraint, as discussed in the econometrics work at paragraph 2.29 above. This relationship is extremely complex and difficult to establish due to confounding factors so before running the CGE model causality between seat capacity and GDP was investigated. The Granger causality test found evidence of a cointegrating relationship and bi-directional causality. Using an Error Correction Model (ECM), a 1% change in seat capacity was found to lead to approximately a 0.15% change in the GDP growth rate.

**2.60** The PwC model was then calibrated to this causal econometric relationship and capacity constraints added. The change in seat capacity was input as a change in airline sector output, of 5% by 2030 and 8% by 2050 to examine the effect on GDP.[18]

**2.61** The results show a 1% increase in seat capacity is associated with a 0.1% increase in GDP when capacity is unconstrained and a 0.06% increase in GDP when capacity is constrained. When capacity is constrained the GDP effect is smaller but still present as the economy will adjust and find other ways of delivering capacity, so some GDP benefit is still realised. Examples of this might include; using larger aircraft, reconfiguring cabins or changing marketing strategies to increase load factors. The full economic gain from the increase in seat capacity is not fully realised with capacity constraints.

**2.62** Assuming a 60 year appraisal period, the total cost of a capacity constraint could be £30 billion between 2021 and 2080, in present value terms. This estimate has formed the lower bound of the range presented in **Chapter 3** of the *Interim Report*.

18 This is based on the latest Airports Commission forecasts of numbers of trips with and without a capacity constrained system (with carbon traded)

**2.63** One key limitation of CGE modelling is the inability to distinguish between the value of different types of seat capacity, with the model simply treating the difference in seat capacity between a constrained and unconstrained scenario as the benefit of releasing the capacity constraint. Ultimately airlines will choose how to make best use of the limited capacity available under a constrained system and these effects cannot be fully examined in such an aggregate model.

**2.64** Undue weight should not be placed on individual figures coming out the model as in practice the effects would be more complex. For example, an additional leisure flight from Stansted to Malaga would not have the same value in terms of potential for increased trade or productivity as, say, a business flight from Heathrow to Shanghai, but this distinction cannot be incorporated.

**2.65** This is particularly important in considering the implications of this analysis in a scenario where a limit on carbon emissions is in place (see **Chapter 4** of the *Interim Report*), where the benefits of releasing capacity constraints may relate more to the type and value of travel that is enabled than to changes in overall passenger numbers.

## Conclusions

**2.66** The research and analysis presented in this section has indicated that the costs of failing to address capacity constraints could be substantial. The social cost-benefit and delay costs analysis indicate a present value cost of £18 billion to £20 billion over a 60 year period.

**2.67** There is also good evidence to suggest that there are costs associated with lost trade, FDI and tourism and that these are likely to affect wider UK economic performance. The Commission's separate CGE analysis found total costs to the economy of capacity constraints could amount to between £30 billion and £45 billion between 2021 and 2080.

**2.68** In Phase 2 the Commission is planning to build on the work presented here, to both better understand how the impacts of a change in aviation connectivity transmit through the economy and to understand how specific options might lead to different outcomes.

**2.69** Further research may include segregation of markets to better understand how different options might affect different types of user and provider. The econometric and CGE modelling approaches presented here may also be taken further in Phase 2.

# Part B: Modelling and forecasts

To assess the need for new aviation capacity the Commission requires credible forecasts of demand for aviation in the UK and the international markets that UK airports serve. In February 2013 the Commission published its first discussion paper, *Aviation Demand Forecasting*.[19] This paper recognised that the DfT aviation model produces the most detailed national level forecasts available. It did, however, raise some important requirements which the Commission felt the existing DfT model did not fully meet. These included the need to deal effectively with the inherent uncertainty in any long-term aviation forecasts and to take account more fully of competition between international hub airports.

19 Airports Commission, Aviation Demand Forecasting discussion paper, February 2013, https://www.gov.uk/government/publications/discussion-paper-on-aviation-demand-forecasting

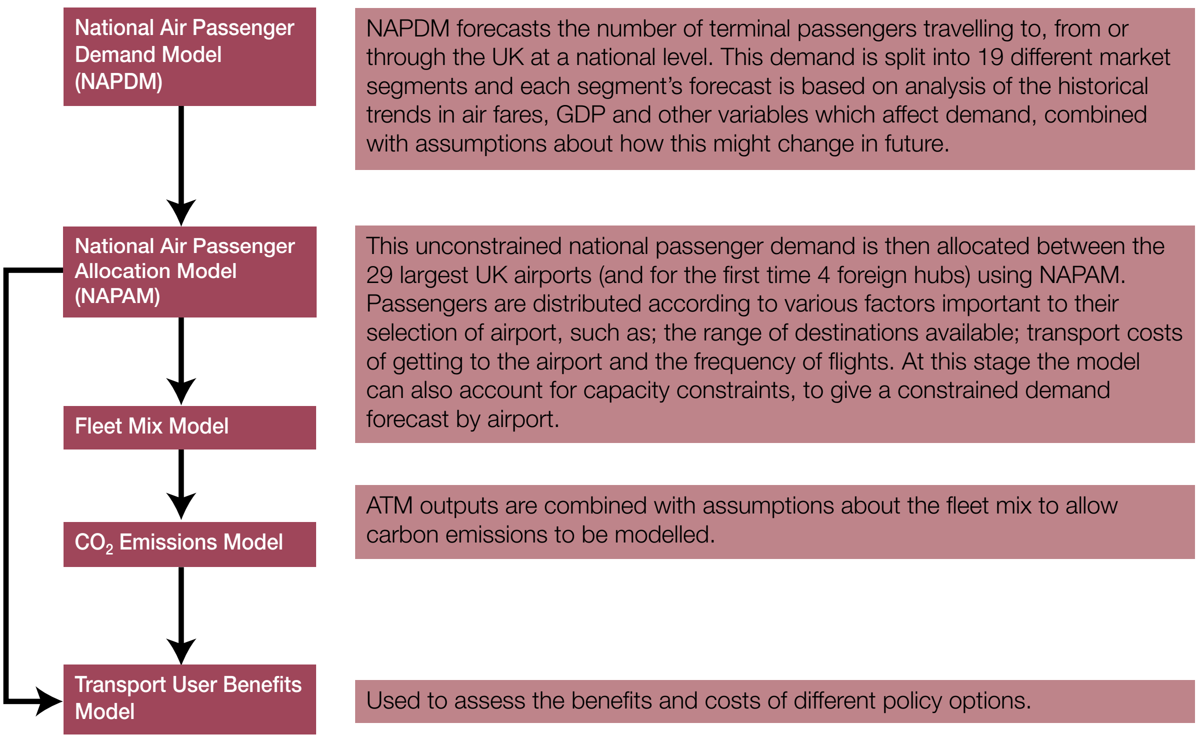
Section 3:

# Model updates

## Introduction

**3.1** This section provides an outline of the DfT's aviation forecasting model (see **Figure 3.1**). It also summarises the responses the Commission received to it's demand forecasting discussion paper and explains the model developments made over the last year.

**Figure 3.1: Outline of the DfT suite of aviation models**




**3.2** The two major components of the DfT's aviation modelling suite that have been updated for these forecasts are:

- the National Air Passenger Demand Model (NAPDM or Demand Model) which forecasts the number of air passengers before taking account of airport capacity constraints; and,

- the National Air Passenger Allocation Model (NAPAM or Allocation Model) which allocates these passengers to airports and can take into account capacity constraints.

**3.3** These models are described in some detail in DfT's *UK Aviation Forecasts*, January 2013.[20]

**National Air Passenger Demand Model**

**3.4** NAPDM combines a set of time series econometric models of past UK air travel demand with projections of key driving variables and assumptions about how the relationship between UK air travel and these drivers will change in the future. The market for passenger air travel is split into separate sub-markets, reflecting different trends, strength of driving forces and availability of data. The markets are split according to:

- the global region (including within the UK) the passenger is travelling to or from;
- whether the passenger is a UK or overseas resident;
- the passenger's journey purpose (leisure or business); and,
- whether the passenger is making an international to international connection which could be made at one of the airports within the model, including the overseas hubs.

**3.5** The drivers of demand are set out in **Section 4.** The estimated responsiveness of demand to these drivers is largely unchanged from that used by DfT in their January 2013 publication.[21] The only change relates to the price elasticity of demand applied to I-I transfer passengers, which was lowered from -0.7 to -0.2 to reflect the fact that many of the choices available to these passengers are now explicitly modelled within the National Air Passenger Allocation Model (see paragraph 3.36 onwards).

20 DfT UK Aviation Forecasts, January 2013, particularly Chapter 2, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013
21 DfT UK Aviation Forecasts, January 2013, particularly Annex A, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

### National Air Passenger Allocation Model

**3.6** NAPAM forecasts passenger demand at the following UK airports:

**Table 3.1: UK airports included in the new version of NAPAM**

| **London** | **Midlands** | **Scotland** |
|---|---|---|
| Heathrow | Birmingham | Glasgow |
| Gatwick | East Midlands | Edinburgh |
| Stansted | Coventry | Aberdeen |
| Luton | | Prestwick |
| London City | | Inverness |
| | | |
| **Other East and South East** | **North** | **Northern Ireland** |
| Southampton | Manchester | Belfast International |
| Norwich | Newcastle | Belfast City |
| Southend | Liverpool | |
| | Leeds Bradford | |
| **South West and Wales** | Durham Tees Valley | |
| Bristol | Doncaster-Sheffield | |
| Cardiff Wales | Humberside | |
| Bournemouth | Blackpool | |

**3.7** In the model used for this set of forecasts, four overseas hub airports are also modelled for the first time – Amsterdam, Paris CDG, Frankfurt and Dubai.

**3.8** NAPAM estimates how passengers making trips to and from the UK choose between UK airports, and in the new version how I-I transfer passengers choose at which hub airport to interline.

**3.9** It comprises several sub-models and routines which are used iteratively and in combination:

- the *Passenger Airport Choice Model* forecasts how passenger demand is split between airports;
- the *ATM Demand Model* translates 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 ATMs (and thus passengers) at UK airports.

**3.10** Airport choice is determined by a combination of factors, which differ by market. They are:

- the travel time and other costs for accessing the airport by road and public transport from the ultimate origin or destination of the journey;
- the availability and frequency of flights;
- where airports become capacity constrained, the 'shadow cost' associated with a constrained airport; this is described in more detail in paragraph 3.55; and,
- in-flight time.

**3.11** Information about the UK zones – which determines where passengers start or end their journeys – is available in DfT's January 2013 publication, along with more detail of how the model works.[22]

## Aviation demand forecasting discussion paper

**3.12** The Airports Commission published a discussion paper, *Aviation Demand Forecasting*, in February 2013,[23] which asked:

- To what extent do you consider that the DfT forecasts support or challenge the argument that additional capacity is needed?
- What impact do you consider capacity constraints will have on the frequency and number of destinations served by the UK?
- How effectively do the DfT forecasts capture the effect on UK aviation demand of trends in international aviation?
- How could the DfT model be strengthened, for example to improve its handling of the international passenger transfer market?
- What approach should the Commission take to forecasting the UK's share of the international aviation market and how this may change in different scenarios?
- How well do you consider that the DfT's aviation model replicates current patterns of demand? How could it be improved?

**3.13** Overall, a total of 36 submissions from airport operators, airlines, industry bodies (including the regulator), environmental and other pressure groups and private individuals were received and analysed.

22 DfT UK Aviation Forecasts, January 2013, particularly Chapter 2, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013
23 Airports Commission, Aviation Demand Forecasting discussion paper, February 2013, https://www.gov.uk/government/publications/discussion-paper-on-aviation-demand-forecasting

**3.14** Responses were cautiously supportive of using the DfT forecasting model, particularly if there was to be some further development. There was a clear steer not to rely on one particular forecast but to consider alternative approaches, especially scenario development. The developments overseen by the Commission this year have aimed at tackling the areas most respondents cited as areas of concern.

**3.15** Recurring themes in the submissions are divided into those which concern the unconstrained demand forecasts produced by DfT's NAPDM shown in **Table 3.2,** and those that relate to the modelling of the choice of airport and aircraft movements in the DfT's NAPAM, shown in **Table 3.3**. These tables also outline the Commission's approach to dealing with the concerns raised.

**Table 3.2: Consultation concerns raised relating to the National Air Passenger Demand Model**

| Concern raised | Commission approach |
|---|---|
| There is significant uncertainty regarding forecast growth in aviation demand.[24] | While uncertainty is an unavoidable part of forecasting, the Commission has made a significant enhancement in how uncertainty is modelled (using Monte Carlo techniques), which is described later in this section. Additionally a range of alternative scenarios has been assessed, both qualitatively and using the DfT model, in order to reflect different visions of how the aviation industry could develop. |
| The current regions for forecasting international growth could be improved.[25] | The classification of countries has been updated (see paragraphs 3.17-3.19). This will be reviewed again in the next round of model updates. |
| The DECC oil price assumptions used are not suitable, particularly after 2030.[26] | IEA oil price forecasts are now used up to 2035 (see paragraphs 4.6-4.8). Beyond 2035 they have been extrapolated and are not held flat. |

24 In particular this concern was raised by the Aviation Environment Federation (AEF), Heathrow Association for the Control of Aircraft Noise (HACAN), Kent County Council, Manchester Airports Group, the British Air Transport Association, the Civil Aviation Authority, Manston Airport, Friends of the Earth, Uttlesford District Council, Dr David Metz and Dr Anne Graham
25 The Mayor of London and Birmingham, Bristol and Newcastle airports raised this concern
26 This concern was expressed by the AEF, Stop Stansted Expansion, WWF-UK and Tim Henderson

**Table 3.3: Consultation concerns raised relating to the National Air Passenger Allocation Model**

| Concern raised | Commission approach |
|---|---|
| Competition between international hubs is an important aspect of the UK aviation market which is not currently modelled.[27] | This area has been the subject of significant enhancement, as described in paragraph 3.36 of this section. |
| Airline and airport competition are not well represented in the model; the historic data used does not account for the changes in the aviation sector.[28] | The Commission has developed a number of scenarios that consider different ways the aviation industry may develop in the future. These are discussed in the Commission's *Interim Report* and have been tested using the aviation model, as set out in **Section 7**. The modelling of competition between hub airports has been significantly enhanced. |
| The model does not adequately represent changes in the size of the aircraft and load factors that may be operated in the future.[29] | Both of these issues have been subject to review. This has indicated that historic gains in load factors have been driven by a series of 'one-off' changes that cannot be continued in the future, e.g. removal of business class from short-haul, or the increase in load factors on many flights. However, assumptions about the growth in aircraft size have been updated (see paragraphs 3.46-3.53). |
| The model inadequately represents the effect of traffic 'spilling' out to the regions when the London and South East airports reach their practical capacity.[30] | A number of changes have been made to the model which reduces this 'spill' effect. See paragraphs 3.55-3.59. |
| Air fares and flight times should not be excluded from modelling the airport choices that passengers make.[31] | Although at the personal level passengers do take account of fares in their choice of airport, over a full year the differences in fares tend to average out. As such, fares are difficult to prove robustly as a significant driver of passenger choice of airport. This approach was supported by the 2011 independent peer review of NAPAM.[32] More detail is also included in DfT's January 2013 publication.[33] Air fares are used in the modelling of passenger choice on whether or not to travel.<br><br>Flight time influences international to international transfer passenger choices and is prominent in that model. Since there is little variation in flight times for direct international flights from UK airports, its omission here is judged as unlikely to be material. |

27 Mentioned in responses by Heathrow Airport Limited and British Airways
28 Argued by, for example, British Airways, Birmingham and Gatwick airports and Gatwick Area Conservation Campaign
29 This was argued by Gatwick Airport, Tim Henderson and Stop Stansted Expansion
30 For example, see the responses of Newcastle, Birmingham and Bristol airports
31 Argued by, for example, Bristol and Newcastle airports and the Chartered Institute of Logistics and Transport
32 John Bates Services, Peer Review of NAPALM, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4506/review-napalm.pdf
33 DfT UK Aviation Forecasts, January 2013, in particular paragraph 2.39, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

## Commission changes to the DfT model

**3.16** In the discussion paper on forecasting the Commission stated that the DfT's approach to forecasting was to be taken as a starting point, and this paper invited views on areas where the DfT suite of models could be improved. The key updates are explained below.

## Definition of Newly Industrialised Countries

**3.17** Passengers are split into regional markets to reflect local characteristics as econometric evidence shows that the strength of demand drivers vary depending on the type of country a passenger is travelling to or from. Differences in driver data, which varies by regional market (for example, growth in GDP), will affect passenger forecasts. Therefore, passengers are split into five global regions:

- OECD countries;
- Less Developed Countries (LDCs);
- Newly Industrialised Countries (NICs);
- Western Europe (WE); and,
- UK.

**3.18** The definition of which markets were treated as NICs in the DfT January 2013 publication dates back to the 2003 *Future of Air Transport White Paper* and DfT aviation forecasts of 1997 and 2000. The Commission agreed with many of the responses to the discussion paper which stated that the definition was outdated, especially as some countries previously categorised as LDCs now have relatively high levels of GDP per capita.

**3.19** Therefore the grouping of some countries has been updated to better reflect their characteristics. Although a full update of the econometric models has not been possible in the time available, a number of countries were re-assigned so that they are now treated as NICs. The identification of newly classified NICs was based on G20 membership and a GDP per capita threshold. All countries previously classified as NICs have remained classified as NICs. **Table 3.4** shows the countries which have been reclassified.

| Table 3.4: Reclassification of NICs | | |
|---|---|---|
| Country | Previous Classification | New Classification |
| Brazil | LDC | NIC |
| Chile | LDC | NIC |
| Indonesia | LDC | NIC |
| India | LDC | NIC |
| Israel | LDC | NIC |
| Kuwait | LDC | NIC |
| Mexico | OECD | NIC |
| Qatar | LDC | NIC |
| Saudi Arabia | LDC | NIC |
| South Africa | LDC | NIC |
| United Arab Emirates | LDC | NIC |

## A new approach to uncertainty – Monte Carlo analysis

### Background

3.20 Understanding the uncertainty attached to demand forecasts is important because it aids policymakers in assessing the extent to which decisions based on evidence are robust to alternative outcomes. As set out in the demand forecasting discussion paper,[34] uncertainty can be reflected in a variety of ways:

- sensitivity analyses test the impact on forecasts of changing individual variables one at a time;
- scenario testing develops alternative coherent views of the future to test the robustness of decisions; and,
- probability analysis estimates the likelihood of different outcomes occurring.

3.21 DfT aviation demand forecasts have in the past relied on sensitivity analysis and the use of a range of high and low forecasts to understand uncertainty. The Commission has chosen to apply probability analysis to assess uncertainty in the forecasts.

34 Airports Commission, Aviation Demand Forecasting discussion paper, February 2013, https://www.gov.uk/government/publications/discussion-paper-on-aviation-demand-forecasting

### Probability analysis

**3.22** This type of analysis estimates the probability of different forecasts occurring in a largely systematic and objective way, although some user judgements remain. A further advantage is that probability analyses permit greater subtleties in specifying how correlated specific inputs are to each other. For example, rather than simply assuming that oil price and GDP growth are perfectly inversely correlated, historic data is used to estimate the extent of the correlation.

**3.23** The Commission therefore undertook a form of Monte Carlo analysis.[35] This approach involved:

- identifying the key variables that determine demand;
- checking past data on these variables for stationarity and transforming them when needed;
- assigning probability distributions to the forecast values of these variables;
- assigning correlations between variables; and,
- running repeated simulations of NAPDM.

**3.24** The key demand variables were identified through a combination of judgement and systematic means, such as calculating the correlation matrix between passenger demand and each variable, and the sensitivity of forecasts to a change in each variable. Each variable was checked for stationarity, using the Augmented Dickey Fuller test, and transformed if necessary. The distribution of the forecast values of each variable was assigned by, where possible, assessing which statistical distribution best described the variation of that variable in historic data.

**3.25** Where no robust evidence was available – for example around the uncertainty attached to market maturity parameters – judgements were made. Finally, for those variables where historic data was available, a correlation matrix was estimated.

**3.26** **Table 3.5** shows the resulting stationary variables that were subject to Monte Carlo analysis and the source for their probability distribution.

35 The Latin Hypercube sampling method was in fact used, as it generates more efficient estimates than the Monte Carlo sampling method, but the principles of the two approaches are the same

| Table 3.5: Stationary variables used in the Monte Carlo analysis | |
|---|---|
| Variable | Source for distribution |
| Annual UK GDP growth to 2017 | OBR forecasts |
| Annual UK GDP growth 2018-2050 | Historic data |
| Annual UK consumer expenditure growth | Historic data |
| Annual foreign GDP growth | Historic data |
| Annual oil price growth | Historic data, adjusted to reflect assessment of ceilings and floors for oil price levels |
| Carbon prices | It is assumed that the DECC range covers a 90% confidence interval |
| Impact of enhanced communications technology | Assumption (uniform distribution across existing range) |
| Relationship between input variables and demand (econometric coefficients) | Normal distribution with parameters informed by t-stats output from underpinning econometric analysis |
| Income elasticities under market maturity | Assumption (uniform distribution across existing judgement based range) |

**3.27** Running more than two thousand simulations of NAPDM generated an estimated probability distribution around unconstrained (in respect of capacity and carbon capping) national demand forecasts. By observing the distribution of simulations, the probability of demand reaching certain levels can be estimated.

**3.28** To determine the high and low forecasts used in this report, the national demand level associated with, approximately, a 60% confidence interval – spanning the twentieth and eightieth percentiles – was then run through NAPDM for all years up to 2050 in both capacity constrained and capacity unconstrained scenarios, with carbon levels uncapped.

### Caveats

**3.29** Any approach attempting to quantify uncertainty cannot capture everything. In respect of the Monte Carlo method described here, the following issues should be noted:

- the estimates of the degree of uncertainty associated with individual inputs are themselves uncertain, particularly for those drivers where the evidence base is weak and informed largely by judgement rather than by data;

- it is nearly impossible to quantify the likelihood of structural breaks occurring in the future, so past relationships between passenger demand and its drivers may no longer hold; and,
- only factors relating to NAPDM have been subject to Monte Carlo analysis. Factors relating to, for example, how passengers react to changes in flight frequency or competition from overseas hubs are included within NAPAM but are not subject to Monte Carlo analysis.

**3.30** It is not practical to estimate the probability distribution attached to each of the 19 NAPDM markets; instead, only the uncertainty attached to the national level demand forecast is quantified, and it is assumed that the level of uncertainty expressed as a proportion of demand is identical across each market.

**3.31** These probability analyses supplement but do not replace other ways of reflecting uncertainty, such as scenario analysis. The Commission has also developed a set of qualitative scenarios to support its consideration of how different versions of the aviation industry and global economy might develop. As part of its analysis these were tested using modelled forecasts. This is discussed in **Section 7**.

### Results

**3.32** **Figure 3.2** shows that with capacity unconstrained the median passenger demand forecast is 450 million passengers per annum (mppa) by 2050, in a range of 380 mppa to 530 mppa. **Figure 3.3** shows that with capacity constrained both the level of demand forecast and the associated uncertainty are reduced. The median forecast is 400 mppa by 2050, in a range of 350 mppa to 455 mppa.

**Figure 3.2: Uncertainty range forecast of carbon traded and capacity unconstrained passengers**

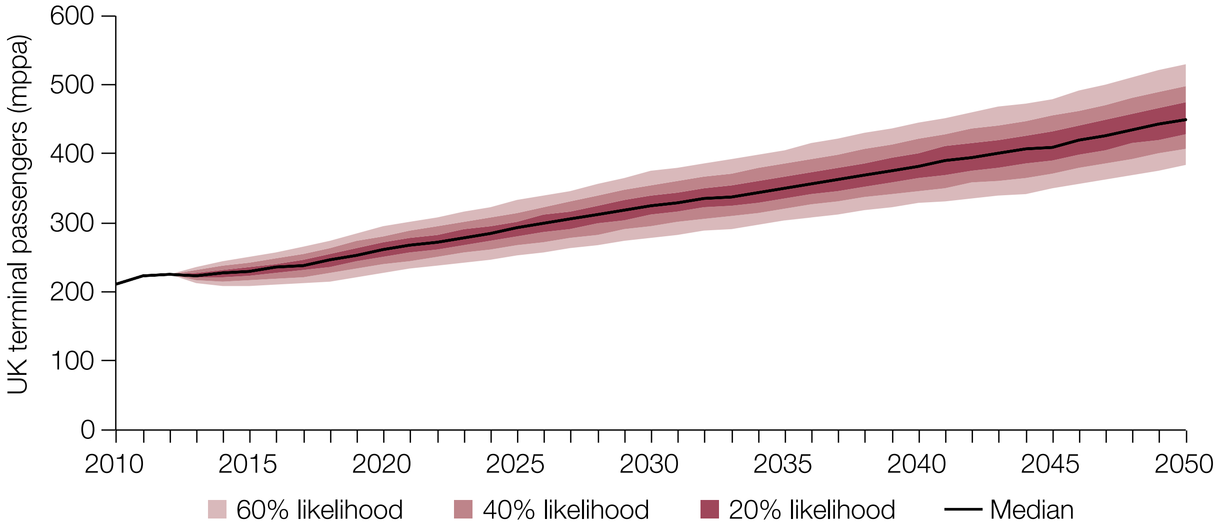
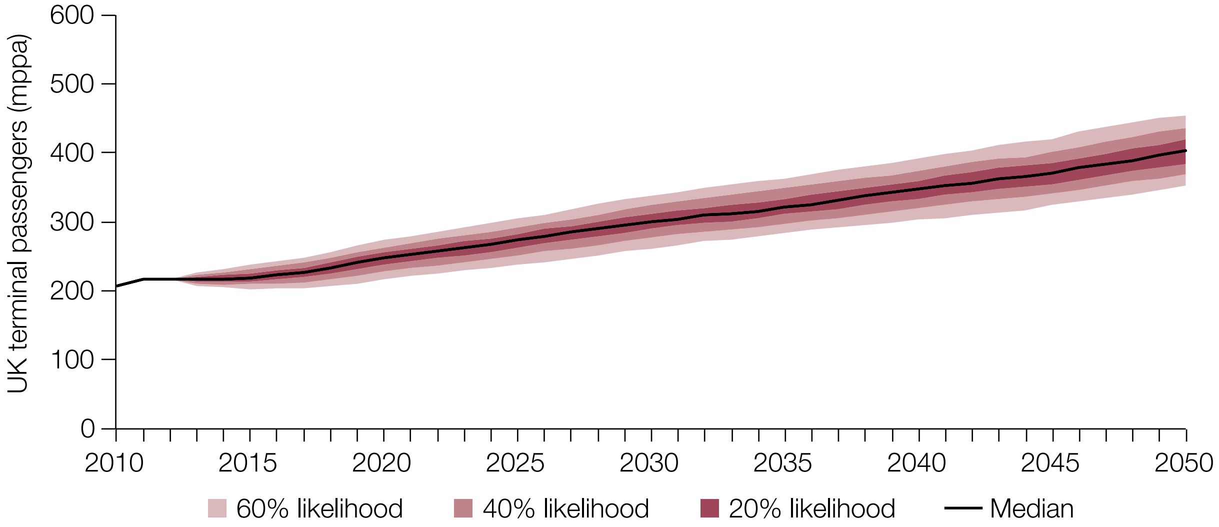


**Figure 3.3: Uncertainty range forecast of carbon traded and capacity constrained passengers**



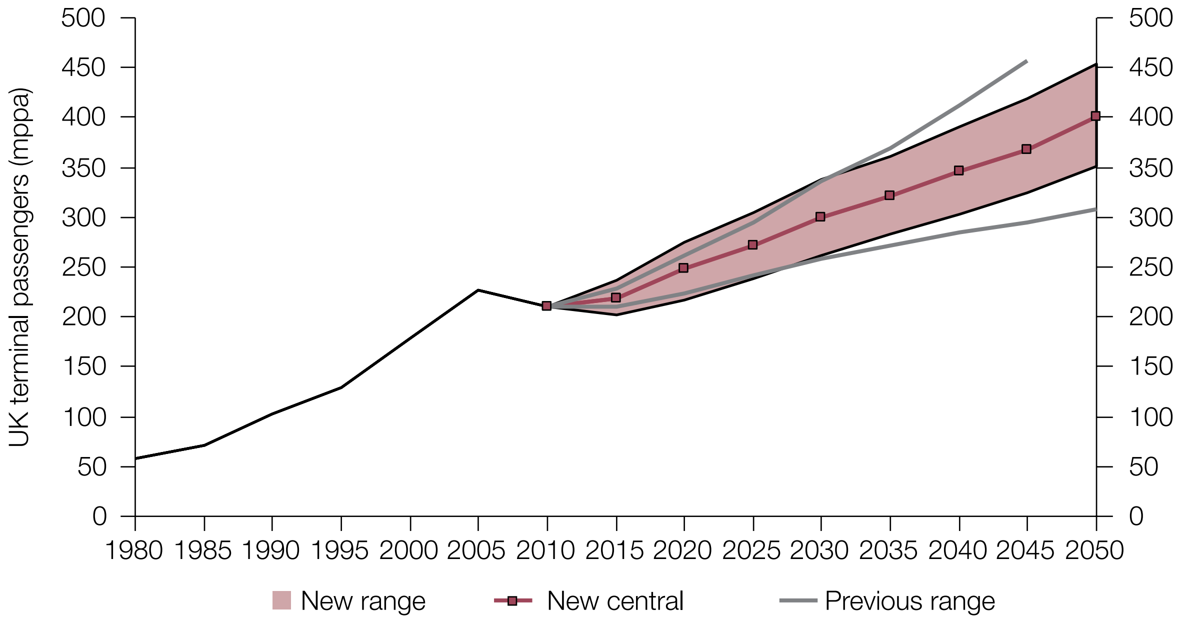

**3.33** **Figure 3.4** compares the Commission's method of reflecting uncertainty to the previous DfT scenario-driven approach, using the same model as above, with the same set of central inputs. The high end of the DfT scenario-driven range was characterised by:

- high GDP growth in both the short-run and the long-run;
- a set of assumptions that resulted in market maturity having relatively little impact on demand;
- an assumption that new communications technology would stimulate more demand; and,
- high oil and carbon prices.

**3.34** The low end of the range was characterised by directly opposing assumptions – for example, low GDP growth. More details of this scenario can be found in chapter 3 of DfT's *UK Aviation Forecasts,* January 2013.[36]

36 DfT UK Aviation Forecasts, January 2013, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

**Figure 3.4: Comparison of new uncertainty forecasts with previous DfT low-high range forecasts**




**3.35** It can be seen that towards the end of the modelled period, this new approach results in a narrower band of uncertainty. This is because, based on the probability distributions applied in this analysis, it is considered very unlikely that all the characteristics of the high or low demand scenarios would occur in combination throughout the modelled period.[37]

## Overseas hub airports

**3.36** The most significant change made in response to the Commission's discussion paper on demand forecasts was for the DfT model to extend its treatment of the competition between UK airports and its principal rival overseas hubs for transfer passengers: Amsterdam (Schiphol), Paris Charles de Gaulle (CDG), Frankfurt and Dubai International. This was achieved by creating an integrated north west Europe (and Middle East) demand pool for both inter continental and longer distance intra-European transfer movements.

### Scope

**3.37** The aim of the enhancement to NAPAM was:

- to allow international-international (I-I) transfers using the UK to be allocated to an overseas hub airport instead of using a higher suppression elasticity as a proxy for reallocation effects;

37 It should be noted that Figure 3.4 shows that the DfT January 2013 constrained forecast failed to reach 2050 because of the higher level of demand

- to include a European demand pool of I-I transfer passengers capable of assessing whether transfer demand currently not using UK hub airports might do so in the future;
- to better model the capacity of neighbouring overseas hubs that compete directly with UK hub airports, both in terms of airport capacity and the route networks that might operate in response to future demand. This was to be achieved by adding the four main competing hubs to NAPAM with approximately the same level of detail as UK airports;
- in the absence of the equivalent of CAA passenger interview data at the foreign competitor hubs, the project needed to assess and use ticketing data as a source of baseline overseas origin-destination movements;
- to rebuild and recalibrate the logit model which attempts to explain international-international passenger choice between hub airports; and,
- to assess future levels of demand at overseas hub airports both for transfer traffic and 'local' movements at those airports, and to allow full capacity constraint modelling.

**Data**

**3.38** OD data at the overseas hubs was not available through a consistent set of passenger interviews as in the case of the UK.[38] Therefore, the principal source of data for all passengers at the overseas hubs was PaxIS ticket data obtained from IATA.

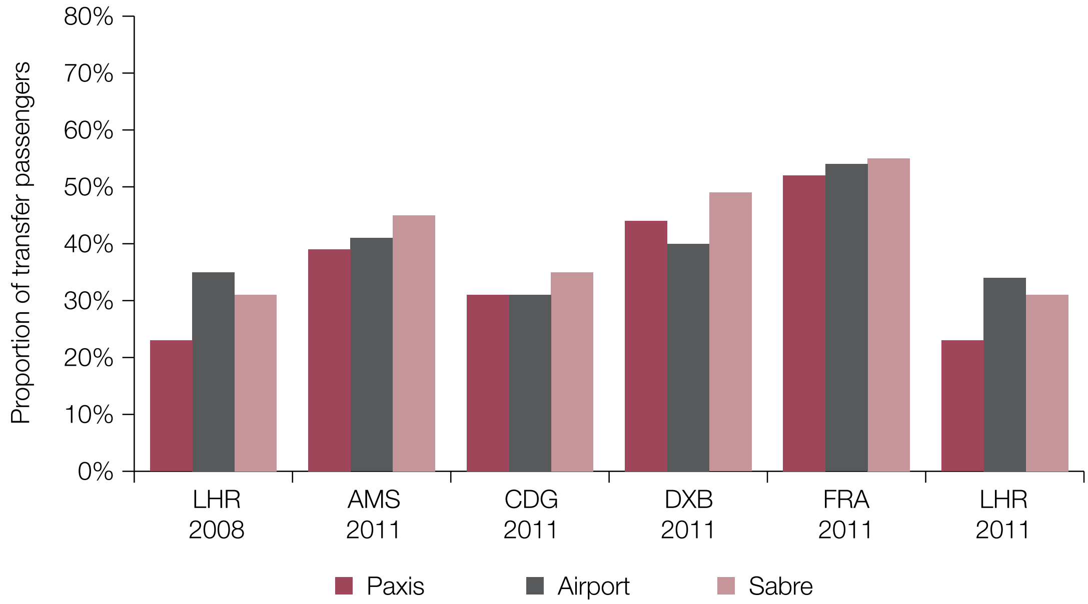
**3.39** PaxIS data was provided for the years 2008 (the demand base year) and 2011 (the current model validation year) for Paris CDG, Amsterdam Schiphol, Frankfurt and Dubai International. Heathrow data was also obtained to provide an independent quality check of the ticket data against other independent data sources available for the UK. Unlike the CAA dataset, journey purpose information and charter flights were not included.

**3.40** As the ticket data was primarily being used to develop an expanded European demand matrix of I-I transfers, the totals of such transfers were checked against independent estimates**. Figure 3.5** shows the comparison. The only instance where there was any discrepancy was at Heathrow, where the CAA data was preferred on the basis that there was a long continuous time series of observations and because it matched up relatively well with Sabre ticket data. When the transfer traffic at the

38 UK data provided from the programme of CAA passenger interview surveys. Individual surveys were potentially available at Amsterdam Schiphol, but there was no equivalent datasets at the competitor hubs

overseas hubs was processed for modelling, transfers which had a UK origin or destination were excluded to avoid double counting, as these movements were already captured as 'international interliners' in the modelling. Instead, they were treated as point-to-point traffic for capacity purposes.

**Figure 3.5: Comparisons of ticket data with independent estimates of transfer traffic**




**3.41** Other data sources used in the model extension were OAG and Innovata timetable data for ATMs by route. Independent checks on the variables were conducted using data from Eurostat and information sourced directly from airports.

### Overseas hub capacities

**3.42** Through discussions with operators and examination of airport masterplans, the Commission estimated current and future overseas hub capacities, to establish potential future annual capacities for modelling. The runway capacities adopted are shown in **Table 3.6**. Dubai International is effectively given the runway capacity of two four runway airports, growing to reach its ultimate input capacity of 1,760,000 annual ATMs by 2035. Heathrow is not shown**,** but in capacity constrained scenarios is assigned a runway capacity of its current planning cap of 480,000 ATMs; Gatwick is allowed to reach an ultimate annual capacity of 280,000 ATMs.

| Table 3.6: Input overseas hub ATM capacities | | | | | |
|---|---|---|---|---|---|
| 000s annual ATMs | 2010 | 2020 | 2030 | 2040 | 2050 |
| Paris CDG | 660 | 690 | 690 | 690 | 690 |
| Amsterdam | 510 | 510 | 630 | 750 | 750 |
| Frankfurt | 480 | 700 | 700 | 700 | 700 |
| Dubai | 400 | 560 | 1360 | 1760 | 1760 |

**3.43** A key assumption adopted in the modelling is that the foreign hubs will not be constrained by terminal capacity, i.e. sufficient terminal capacity will be provided to service the maximum passenger throughput achievable by the runway (ATMs multiplied by average aircraft load).

**International to international transfer passengers logit model**

**3.44** As an interim measure, the existing logit parameters (resulting from the last DfT recalibration exercise in 2010) have been utilised in order to allocate the passenger traffic between international hub airports. While this logit model was estimated using data from UK airports only, results have been validated (see paragraph 3.75 onwards) and sense checked. The allocation of I-I passengers using the existing DfT logit model parameters compares well with observed transfers at the foreign hubs.

**3.45** The Commission has also undertaken a study to recalibrate the logit models used to allocate I-I passengers between hub airports available in the model. This used a combination of ticket data for demand and fares and timetable data for frequency, and in-flight times. The results of the study are still subject to peer review and once concluded, any recommendations will be considered by the Commission in the next phase of its work programme.

## Aircraft size and passenger loads

**3.46** For each route from each airport, the DfT ATM demand model forecasts the size of aircraft, load factor, and frequency of operation needed to meet forecast passenger demand by applying relationships between passenger demand, aircraft size and load factors, and flight frequency, derived statistically from historical data. These relationships were inherited and developed from earlier research by the CAA.[39] They 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.

39 NATS FAG Paper 1, SPAM Larame Graphs, internal CAA working paper

**3.47** Some responses to the discussion paper made specific reference to the DfT's use of Larame graphs in determining the size of aircraft operating on routes. In particular, it was suggested that the load factors used in the modelling process should be increased, allowing a greater number of passengers to be accommodated within the same number of ATMs.[40]

**3.48** The Commission's research supports the finding that historic gains in load factors are driven by a series of one-off changes that cannot be continued in the future, such as removal of business class from short-haul, development of low-cost carrier business models and developments of yield management systems.

**3.49** The assumed growth between 2011 and 2020 is in line with historic growth rates, but it is reasonable to expect this improvement to tail off as load factors reach 80% to 90%. Therefore, after reviewing the evidence, the Commission has decided to continue to use the DfT's assumptions.

**3.50** Various responses to the discussion paper also highlighted the need to review the assumptions around fleet size and questioned the low growth in aircraft sizes being assumed in the short-term.[41]

**3.51** The Commission's research into fleet orders suggests that the assumption about short-term growth was being driven primarily by the short-haul market, and in fact 0.3% per annum growth in aircraft size was more realistic in the short-term, with further increases in the late 2020s when low-cost carriers start to update their fleets. **Table 3.7** shows how the aircraft size assumptions have been updated.

**Table 3.7: Updated assumptions on growth of aircraft size**

| Period | DfT January 2013 Assumptions | Airports Commission December 2013 Assumptions |
|---|---:|---:|
| 2011–2020 | -0.1% pa | 0.2% pa |
| 2020–2030 | 0.0% pa | 0.5% pa |
| 2030–2040 | 0.0% pa | 0.3% pa |
| 2040–2050 | 0.1% pa | 0.4% pa |

40 Including Stop Stansted Expansion
41 The modelling of aircraft sizes was mentioned in responses from Gatwick Airport, Manchester Airports Group and Manston Airport

**3.52** The retention of DfT load factors and the updated assumptions about growth in aircraft size outlined here have produced higher loadings per passenger ATM in the Commission's forecasts. The load factor and aircraft size assumptions described here combine to result in the output baseline aircraft passenger loading growth shown in **Table 3.8**.

**Table 3.8: Growth in modelled overall passenger loads per ATM**

| Period | DfT January 2013 assumptions |
|---|---|
| 2011–2020 | 0.6% pa |
| 2020–2030 | 0.6% pa |
| 2030–2040 | 0.3% pa |
| 2040–2050 | 0.4% pa |

**3.53** This equates to a 2% growth in the average load per passenger aircraft between 2011 and 2050 for all airports in the model, including overseas hub airports.

## Other changes to the DfT model

**3.54** In addition to the specific requests of the Commission following consultation, the DfT have also led improvements and updates to their suite of aviation models this year. These updates are also reflected in these forecasts and are summarised here.

## 'Spill' between the London airport system and regional airports

**3.55** NAPAM models the impact on passengers of airport capacity constraints, and the response to these constraints. If unconstrained passenger demand at an airport exceeds capacity, the model increases the cost of using the airport until demand falls to within capacity. This additional cost is known as a 'shadow cost', which acts as a congestion premium (or clearing price), limiting the number of passengers at an airport to its capacity. More information on this is available in DfT's January 2013 publication.[42]

**3.56** This shadow cost has two effects:

- some passengers choose an alternative airport including using overseas hubs; and,
- some passengers choose not to fly, reducing the total volume of terminal passengers.

42 DfT UK Aviation Forecasts, January 2013 particularly Chapter 2, p.35, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

**3.57** The balance between these effects is determined by the model's 'suppression elasticities' – the higher the elasticity, the more passengers decide not to fly rather than choose a less preferred airport.

**3.58** Previous DfT forecasts appeared to have an exaggerated spill effect from the South East to smaller regional airports. The suppression elasticities were based on NAPDM fares elasticities and this method did not account for the fact that passengers were suppressed in response to their overall generalised cost of travel, of which fare was approximately half.[43] Demand suppression elasticities were therefore factored by two which has reduced the spill effect, removing the need for artificial airport surface access area catchment cut-offs.

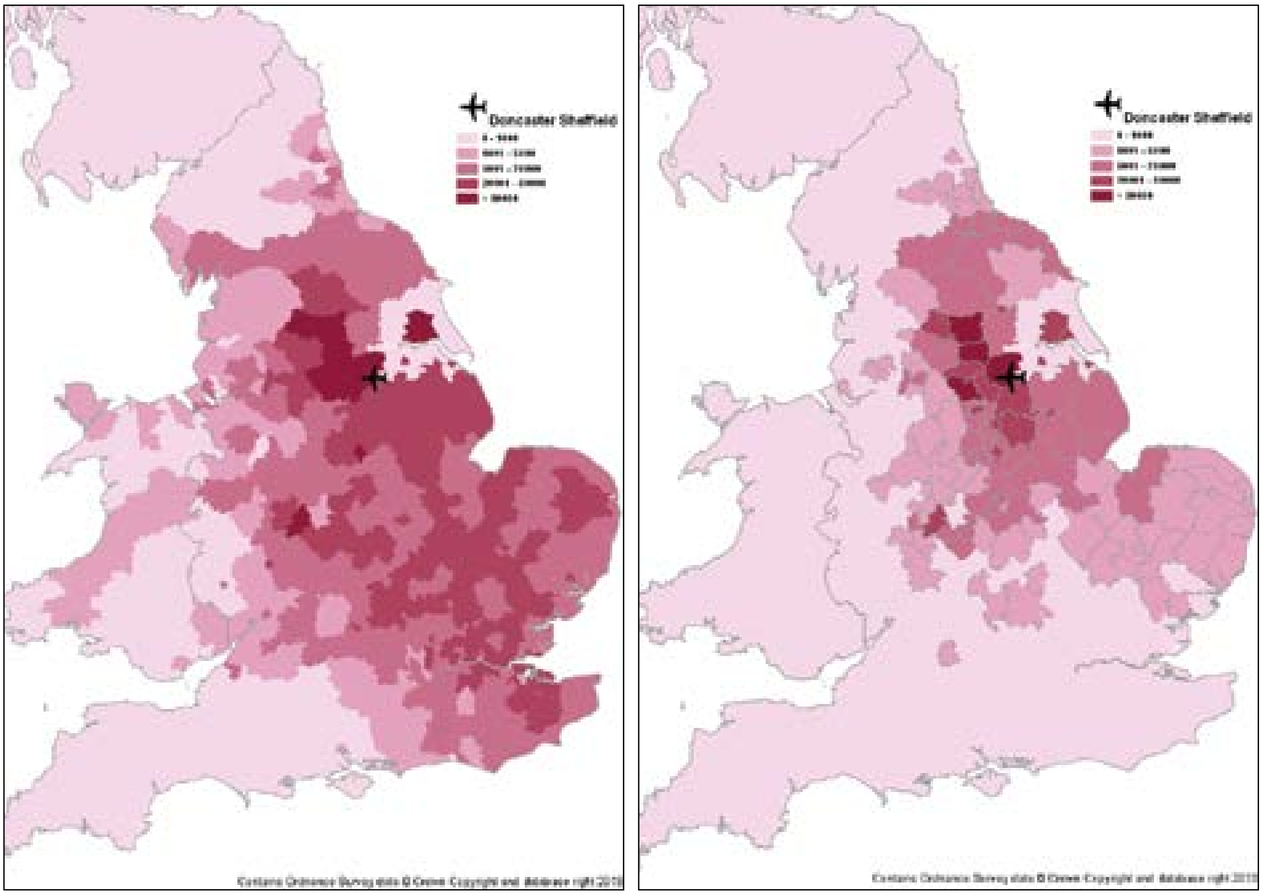
**3.59** **Table 3.9** monitors changes in the modelled throughputs at airports that the Commission had identified as problematic in the final years of the capacity constrained forecast. **Figure 3.6** demonstrates the improvement at an airport which typified the problem of some excessive catchment areas in previous capacity constrained forecasts.

**Table 3.9: Changes in the modelled increase in traffic at smaller airports, 2040-2050**

| | 2040-2050 annual growth rate | |
|---|---|---|
| | DfT January 2013 | Airports Commission December 2013 |
| Cardiff | 17% | 8% |
| Humberside | 12% | 0% |
| Doncaster Sheffield | 11% | 4% |
| Newquay | 10% | 2% |
| Norwich | 9% | 7% |
| Liverpool | 7% | 2% |
| East Midlands | 5% | 8% |
| Exeter | 6% | 7% |

43 Although air fare is not used in the allocation of passengers between airports, it is used in the calculation of total national demand that will not travel, a calculation made prior to the allocation process for every modelled year

**Figure 3.6: Change in a regional airport catchment area between generations of forecast (Doncaster-Sheffield, forecast passengers 2050)**




## Impact of including HS2 in the demand model

**3.60** HS2 significantly improves long-distance rail journey times, and affects aviation demand in two ways – improving access to airports and through direct competition for long distance, cross-country trips. It has been introduced into the model in a manner consistent with HS2 Ltd forecasts available at the time the modelling was undertaken. The first phase improves journey times between London and other cities including Birmingham, Manchester, Liverpool and Glasgow, without a direct Heathrow connection, and is introduced in 2026. The second phase extends HS2 to Leeds and provides further journey time improvements to cities in the North West corridor, and is introduced in 2033. In the modelling undertaken, it is assumed that direct Heathrow services are introduced in this second phase.[44]

**3.61** HS2 Ltd provided DfT with average weekday estimates of the impact of HS2 on aviation demand by OD and journey purpose. DfT factored these to annual levels and used only the internal cross-country forecasts. The HS2 estimates were taken

44 Analysis was undertaken using data from the HS2 Ltd modelling undertaken before the Government's decision to pause consideration of the Heathrow Spur while the Commission conducts its review

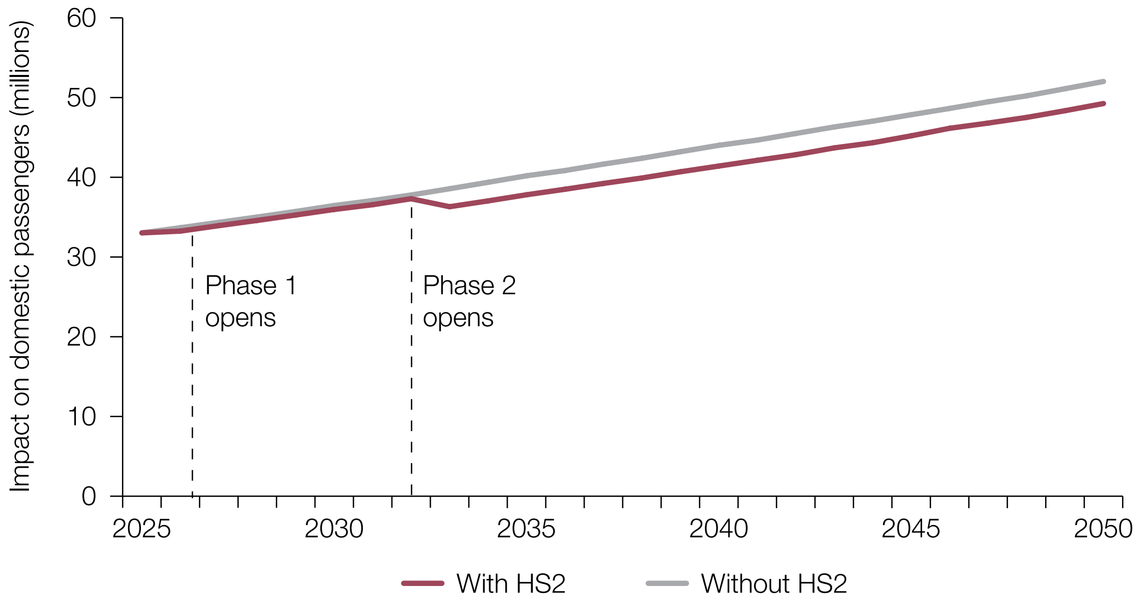
from their PLANET suite,[45] and the factored demand overlaid in the aviation model demand matrices in the appropriate years.

**3.62** As the baseline case includes HS2, a model run was undertaken adding the transfers back in to test the effect. As **Figure 3.7** shows, the number of domestic air passengers falls slightly between 2026 and 2033 and more significantly beyond this date, when the second phase of HS2 to Manchester and Leeds is implemented.

**3.63** HS2 is also forecast to have an impact by improving accessibility to UK airports for passengers taking international flights. It was considered that this aspect was already adequately incorporated into existing DfT modelling, so the HS2 surface access methodology has been retained from the previous forecast.[46]

**Figure 3.7: Impact of HS2 on domestic passenger forecasts**

Domestic passenger demand with and without HS2, 2025 – 2050




## Demand growth precision

**3.64** The allocation model NAPAM, was developed some years before the demand model, NAPDM. Originally NAPAM had been set up to accept growth factors for ten markets as shown in **Table 3.10**.

45 PLANET is a rail forecasting model originally developed for the Strategic Rail Authority in 2002 as part of a study considering the case for new high speed rail lines in the UK, and is now used by HS2 Ltd

46 DfT UK Aviation Forecasts, January 2013, paragraphs 3.43-3.46, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

| Table 3.10: Original markets for NAPAM growth rates | |
|---|---|
| Scheduled UK business | Domestic |
| Scheduled UK leisure | International LCC |
| Scheduled foreign business | Domestic LCC (obsolete as domestic legacy and LCCs merged) |
| Scheduled foreign leisure | I-I transfer |
| Charter | Miscellaneous ('others') |

**3.65** This led to a loss of accuracy in translating growth rates between NAPDM and NAPAM. NAPDM has five geographical regions: Domestic, Europe, OECD, NIC and LDC. NAPAM and its local growth interface have been extensively modified to incorporate separate growth rates for all 27 demand markets output by the upstream demand model NAPDM. This ensured that the two models were accurately aligned and no forecasting precision was lost. NAPAM now applies growth rates for these 27 markets as shown in **Table 3.11**.

| Table 3.11: Markets for NAPAM growth rates | |
|---|---|
| 1-4) | Scheduled UK Business for WE, OECD, NIC, LDC |
| 5-8) | Scheduled UK Leisure for WE, OECD, NIC, LDC |
| 9-12) | Scheduled Foreign Business for WE, OECD, NIC, LDC |
| 13-16) | Scheduled Foreign Leisure for WE, OECD, NIC, LDC |
| 17) | Charter short-haul |
| 18) | Charter long-haul |
| 19) | LCC UK Business |
| 20) | LCC UK Leisure |
| 21) | LCC Foreign Business |
| 22) | LCC Foreign Leisure |
| 23) | Domestic Business |
| 24) | Domestic Leisure |
| 25) | Miscellaneous/others |
| 26) | Blank (formerly Domestic LCC) |
| 27) | I-I interliners |

**3.66** Only categories 1 to 24 are modelled at the district level, requiring differential local growth rates to be applied in the local growth interface module.

## Model convergence

**3.67** NAPAM finds an equilibrium solution to runway and terminal capacity constraints. As demand begins to exceed capacity in regional airport systems, the process of finding a shadow cost to clear excess demand (either by suppressing it or through reallocation to less preferred airports) becomes increasingly difficult computationally. Therefore solving to airport passenger or terminal capacity is done within user input tolerances.

**3.68** The key tolerances which were changed from the January 2013 forecasts were:

- passenger capacities were to be within +/- 1.5% of input capacity (previously +/-3%); except:
  - at smaller airports where the tolerance was an absolute number set at 200,000 (previously 600,000);
  - where an airport is overloaded on both runways and terminals and where a runway shadow cost is used to solve both a runway and terminal constraint, the terminal capacity tolerance was decreased to +4.5% (previously +12%); and,
- runway capacity is internally calculated as a runway passenger capacity (average aircraft passenger load multiplied by number of ATMs), but with a final check that the ATMs calculated by the Larame graphs match the input ATM capacities at airports with runway shadow costs.

**3.69** These changes were made possible by the falling level of the input demand forecasts since 2008. For particular tests, such as high demand cases, it can still be necessary to relax some of these tolerances back towards their previous levels. However, for all new baseline forecasts, the tightened constraints have been applied with the result that the model requires more iterations for convergence, and that output shadow costs are slightly higher due to the more stringent convergence targets.

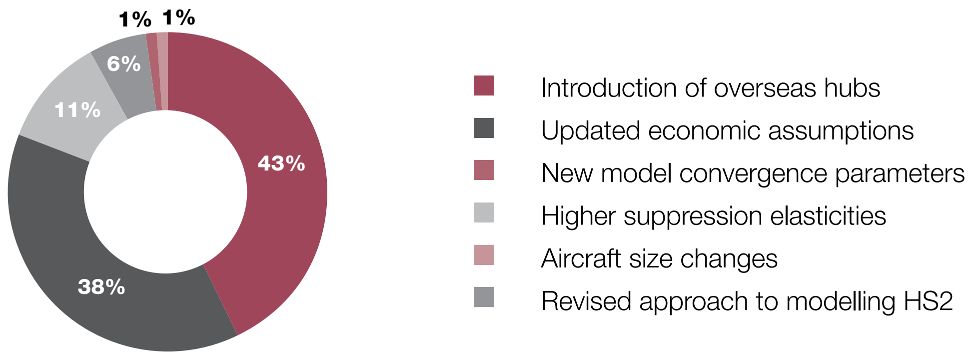
## Summary of the impact of model developments

**3.70** To assess the impact of individual model updates, successive model runs were undertaken removing each. To ensure each update was treated equally, all were individually assessed against the same capacity constrained baseline. The complexity of some changes meant it was not practical to conduct model runs to assess the impact of updates – for example, the impact of improving the mapping between NAPDM and NAPAM has not been assessed.[47] **Figure 3.8** provides an indication as to the relative importance of each update on UK demand in 2050.

**3.71** The biggest change in demand was caused by the introduction of overseas hubs for non-UK based I-I transfer traffic. This is a significant change to the model and has the effect of allowing international transfer passengers an alternative location for transfers (rather than being suppressed), therefore reducing international transfer passenger demand at capacity constrained Heathrow. This change reduces the modelled shadow cost at constrained airports. As a sensitivity a second appraisal has been undertaken. Further details can be found at paragraph 2.14 of this appendix.

**3.72** The other large impact is due to the updated economic assumptions, described in more detail in **Section 4.**

**Figure 3.8: Proportion of change in demand by model update, 2050**




## Model validation

**3.73** The model updates described so far necessitated a revalidation exercise. The purpose of this was to ensure that the model could accurately reflect current patterns of airport use, traffic on particular routes, aircraft movements and aircraft passenger loads. **Table 3.12** (with graphic) compares modelled passengers at the most significant airports, including overseas hubs, with observed data. It can be seen that a good correspondence between modelled and observed data has been achieved.

47 For this reason, and also because these developments interact with each other, summing up the impact of each of these estimates does not exactly match the total change from the forecasts produced by DfT in January 2013 to these Airports Commission forecasts

**Table 3.12: Actual compared with modelled passengers (millions) in 2011 at larger UK airports and the foreign hubs**

| Airport | Actual | Fitted |
|---|---|---|
| Heathrow | 69.4 | 68.8 |
| Gatwick | 33.6 | 34.1 |
| Stansted | 18.0 | 17.8 |
| Luton | 9.5 | 10.2 |
| London City | 3.0 | 3.3 |
| **London total** | **133.6** | **134.1** |
| Manchester | 18.8 | 20.2 |
| Birmingham | 8.6 | 8.2 |
| Glasgow | 6.9 | 6.5 |
| Edinburgh | 9.4 | 8.6 |
| Bristol | 5.8 | 5.5 |
| Newcastle | 4.3 | 4.1 |
| Belfast International | 4.1 | 4.1 |
| Liverpool | 5.2 | 5.1 |
| East Midlands | 4.2 | 3.5 |
| Other airports in model | 16.8 | 16.7 |
| **UK total** | **217.7** | **216.8** |
| Paris CDG | 57.7 | 57.4 |
| Amsterdam | 41.7 | 41.0 |
| Frankfurt | 53.6 | 53.2 |
| Dubai | 45.6 | 46.1 |
| **Model total** | **416.2** | **414.6** |

*Data source: CAA (2011) and EuroStat (2011)*

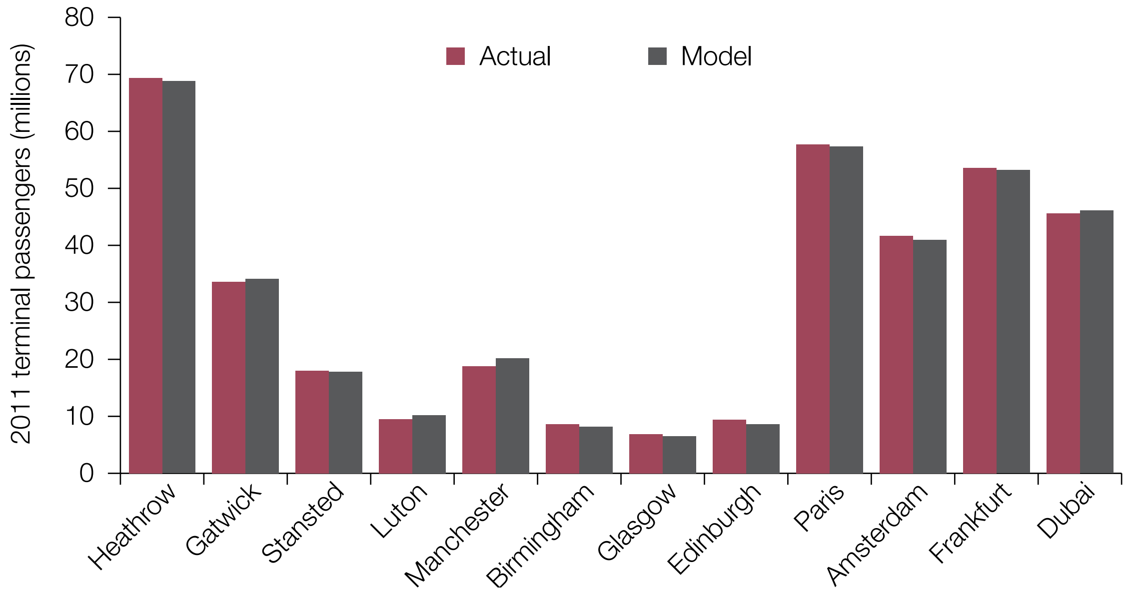
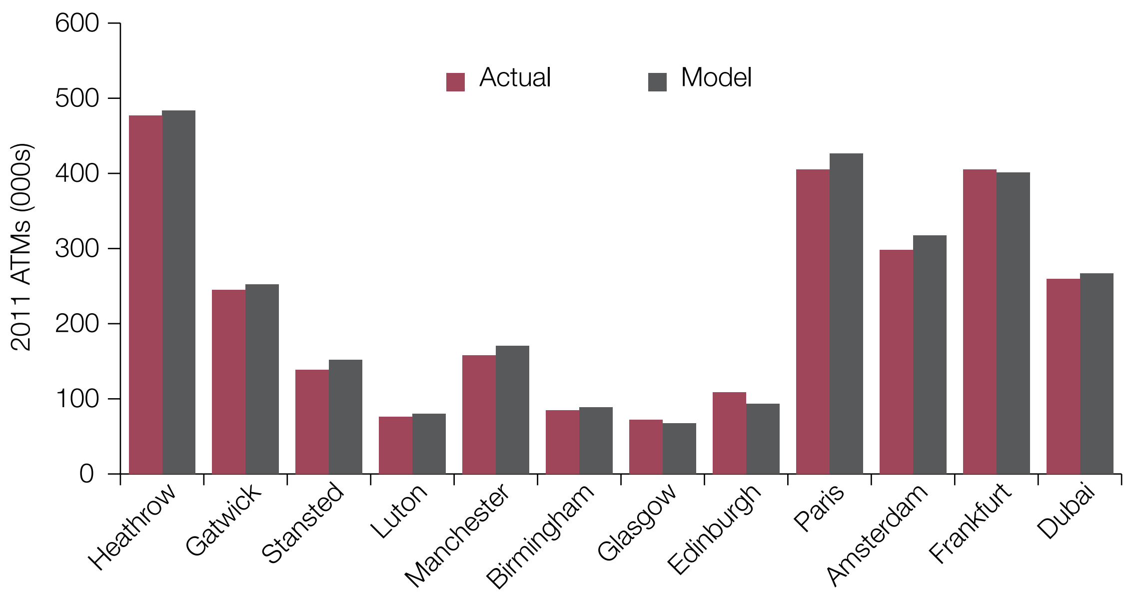


**Table 3.13: Actual compared with modelled ATMs (thousands) in 2011 at larger UK airports and the foreign hubs**

| Airport | Actual | Model |
|---|---|---|
| Heathrow | 477 | 484 |
| Gatwick | 245 | 252 |
| Stansted | 139 | 152 |
| Luton | 76 | 80 |
| London City | 67 | 66 |
| **London total** | **1,004** | **1,035** |
| Manchester | 158 | 170 |
| Birmingham | 85 | 89 |
| Glasgow | 72 | 67 |
| Edinburgh | 109 | 93 |
| Bristol | 53 | 51 |
| Newcastle | 45 | 44 |
| Belfast International | 38 | 44 |
| Liverpool | 46 | 41 |
| East Midlands | 58 | 47 |
| Other airports in model | 341 | 328 |
| **UK total** | **2,010** | **2,008** |
| Paris CDG | 405 | 427 |
| Amsterdam | 298 | 318 |
| Frankfurt | 405 | 401 |
| Dubai | 260 | 267 |
| **Model total** | **3,378** | **3,420** |

*Data source: CAA (2011) and EuroStat (2011)*



3.74 As the overseas hubs are now fully incorporated into the model, it was necessary to ensure that ATMs at these airports are forecast as accurately as at UK airports. This is necessary for accurate modelling of frequencies which in turn drive the representation of connectivity. **Table 3.13** compares modelled ATMs with those reported at the principal airports in the model.

3.75 A new aspect of the modelling has been the allocation of I-I passengers between the seven hubs where the model permits such transfers to take place: Heathrow, Gatwick, Manchester, Paris CDG, Amsterdam Schiphol, Frankfurt and Dubai International. Therefore a new detailed calibration exercise has been undertaken to adjust the allocation of such movements. This has been followed by a hub transfer validation exercise to check that route level transfers taking place at the modelled hubs reflect reality**. Table 3.14** demonstrates a good match between modelled and observed for 2011 data.

**Table 3.14: Goodness of fit of tables of inter-continental traffic at hub airports**

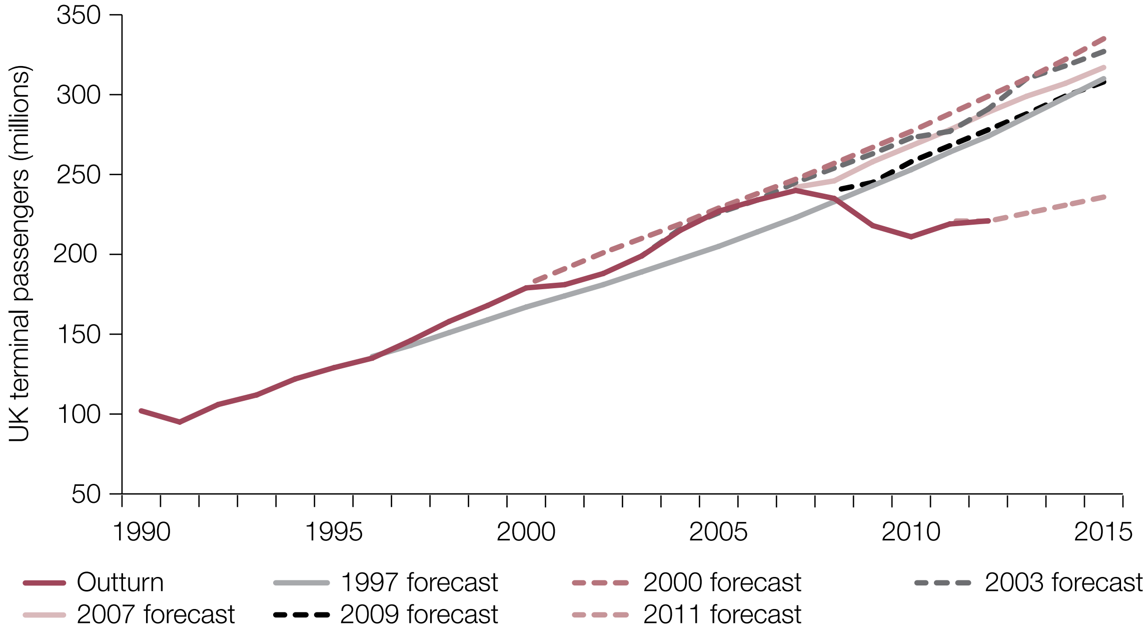
| mppa | Modelled | Actual | Matrix Fit ($r^2$) |
|---|---|---|---|
| Heathrow | 18.5 | 18.6 | 0.989 |
| Amsterdam | 12.6 | 13.1 | 0.992 |
| Paris CDG | 16.6 | 16.3 | 0.996 |
| Frankfurt | 26.4 | 26.7 | 0.995 |
| Dubai | 18.0 | 17.4 | 0.968 |

3.76 The goodness of fit statistic ($r^2$) reports the fit of the modelled inter-continental matrices compared to observed movements based on IATA ticket data.

3.77 The historic performance of DfT forecasts is shown in **Figure 3.9** This shows a step change between the forecasts published by the DfT in 2009[48] and the forecasts prepared in 2011. The new forecasts are discussed in **Chapter 4** of the *Interim Report* and in more detail in **Section 6** of this appendix.

48 The DfT forecasts published in January 2009 had been prepared in the autumn of 2008 and did not take into account the financial crisis which worsened significantly at that time

**Figure 3.9: Historic performance of DfT aviation forecasts**



Section 4:

# Input assumptions

**4.1** Historically, the two main input drivers of aviation demand have been economic activity and air fares. As such, projections of these drivers are required to generate passenger demand forecasts. Forecasts of future economic activity are based on projections of UK and foreign GDP, UK consumer expenditure, and trade. Forecasts of air fares are based on projections of the fare drivers, which include oil prices, fuel efficiency, rates of Air Passenger Duty (APD), carbon prices and other non-fuel costs.

**4.2** This section describes the input assumptions that have been adopted in this set of forecasts, and how they differ from the DfT's January 2013 publication.

## GDP, consumer expenditure and trade

**4.3** The UK GDP and consumer expenditure forecasts are supplied by the Office of Budgetary Responsibility (OBR). The forecasts up to 2017 are taken from *Economic and Fiscal Outlook*, published in March 2013.[49] Long-term UK GDP forecasts are sourced from the OBR's *Fiscal Sustainability Report*, published in July 2013.[50] The Commission assumes that in the long-term, UK consumer expenditure growth follows UK GDP growth rates.

**4.4** Foreign GDP growth rates up to 2018 are sourced from the IMF.[51] Beyond 2018, annualised foreign GDP growth rates from the OECD *Economic Outlook No 93*, published in June 2013, are used.[52] This contains forecasts for selected countries up to 2060. Where a GDP forecast for a country not included in the OECD list is needed, the relevant country has been given the same growth rate as other countries with the same geographical classification in NAPDM – these classifications are described in **Section 3**. This process resulted in the weighted average GDP growth rates detailed in **Table 4.1**.

49 http://budgetresponsibility.org.uk/economic-and-fiscal-outlook-march-2013/
50 http://budgetresponsibility.independent.gov.uk/fiscal-sustainability-report-july-2013/
51 World Economic Outlook, April 2013, http://www.imf.org/external/pubs/ft/weo/2013/01/pdf/text.pdf
52 http://stats.oecd.org/index.aspx?DataSetCode=EO93_INTERNET

| Table 4.1: Foreign GDP percentage growth rates by geographical market | | | | | |
|---|---|---|---|---|---|
| Year | Source | Western Europe | OECD | Newly Industrialised Countries (NIC) | Less Developed Countries (LDC) |
| 2008 | IMF | 0.79 | 0.15 | 5.38 | 5.09 |
| 2009 | | -3.80 | -2.59 | 0.70 | 2.41 |
| 2010 | | 1.43 | 2.63 | 6.97 | 4.58 |
| 2011 | | 1.27 | 1.90 | 5.73 | 2.82 |
| 2012 | | -0.53 | 2.30 | 4.23 | 4.91 |
| 2013 | | -0.14 | 1.94 | 4.47 | 3.80 |
| 2014 | | 1.42 | 2.86 | 4.86 | 4.17 |
| 2015 | | 1.88 | 3.25 | 4.99 | 4.70 |
| 2016 | | 2.07 | 3.17 | 5.06 | 4.89 |
| 2017 | | 2.11 | 3.11 | 5.06 | 4.91 |
| 2018 | | 2.12 | 2.79 | 5.06 | 4.86 |
| 2019 | OECD | 1.83 | 1.90 | 3.82 | 2.58 |
| 2020 onwards | | 1.83 | 1.90 | 3.82 | 2.58 |

**4.5** Based on an assessment of the historic relationship between trade and GDP growth rates, and in line with the DfT forecasts produced in January 2013, it is assumed that trade with Western Europe and other OECD members grows at the same rate as the local GDP of those regions. Trade with NICs and LDCs grows at the same rate as UK GDP. This reflects DfT research which identified these historic relationships between visible trade and GDP by region.[53]

## Oil prices

**4.6** There are two key changes that the Commission has made to assumptions around oil prices which differ to the DfT forecasts produced in January 2013:

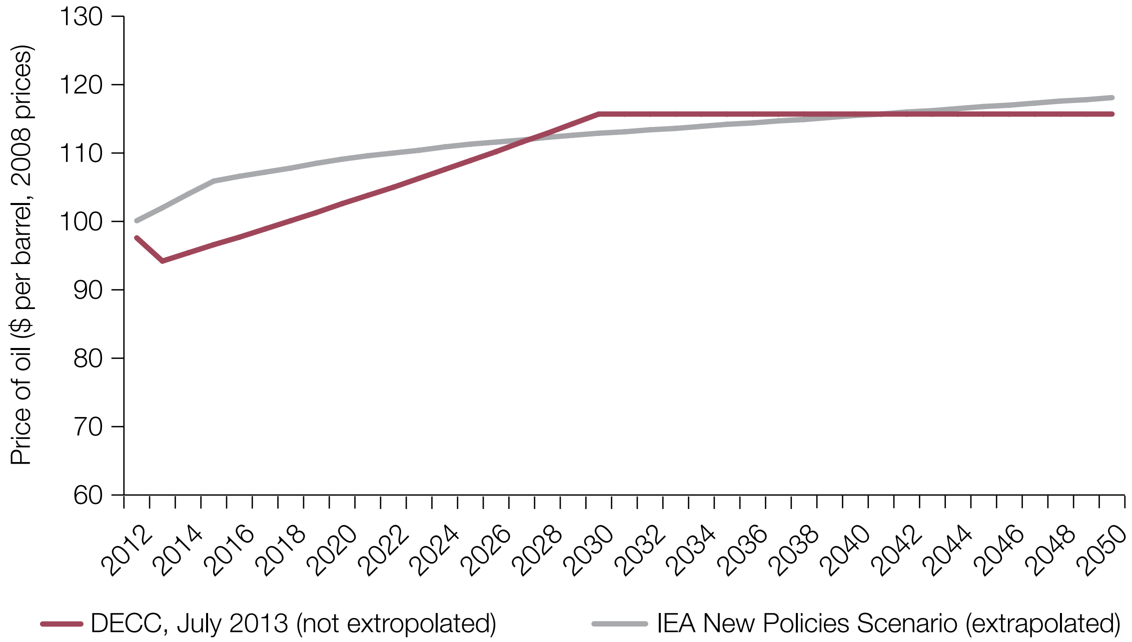
- oil price forecasts are taken from the International Energy Agency (IEA) rather than from the Department for Energy and Climate Change (DECC); and,
- the forecasts have been extrapolated to 2050. In January 2013, the DfT assumed that the DECC oil prices would remain flat after 2030. In the updated assumptions, the IEA forecast is extrapolated by applying the average growth rate between 2030 and 2035 to the rest of the forecast period.

53 DfT UK Aviation Forecasts, January 2013, paragraph 3.8, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

**4.7** The IEA forecasts used are based on their 'New Policies Scenario', which is the central scenario of the *World Energy Outlook*, produced in conjunction with the OECD.[54] The scenario takes account of broad policy commitments and plans that have been announced, including national pledges to reduce greenhouse-gas emissions and the G20 commitment to phase out fossil-fuel subsidies, even if the specific measures to implement these commitments have yet to be identified or announced.

**4.8** **Figure 4.1** shows the difference between the extrapolated IEA oil prices in use and the updated DECC alternative of the type that the DfT had been using.

**Figure 4.1: Oil price forecasts**




## Carbon prices

**4.9** Assumptions regarding carbon price are described in detail in **Section 5**.

## Market maturity

**4.10** Market maturity assumptions act to reduce passenger demand growth when markets are judged to be maturing, i.e. when the historic relationships between drivers of air passenger demand and demand starts to weaken. The approach

54 IEA/OECD "World Energy Model Documentation". 2012 Version, http://www.worldenergyoutlook.org/media/weowebsite/energymodel/documentation/WEM_Documentation_WEO2012.pdf

taken to market maturity is unchanged from that reported by the DfT in the January 2013 forecasts, where it is described in detail.[55]

**Other demand inputs**

**4.11** The Commission has sourced exchange rates up to 2013-14 from the OBR's *Economic and Fiscal Outlook*.[56] Beyond this date, they are assumed to be held constant at the 2013-14 level.

**4.12** APD rates are those currently applied and are sourced from HMRC.

**4.13** Fuel efficiency changes over time are determined by the outputs of NAPAM, as they depend on the mix of routes and aircraft in operation. The approach taken to reflecting changes in aircraft technology and its impact on fuel efficiency and fares is described in chapter 3 of the DfT's January 2013 publication.

**4.14** The DfT assume that biofuels will account for 0.5% of fuel on flights using UK airports by 2030, and 2.5% by 2050. Given the uncertainty surrounding the price and availability of biofuels, the Commission has chosen to retain this conservative approach.

## Summary of updated economic input assumptions

**4.15** **Table 4.2** sets out the economic input assumptions the Commission is using. The biggest change in demand was caused by the update to forecast foreign GDP growth. The new source (OECD) was less optimistic about the prospects for growth in the long-term than the Enerdata forecasts used previously.

55 DfT UK Aviation Forecasts, January 2013 particularly Chapter 3 and Annex A, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013
56 http://budgetresponsibility.org.uk/category/topics/economic-forecasts/

| Table 4.2: Summary of updated economic input assumptions | | | |
|---|---|---|---|
| Item | Period | DfT Jan 2013 source | Airports Commission, December 2013 source |
| UK GDP forecast | 2011-2017 | OBR, December 2012 | OBR, March 2013 |
| | 2018+ | OBR, July 2012 | OBR, July 2013 |
| Consumer expenditure | 2011-2017 | OBR, December 2012 | OBR, March 2013 |
| | 2018+ | Grown in line with UK GDP | Grown in line with UK GDP |
| Exchange rates | 2011-2017 | OBR, December 2012 | OBR, July 2013 |
| Foreign GDP | 2011-2018 | IMF, October 2012 | IMF, April 2013 |
| | 2019+ | Enerdata, January 2012 | OECD, June 2013 |
| Oil prices | 2011-2030 | DECC, October 2012 | IEA New Policies Scenario, November 2012 |
| | 2031-2035 | Held at 2030 level | IEA New Policies Scenario, November 2012 |
| | 2036-2050 | Held at 2030 level | IEA New Policies Scenario Extrapolated |
| Carbon prices | 2011-2030 | DECC, October 2012 | DECC, September 2013 |
| | 2030-2050 | DECC, October 2011 | DECC, October 2011 |
| APD | 2011+ | HMRC, August 2012 | HMRC, April 2013 |
| Fuel efficiency | 2011+ | DfT, January 2013 | DfT, October 2013 |

## Local demand growth at the foreign hubs

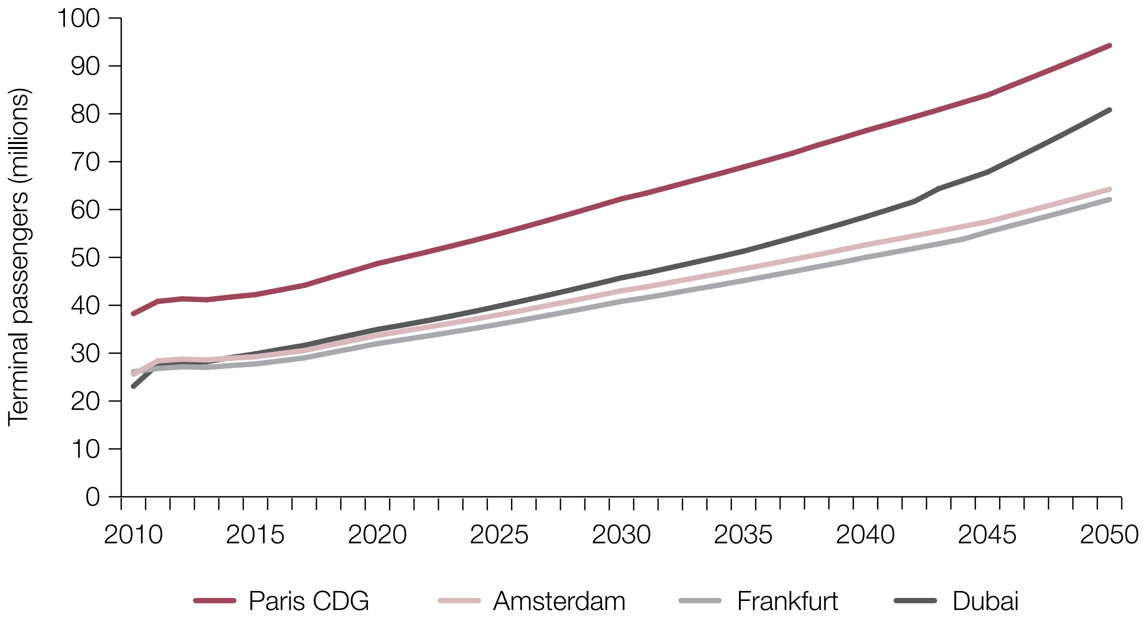
**4.16** The inclusion of overseas hubs as modelled airports in NAPAM means that the Commission has been required to forecast how demand at these airports will change, even for those trips which are not to or from the UK and could not reasonably be expected to be interlining at a UK airport. This local demand affects both the likelihood of a hub reaching capacity and therefore incurring a shadow cost, and the frequencies of services that the airport offers.

**4.17** The impact of this local demand on UK passengers is estimated to be small, and so it is not appropriate to build new econometric models to estimate indigenous overseas demand growth at these airports. Instead, demand at overseas European hubs – excluding international transfer passengers – is assumed to grow at the same rate as total UK unconstrained demand. Local demand at Dubai International airport is assumed to grow at the same rate as demand to and from NICs from UK airports – a faster rate than at European hubs.

**4.18** As demand growth rates are calculated in NAPDM, they respond to changes, for example, in oil and carbon prices. It is effectively assumed that all overseas hubs face the same carbon price as UK airports for all traffic. Although this assumption has been necessitated by the structure of the model, it would be consistent with an assumption that there will eventually be a global carbon market in which international aviation is a participant.

**4.19** Resulting growth in passenger demand modelled in NAPAM for overseas hubs is shown in **Figure 4.2** for the capacity unconstrained and carbon traded scenario.

**Figure 4.2: Passenger demand at overseas hubs, excluding international transfer passengers**




## Baseline airport capacities

**4.20** **Table 4.3** gives the assumed capacities for the baseline capacity constrained option. These capacities are in line with those used by the DfT in their last forecasts.[57] They assume that:

- no new runways are built in the UK;
- extra capacity included in planning applications or published masterplans is constructed;
- terminal capacity is increased incrementally to service additional runway capacity where there is no planning constraint; and,
- depending on location, runways are subject to up to 13% capacity gain through operational and technological improvements.

57 DfT UK Aviation Forecasts, January 2013, pp 56- 57, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

**Table 4.3: ATM and passenger capacities for capacity constrained options**

| | ATMs (000s) | | | Terminal passengers (mppa) | | |
|---|---|---|---|---|---|---|
| | 2011 | 2030 | 2050 | 2011 | 2030 | 2050 |
| **London airports** | | | | | | |
| Heathrow | 480 | 480 | 480 | 90 | 90 | 90 |
| Gatwick | 273 | 280 | 280 | 40 | 45 | 45 |
| Stansted | 245 | 259 | 259 | 35 | 35 | 35 |
| Luton | 130 | 160 | 160 | 12 | 18 | 18 |
| London City | 120 | 120 | 120 | 8 | 8 | 8 |
| **London total** | **1,247** | **1,299** | **1,299** | **185** | **196** | **196** |
| **Rest of UK** | | | | | | |
| Aberdeen | 100 | 150 | 150 | 6 | 6 | 6 |
| Belfast International | 210 | 260 | 260 | 10 | 23 | 23 |
| Belfast City | 45 | 110 | 110 | 4 | 8 | 8 |
| Birmingham | 189 | 206 | 206 | 18 | 37 | 37 |
| Bournemouth | 150 | 150 | 150 | 3 | 5 | 5 |
| Bristol | 150 | 226 | 226 | 10 | 12 | 12 |
| Cardiff | 105 | 150 | 150 | 3 | 8 | 8 |
| East Midlands | 264 | 264 | 264 | 6 | 14 | 14 |
| Edinburgh | 150 | 225 | 225 | 13 | 20 | 20 |
| Exeter | 150 | 150 | 150 | 2 | 4 | 4 |
| Glasgow | 226 | 226 | 226 | 10 | 20 | 20 |
| Humberside | 150 | 150 | 150 | 1 | 3 | 3 |
| Inverness | 150 | 150 | 150 | 1 | 3 | 3 |
| Leeds/Bradford | 150 | 150 | 150 | 3 | 8 | 8 |
| Liverpool | 213 | 213 | 213 | 7 | 15 | 15 |
| Manchester | 324 | 400 | 500 | 25 | 38 | 55 |
| Newcastle | 213 | 226 | 226 | 9 | 15 | 15 |
| Newquay | 75 | 75 | 75 | 1 | 3 | 3 |
| Norwich | 175 | 175 | 175 | 2 | 3 | 3 |
| Southend | 0 | 53 | 53 | 0 | 2 | 2 |
| Southampton | 150 | 150 | 150 | 3 | 7 | 7 |
| Durham Tees Valley | 150 | 150 | 150 | 1 | 2 | 2 |
| Blackpool | 150 | 150 | 150 | 1 | 3 | 5 |
| Coventry | 150 | 150 | 150 | 1 | 2 | 2 |
| Doncaster Sheffield | 57 | 80 | 80 | 2 | 7 | 7 |
| Prestwick | 150 | 225 | 225 | 3 | 12 | 12 |
| **Rest of UK total** | 3,996 | 4,614 | 4,714 | 143 | 277 | 296 |
| **UK total** | **5,243** | **5,913** | **6,013** | **327** | **473** | **492** |

Section 5:

# $CO_2$ modelling

## $CO_2$ emission targets

**5.1** Two types of carbon scenario have been modelled. The carbon traded scenarios assume that aviation participates in an emissions trading system (ETS), and so 'net' $CO_2$ costs are included in fares. Under an ETS, net $CO_2$ emissions from flights covered by the system cannot increase above the level of the cap, and an increase in the 'gross' $CO_2$ emissions from flights covered by the system would therefore not increase the net $CO_2$ emissions from these flights. However, it is assumed that there would be no cap on the gross emissions from the sector.

**5.2** Carbon prices are based on the recommended traded values provided by DECC for use in policy appraisals, and it is assumed that the $CO_2$ emissions from flights to and from the UK would be covered by the EU ETS until at least 2020 and covered by a global carbon market beyond then.[58]

**5.3** The Climate Change Act 2008 set a target for total UK greenhouse gas emissions to be reduced by 80% by 2050, relative to a 1990 baseline. Current plans to meet this target assume that $CO_2$ emissions from UK aviation in 2050 should be at or below 2005 levels. This is the carbon capped scenario. When modelling the carbon capped scenarios, UK departing flights' emissions are limited to the 2005 level of 37.5Mt$CO_2$ in 2050.[59]

**5.4** The targeted emissions level is met through supplementing the DECC price of traded carbon already included in the traded carbon scenario. This does not represent a new forecast of carbon prices, but is simply the value required, in the assumed absence of any other mechanism, to achieve the target of no more than 37.5Mt$CO_2$ from aircraft departing UK airports in 2050. The carbon price adjustment only aims at hitting the emissions level in 2050, as achieving the target earlier would require further transitions of the fleet and operational practices, fuels

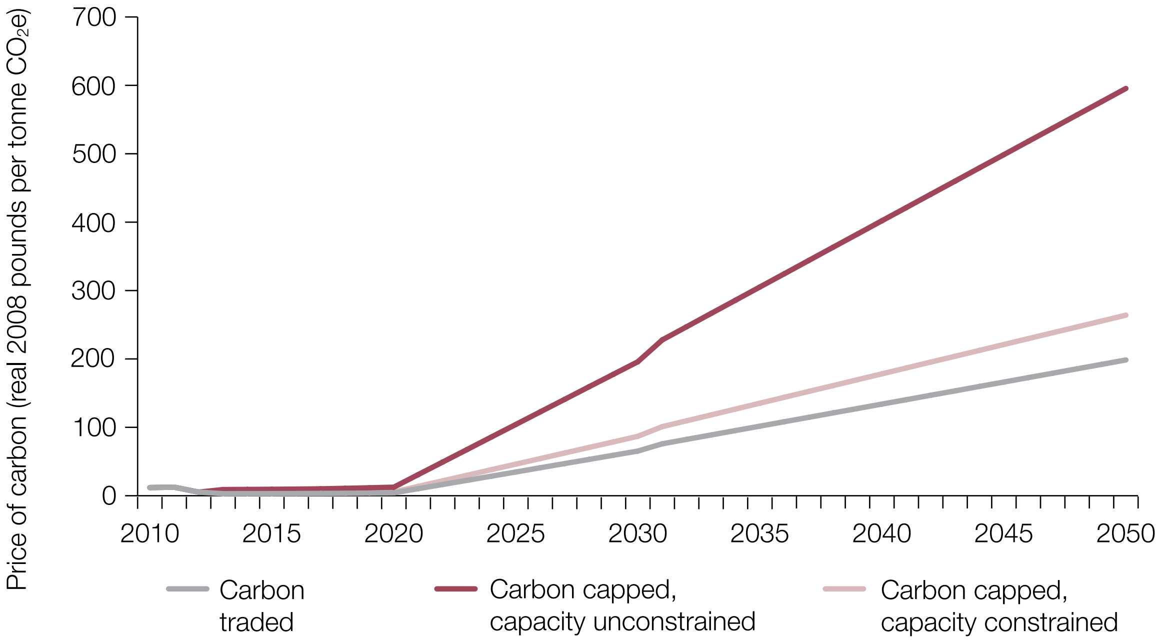
58 This is in line with the Aviation EU ETS scope for 2013 to 2020, which is existing legislation. The EC has adopted a proposal to amend the scope of the Aviation EU ETS following the the ICAO Assembly which agreed to develop a global market based measure to address aviation emissions from 2020. In particular, the EC has proposed that the EU ETS continue to cover the $CO_2$ emissions from flights between airports in the EEA from 2013 to 2020 and that the EU ETS would also cover the $CO_2$ emissions from flights between the EEA and third countries in proportion to the distance travelled within 'European regional airspace' from 2014 to 2020. Further details of the proposal are available at: http://ec.europa.eu/clima/news/articles/news_2013101601_en.htm

59 Committee on Climate Change (2009), Meeting the UK aviation target – options for reducing emissions to 2050, http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/

etc. beyond those included in the baseline. It therefore follows that emissions can, and do, exceed 37.5Mt$CO_2$ prior to 2050.[60] Analysis by the CCC and the DfT has demonstrated that this target could be achieved by mechanisms other than the carbon price.[61]

**5.5** **Figure 5.1** shows the different carbon prices assumed in three scenarios: the traded carbon case; the unconstrained capacity but capped carbon case; and the constrained capacity and capped carbon case.

**Figure 5.1: Carbon prices under different constraint scenarios**




**5.6** The profile of carbon prices is similar up to 2020, because the absolute carbon price is low, and the same proportionate change is applied to the carbon price in all years.

**5.7** The new forecasts show that with carbon capped to the 2005 level of 37.5Mt$CO_2$, passenger numbers in the unconstrained capacity case can increase by 65% and ATMs by 33% above 2005 levels.[62]

60 See DfT UK Aviation Forecasts, January 2013, Chapter 3, paragraphs 3.54-3.68, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

61 Committee on Climate Change (2009), Meeting the UK aviation target – options for reducing emissions to 2050, http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/ and EMRC & AEA, August 2011. A marginal abatement cost curve model for the UK aviation sector, http://assets.dft.gov.uk/publications/response-ccc-report/mac-report.pdf

62 The base 2005 levels are the full UK passenger and ATM totals of 229m and 160m respectively, as reported by the CAA and used by CCC. These totals include some passengers and ATMs at airports not included in the DfT modelling. If they were excluded from the base, the growth rates would rise to 67% and 36% for passengers and ATMs

**5.8** With carbon capped there is higher growth in the capacity constrained scenario than when capacity is unconstrained. This is attributable to an increase in short-haul journeys. When capacity constraints are applied in the carbon capped scenarios, ATMs in 2050 are 5% higher because more demand is displaced to regional airports serviced by smaller aircraft.

## Comparison with CCC forecasts

**5.9** The CCC forecasts used a base of 2005 in contrast to the new model base of 2011.[63] Despite this, there are many similarities between the forecasts:

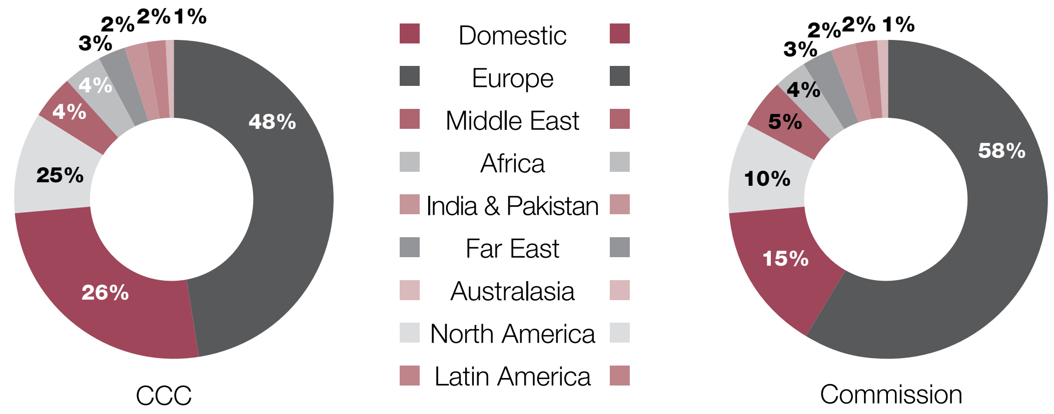
- both forecast total passengers of around 380 million in 2050 with a carbon cap in effect;
- both project similar proportions of long-haul and short-haul passengers and ATMs;
- there are broadly similar forecasts of total long-haul passengers and of growth rates between the different long-haul markets; and,
- the CCC project a fuel efficiency gain between 2005 and 2050 of 0.8% per annum, while this forecast projects a gain of 0.9%.

**5.10** The CCC model forecast of carbon capped and unconstrained capacity results in UK total terminal passengers of 380 million compared to 377 million in these forecasts.[64] There is also much similarity in the modelled destinations of these passengers. **Figure 5.2** compares the destinations of the passengers modelled in 2050 in the two forecasts. Both assume that by 2050 long-haul flights carry 26% of passengers and are 12% of ATMs. The most obvious difference in the pattern of destinations is in the split between the domestic and short-haul passengers.

63 Committee on Climate Change (2009), Meeting the UK aviation target – options for reducing emissions to 2050, http://www.theccc.org.uk/reports/aviation-report

64 ‘Unconstrained’ in the CCC model assumed the then (2009) policy of one additional runway at Heathrow and one additional runway at Stansted, unlike the Commission’s unconstrained forecasts where every airport is unconstrained

**Figure 5.2: Destinations of passengers in CCC and Commission forecasts for 2050**




**5.11** But the most significant difference between the CCC and Commission forecast is in the number of ATMs that can be accommodated within the carbon cap. While ATMs in the CCC forecasts grew by 55% from 2.2 to 3.4 million, in the new forecasts they grow by just 33% to 2.9 million. The difference is driven mainly by the modelling of, and underlying assumptions about, the loads on aircraft (passengers/ ATM) and the distances passengers will be flying.

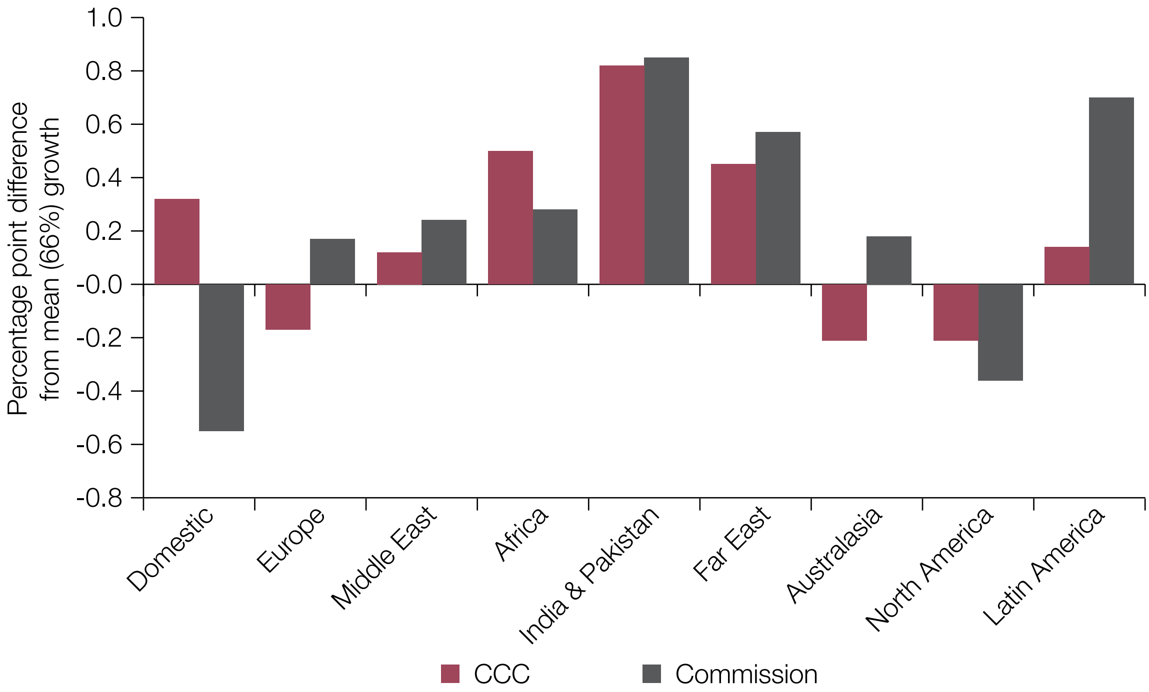
**5.12** The CCC forecasts were made in 2009 from a 2005 baseline. The CCC projected that with carbon capping, passenger demand would grow by 66% from 229 to 380 million and that revenue passenger-km (seats sold multiplied by distance travelled) would grow from 541 billion passenger-km to 905 billion passenger-km, an increase of 67%. This shows that overall the distance travelled did not increase in the forecasts made by the CCC in 2009. In these new forecasts (which have been modified here to provide a direct comparison to the CCC, including a 2005 base year[65]), the average distance flown in the model baseline is higher but there is still an increase in passenger-km travelled of 95%, which results in an 18% increase in the average flight length. Therefore fewer ATMs are accommodated within the same overall emissions total.

**5.13** **Figure 5.3** shows the difference from the average passenger growth rate of 67% by destination in the two forecasts. The graphic is not scaled by passenger numbers,[66] but helps explain the effect described above.

65 2005 base outputs are taken from an earlier DfT model version

66 Note that in **Figure 5.3** short-haul followed by domestic are much the biggest markets in both 2005 and 2050, while the smallest markets (with between 3 and 9 million passengers) are Australasia, Latin America and Indian and Pakistan

**Figure 5.3: Difference (percentage points) from average (66%) passenger growth, 2005-2050 in both CCC and Commission forecasts**




**5.14** Although both forecasts have broadly similar long-haul trends, with common patterns of growth in the Asian and maturity in the North Atlantic markets, the most significant difference is that domestic air passengers have grown by 98% from 2005 to 2050 in the CCC forecasts, but by only 11% in the Commission's forecast. This offsets a lower CCC European short-haul forecast. As domestic flights are made by smaller aircraft over shorter distances, this difference helps to explain the CCC's shorter flight lengths. It should be noted that this new domestic forecast takes into account:

- the decline in domestic passengers from around 50 million in the 2005 CCC model baseline to around 36 million passengers in the current model's 2011 baseline;
- the impact of HS2; and,
- a lower underlying unconstrained growth forecast for domestic passengers.[67]

67 An additional factor is that the CCC also included all UK passenger movements in the 2005 base whereas this modelling includes the 29 largest airports. The additional passengers at the smaller airports account for some 2.5 million passengers in the base year, but they are almost all domestic and on small aircraft

**5.15** Although the Commission's forecast shows a lower number of ATMs with the capacity constraint, overall passenger numbers are broadly consistent with the CCC forecast. This reflects the assumption of higher passenger loads per ATM in the Commission forecast. In paragraphs 3.46-3.53 it has been described how aircraft size and loading modelling has been kept under review by the Commission with the result of larger aircraft sizes being increasingly modelled.[68] There was no equivalent to this type of detailed route by route aircraft modelling in the CCC's forecasts.

**5.16** In the CCC forecast passengers per ATM only increased by 5% in the modelled period. In the Commission's forecast the average load per aircraft increases by 24% by 2050, with short-haul aircraft seeing a 21% increase in passenger loads, and long-haul aircraft seeing a 38% increase. The CCC model therefore forecasts a significantly smaller fleet of aircraft, requiring a greater number of ATMs to service broadly the same number of passengers.

**5.17** **Table 5.1** draws together a set of key indicators which illustrate and help explain the differences between the two forecasts. It should be noted that in the table, passenger and ATM data have been compared with common baseline statistics from the CAA. However, the distance based statistics of fleet outputs in the second half of the table do not have published statistics, so are therefore compared with their respective model bases which differ slightly in terms of the numbers of airports and routes included.[69] The underlying demand forecasts have also been made at different times: 2009 for the CCC and late 2013 for these forecasts. Therefore they inevitably have some significantly different input assumptions, not least differing GDP profiles.

68 'Larame' graphs

69 The Commission modelling includes the 29 largest UK airports which excludes around 1% of total passengers travelling mainly on domestic flights at small airports. The Commission model has a base year of 2008 and validation year of 2011, so the 2005 base outputs are taken from an earlier DfT model version which was validated to 2005. The 2050 unconstrained forecasts also have different capacity assumptions as the CCC assumed maximum use of existing capacity with additional runways at Heathrow and Stansted whereas these new forecasts assume no constraint anywhere

**Table 5.1: Comparison of key indicators and outputs in the CCC 2009 and Commission forecasts**

| | 2005 Base | | 2050 Carbon capped | |
|---|---|---|---|---|
| | Actuals | | CCC | Airports Commission |
| Passengers and ATMs | | | | |
| Passengers (m) | **229** | | 380 | 377 |
| *Growth* | | | *66%* | *65%* |
| ATMs (thousands) | **2,160** | | 3,418 | 2,870* |
| *Growth* | | | *58%* | *33%* |
| Short-haul passengers (m) | **171** | | 281 | 278 |
| *Growth* | | | *64%* | *62%* |
| Long-haul passengers (m) | **58** | | 100 | 99 |
| *Growth* | | | *73%* | *72%* |
| Short-haul ATMs (thousands) | **1,887** | | 2,993 | 2,529 |
| *Growth* | | | *59%* | *34%* |
| Long-haul ATMs (thousands) | **274** | | 424 | 340 |
| *Growth* | | | *55%* | *24%* |
| Passengers per ATM | **106** | | 111 | 131 |
| *Growth* | | | *5%* | *24%* |
| | CCC | Airports Commission | CCC | Airports Commission |
| Output | | | | |
| Fuel efficiciency: seat-km/ tonne fuel | 73,845 | 81,157 | 107,479 | 123,680 |
| *Growth per annum* | | | *0.8%* | *0.9%* |
| Revenue-km (passenger-km) (m) | 540,829 | 588,937 | 905,344 | 1,145,505 |
| *Growth* | | | *67%* | *95%* |
| Seat-km (m) | 692,790 | 782,794 | 1,060,117 | 1,440,237 |
| | | | *53%* | *84%* |
| Load factor (distance weighted) | 78% | 75% | 85% | 80% |
| Average journey length (km) | 2,362 | 2,572 | 2,379 | 3,039 |

** Excludes freight*

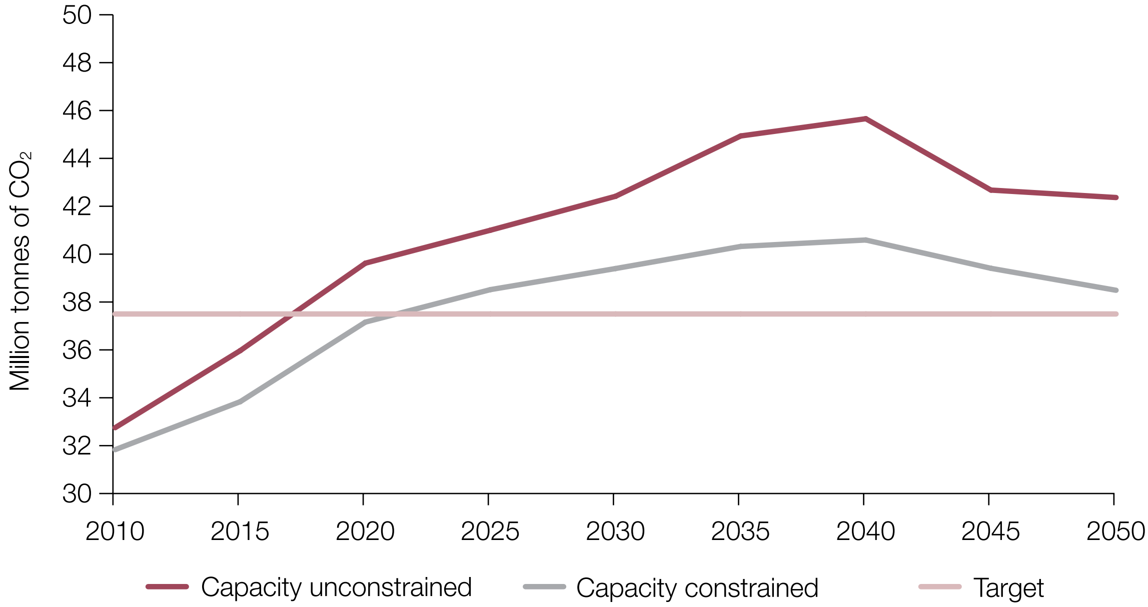
## Aircraft fleets and fuel efficiency

**5.18** The forecasting of the size of future aircraft, the composition and turnover of future aircraft fleets, fuel efficiency and emissions makes use of the DfT's Fleet Mix and $CO_2$ models. The Commission described the DfT's techniques in the discussion paper *Aviation and Climate Change* and adapted the model to make additional analyses of carbon leakage. Given the relatively static nature of UK fleets in recent years, the existing models have been used again for this analysis.[70]

## $CO_2$ emission forecasts

**5.19** **Figure 5.4** shows the $CO_2$ emissions forecasts before the carbon capping through pricing is applied. This shows that even on the basis of the new forecasts and with runway capacity remaining constrained, some additional measures would still be required to keep 2050 emissions to 2005 levels.

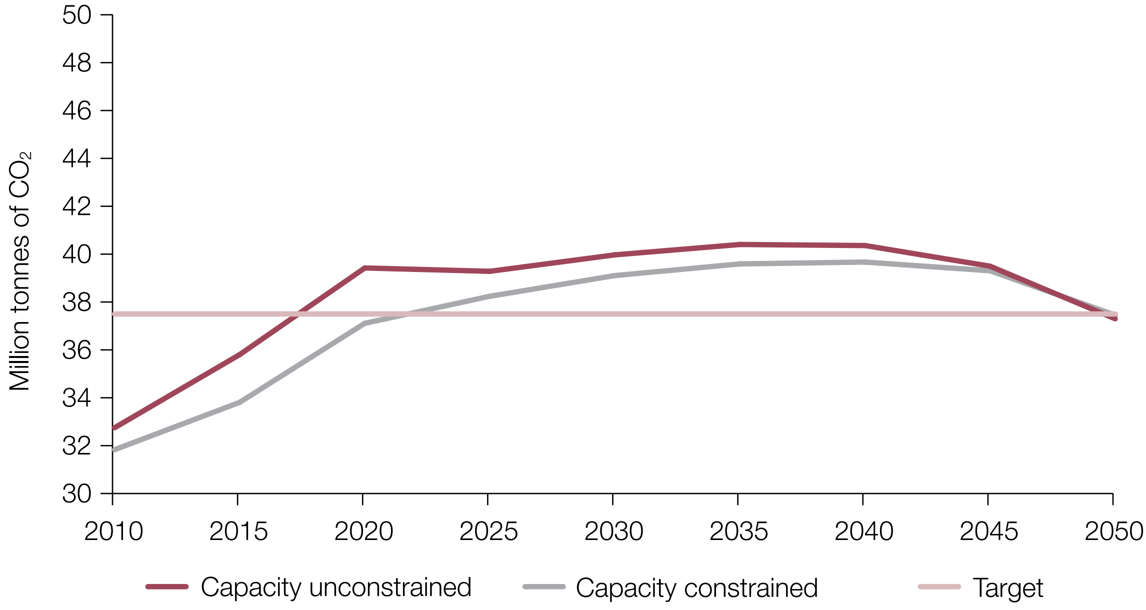
**Figure 5.4 Departing $CO_2$ forecasts without a carbon cap (carbon traded)**




**5.20** **Figure 5.5** shows the effect of increasing carbon prices to achieve the carbon cap, without making any additional or operational adjustments. The 37.5Mt$CO_2$ target would be exceeded before it is achieved in 2050.

70 Airports Commission, Aviation and Climate Change discussion paper, April 2013, in particular Chapter 4, for a critique of the DfT fleet and carbon modelling, https://www.gov.uk/government/publications/discussion-paper-on-aviation-and-climate-change. DfT description in UK Aviation forecasts, January 2013, Chapter 3, paragraphs 2.51-2.61and paragraphs 3.54-3.68, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

**Figure 5.5 Departing $CO_2$ forecasts with carbon capped**




## Export of $CO_2$

**5.21** In an uncapped carbon world (but one subject to an ETS) the effect of capacity constraints at UK airports is to reduce UK $CO_2$ emissions by around 3Mt in 2030, 5Mt in 2040 and 4Mt in 2050 (as indicated by **Figure 5.4**).

**5.22** The Commission, in its discussion paper on climate change, examined the extent to which these savings in $CO_2$ emissions from aviation in the UK are not global savings but 'leaks' to overseas airports.[71] As it is assumed in the forecast that all flights departing European airports are covered by the EU ETS and by a global trading scheme after 2020, despite leakage the net global emissions will be zero after 2020 but national emissions inventories will be affected.

**5.23** The modelling provides opportunities to extend the leakage analysis by applying it to the latest forecasts. Leakage out of the UK airport system can take two forms:

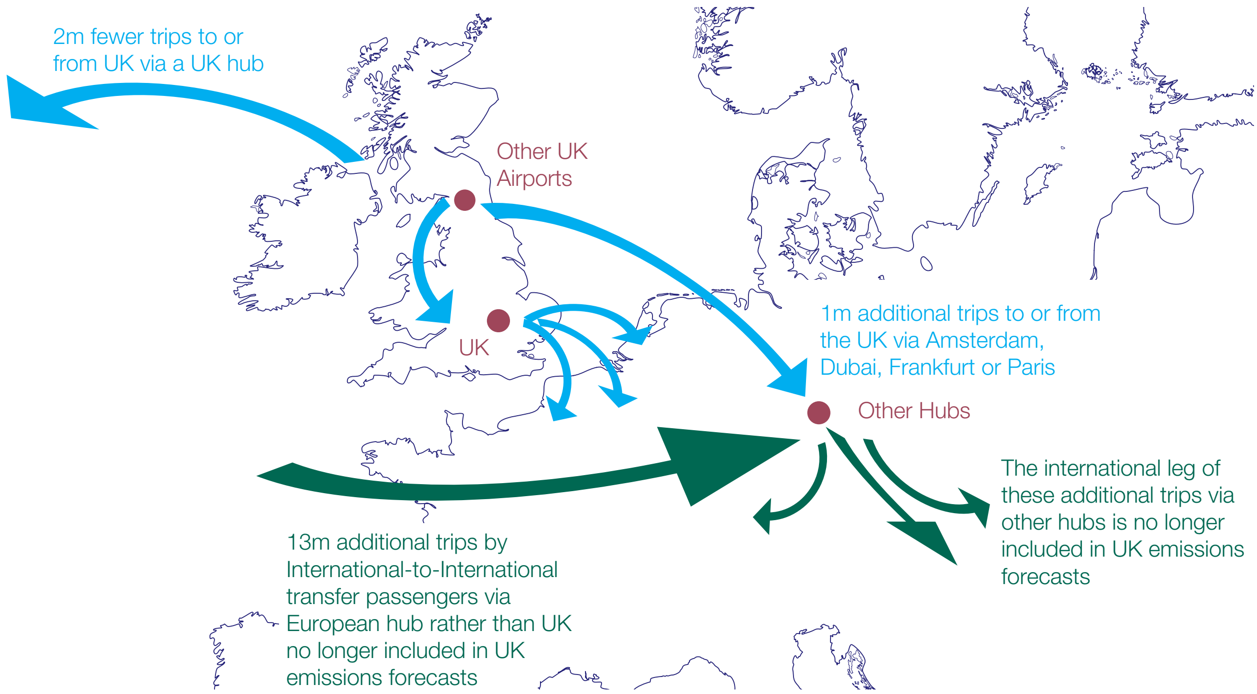
- passengers who begin or end their journeys in the UK who might previously have reached their ultimate destination by a direct route or via a UK hub but who now have to use an overseas hub to make an onward connection for what will usually be the longer leg of their overall journey – these are referred to as 'international interliners'; and,
- passengers who are not resident in or visiting the UK but who use a UK hub airport to make a transfer – referred to as 'I-I interliners'.

71 Airports Commission, Aviation and Climate Change discussion paper, April 2013, in particular Chapter 5 for a discussion on the leakage of carbon, https://www.gov.uk/government/publications/discussion-paper-on-aviation-and-climate-change

**5.24** When the UK airport system is capacity constrained, some passengers making transfers at UK hubs are likely to change route. If such passengers continue to travel by alternative routes to their final destination, then although their emissions are removed from the UK $CO_2$ inventory, their emissions are transferred to another airport somewhere else in the world.

**5.25** In 2050, if capacity constraints are imposed, 25 million trips (approximately 50 million terminal passengers) are no longer made from UK airports. Of these 25 million passenger trips, around nine million are direct international journeys from the UK; there are a further one million internal domestic trips. The rest of the change is in transfer traffic. **Figure 5.6** illustrates the changing pattern of transfer movements between the UK and overseas hubs in the presence of capacity constraints and how these have an impact on the calculation of emissions.

**Figure 5.6: Changes in transfer trips between the capacity constrained and unconstrained scenarios in 2050**




**5.26** Trips which will continue to count towards UK emissions are highlighted in blue. Trips that will now count towards other countries' emissions, and where the associated emissions can therefore be said to have 'leaked', are highlighted in green.

**5.27** The most significant contributor to exported emissions are the 26 million I-I terminal passengers (13 million trips) who move from the UK to foreign hubs by 2050. This is higher than the figure presented in the Commission's discussion paper.[72] The main reason for this is the incorporation of Amsterdam Schiphol, Paris CDG, Frankfurt and Dubai International into the model, which enables a more accurate assessment of the $CO_2$ impact of this transfer. It should be noted, however, that an emissions trading system would neutralise the global carbon impact.

5.28 **Table 5.2** examines the leakage of UK emissions, calculated on a per-passenger basis, for the period 2020 to 2050. The analysis suggests that almost all of the $CO_2$ potentially saved from the reduction in UK terminal passenger trips is exported to foreign hubs.

**Table 5.2: Contribution of exported $CO_2$ to UK departing flight emissions inventory**

| $MtCO_2$ | UK departing $CO_2$ capacity unconstrained | UK departing $CO_2$ capacity constrained | Change | Total $CO_2$ exported | Exported international interliner $CO_2$ | Exported I to I interliner $CO_2$ | Constrained $CO_2$ total | Additional export % |
|---|---|---|---|---|---|---|---|---|
| 2020 | 39.6 | 37.2 | -2.5 | 2.8 | 0.1 | 2.7 | 40.0 | 8% |
| 2030 | 42.4 | 39.4 | -3.0 | 3.9 | 0.1 | 3.8 | 43.3 | 10% |
| 2040 | 45.7 | 40.6 | -5.1 | 4.6 | 0.2 | 4.4 | 45.1 | 11% |
| 2050 | 42.4 | 38.5 | -3.9 | 3.4 | 0.2 | 3.2 | 41.9 | 9% |

5.29 The onward trip lengths of the international interliners tend to be shorter than those of I-I transfers. **Table 5.3** illustrates a relatively constant relationship between these 'leaked' passengers and their associated emissions. However, the I-I interliners exported make longer connecting flights through foreign hubs and potentially contribute around a further 10% to the UK emissions attributable to passenger aviation.

**Table 5.3: Share of exported passengers and $CO_2$ of capacity constrained total, 2020-2050**

| | International interliners | | I to I interliners | |
|---|---|---|---|---|
| | Total passengers | Total UK $CO_2$ | Total passengers | Total UK $CO_2$ |
| 2020 | 0.1% | 0.2% | 4.0% | 7.3% |
| 2030 | 0.2% | 0.3% | 5.5% | 9.6% |
| 2040 | 0.3% | 0.4% | 6.3% | 10.8% |
| 2050 | 0.5% | 0.6% | 5.1% | 8.2% |

72 The standard calculation of emissions is made on a per ATM basis. However for transfer passengers emissions have to use a hybrid per passenger methodology. The approach taken is to make use of the DfT $CO_2$ model which takes account of changes to the future aircraft fleets and which now also allows detailed fleet modelling at the overseas hub airports. The DfT $CO_2$ model can output a rate per passenger for each of the 48 international destinations for each modelled year and locally varied for the future fleet at each hub airport. These rates can then be applied to the net change in transfer passengers to each destination zone

# Section 6:

# Baseline passenger forecasts

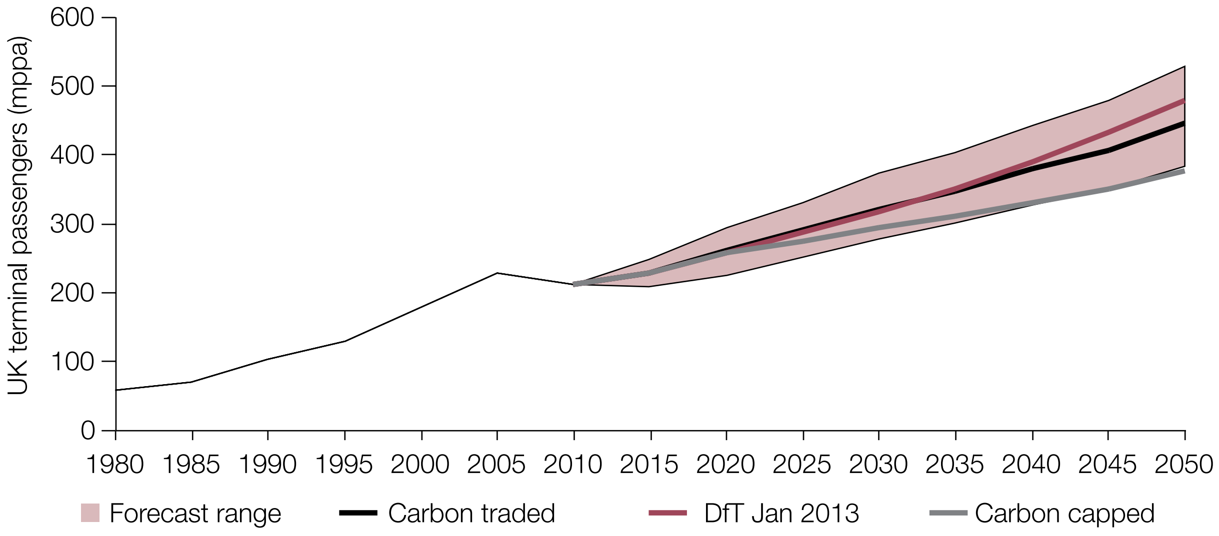
**6.1** This section sets out the detail behind the forecasts presented in **Chapter 4** of the *Interim Report*.

## National demand

**6.2** **Figure 6.1** illustrates the range forecast in a carbon traded scenario, using the new approach to uncertainty modelling described in **Section 3**. By 2050, unconstrained demand lies in the range 380 million to 530 million with a central forecast of 450 million, some 30 million lower than the DfT January 2013 forecast.

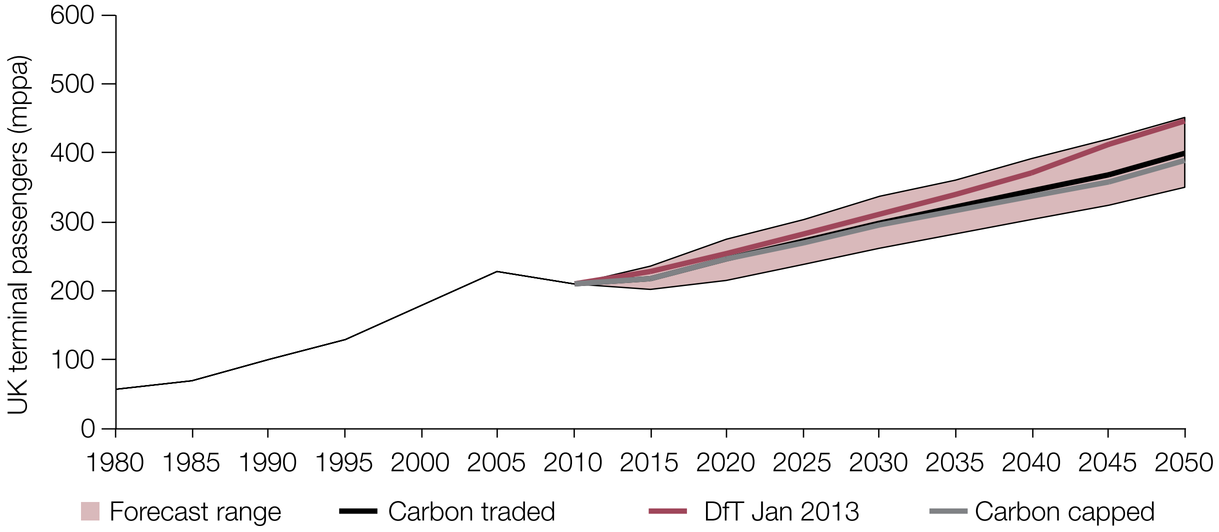
**6.3** It is not possible to present a range around the carbon capped forecasts because the methodology employed is to find a level of carbon price which drives down flights to a level which limits $CO_2$ emissions to 37.5Mt. This methodology precludes all but the narrowest of ranges and is unsuited to the Monte Carlo approach described in **Section 3.**

**Figure 6.1: Unconstrained capacity and low-high demand range**




**6.4** As **Figure 6.2** shows, the range narrows to 350 million to 450 million by 2050 when capacity constraints are applied. The new central forecast of 400 million is lower than the previous DfT central forecast of 450 million.

**Figure 6.2: Constrained capacity and low-high demand range**




**6.5** **Table 6.1** shows demand forecasts across the London airport system and at a selection of other large airports for the case where no additional runway capacity is added. After 2030 growth in the London airport system slows down dramatically as airports reach capacity, with growth accelerating at airports outside the London airport system in the final years of the forecast as a result.

**6.6** **Table 6.2** repeats the analysis for the carbon capped scenario. The pattern of growth in the London airport system is similar to the carbon traded scenario. There is slightly slower growth in airports outside the London airport system in the final years of the forecast than in the carbon traded scenario.

**Table 6.1: Terminal passenger forecasts, carbon traded, capacity constrained (million passengers)**

| Airport | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 69 | 75 | 81 | 83 | 90 |
| Gatwick | 34 | 39 | 41 | 44 | 46 |
| Stansted | 18 | 19 | 26 | 35 | 35 |
| Luton | 10 | 13 | 18 | 18 | 18 |
| London City | 3 | 5 | 7 | 7 | 7 |
| **London total** | **134** | **151** | **173** | **187** | **196** |
| **London annual growth rate** | | **1.4%** | **1.3%** | **0.8%** | **0.5%** |
| Manchester | 20 | 22 | 28 | 35 | 47 |
| Birmingham | 8 | 13 | 18 | 26 | 30 |
| Glasgow | 6 | 7 | 8 | 9 | 11 |
| Edinburgh | 9 | 10 | 14 | 16 | 19 |
| Bristol | 6 | 5 | 8 | 10 | 12 |
| Newcastle | 4 | 4 | 5 | 6 | 7 |
| Belfast International | 4 | 5 | 6 | 8 | 9 |
| Liverpool | 5 | 5 | 6 | 8 | 9 |
| East Midlands | 4 | 4 | 4 | 6 | 12 |
| Other modelled UK | 17 | 22 | 29 | 36 | 48 |
| Non-London annual growth rate | | 1.7% | 2.7% | 2.3% | 2.6% |
| **UK total** | **217** | **248** | **299** | **346** | **400** |
| **UK annual growth rate** | | **1.5%** | **1.9%** | **1.5%** | **1.5%** |
| Paris CDG | 57 | 66 | 81 | 94 | 117 |
| Amsterdam | 41 | 47 | 59 | 71 | 91 |
| Frankfurt | 53 | 64 | 83 | 103 | 114 |
| Dubai | 46 | 57 | 70 | 86 | 113 |
| **Foreign hub total** | **198** | **233** | **292** | **354** | **435** |
| **Foreign hub annual growth rate** | | **1.9%** | **2.3%** | **1.9%** | **2.1%** |

| Table 6.2: Terminal passenger forecasts, carbon capped, capacity constrained (million passengers) | | | | | |
|---|---|---|---|---|---|
| Airport | 2011 | 2020 | 2030 | 2040 | 2050 |
| Heathrow | 69 | 75 | 82 | 83 | 91 |
| Gatwick | 34 | 39 | 41 | 43 | 45 |
| Stansted | 18 | 19 | 25 | 35 | 35 |
| Luton | 10 | 13 | 18 | 18 | 18 |
| London City | 3 | 5 | 6 | 7 | 7 |
| **London total** | **134** | **151** | **172** | **186** | **195** |
| **London annual growth rate** | | **1.3%** | **1.3%** | **0.8%** | **0.5%** |
| Manchester | 20 | 22 | 28 | 33 | 44 |
| Birmingham | 8 | 13 | 17 | 24 | 29 |
| Glasgow | 6 | 7 | 8 | 9 | 10 |
| Edinburgh | 9 | 10 | 13 | 16 | 19 |
| Bristol | 6 | 5 | 7 | 9 | 12 |
| Newcastle | 4 | 4 | 5 | 6 | 6 |
| Belfast International | 4 | 5 | 6 | 7 | 9 |
| Liverpool | 5 | 5 | 6 | 7 | 9 |
| East Midlands | 4 | 4 | 4 | 5 | 10 |
| Other modelled UK | 17 | 22 | 28 | 35 | 46 |
| Non-London annual growth rate | | 1.7% | 2.5% | 2.2% | 2.4% |
| **UK total** | **217** | **247** | **295** | **338** | **389** |
| **UK annual growth rate** | | **1.5%** | **1.8%** | **1.4%** | **1.4%** |
| Paris CDG | 57 | 65 | 80 | 92 | 113 |
| Amsterdam | 41 | 47 | 58 | 69 | 87 |
| Frankfurt | 53 | 64 | 81 | 102 | 113 |
| Dubai | 46 | 57 | 69 | 84 | 110 |
| **Foreign hub total** | **198** | **233** | **288** | **347** | **423** |
| **Foreign hub annual growth rate** | | **1.8%** | **2.1%** | **1.9%** | **2.0%** |

6.7 **Table 6.3** presents the low–high demand range.[73] The maximum throughput that can be accommodated in the UK airport system, given the capacity constraints, is around 450 million passengers per annum (mppa) in the high range.

73 The Monte Carlo analysis has been used to vary the input forecast variables so that it is estimated that there is only a 20% probability that demand will fall below the low forecast and only a 20% probability that demand will exceed the high forecast

**Table 6.3: Low-high range of terminal passenger forecasts capacity constrained, carbon traded, principal UK airports and foreign hubs**

| Airport | Base 2011 | Low end of range 20pc | | | | High end of range (80pc) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2020 | 2030 | 2040 | 2050 | 2020 | 2030 | 2040 | 2050 |
| Heathrow | 69 | 74 | 78 | 81 | 85 | 76 | 82 | 85 | 99 |
| Gatwick | 34 | 28 | 36 | 42 | 44 | 40 | 43 | 47 | 45 |
| Stansted | 18 | 17 | 21 | 28 | 35 | 23 | 35 | 35 | 35 |
| Luton | 10 | 11 | 15 | 18 | 18 | 17 | 18 | 18 | 18 |
| London City | 3 | 5 | 7 | 6 | 7 | 7 | 7 | 7 | 7 |
| **London total** | **134** | **134** | **157** | **175** | **188** | **163** | **184** | **192** | **204** |
| **London annual growth rate** | | **0.0%** | **1.6%** | **1.1%** | **0.7%** | **2.2%** | **1.2%** | **0.4%** | **0.6%** |
| Manchester | 20 | 19 | 25 | 31 | 39 | 25 | 33 | 44 | 55 |
| Birmingham | 8 | 11 | 14 | 19 | 26 | 16 | 25 | 30 | 37 |
| Glasgow | 6 | 6 | 7 | 8 | 9 | 8 | 9 | 11 | 15 |
| Edinburgh | 9 | 9 | 12 | 14 | 17 | 11 | 16 | 18 | 20 |
| Bristol | 6 | 4 | 5 | 6 | 9 | 6 | 10 | 12 | 12 |
| Newcastle | 4 | 4 | 4 | 5 | 6 | 5 | 6 | 7 | 8 |
| Belfast International | 4 | 4 | 5 | 7 | 8 | 6 | 7 | 9 | 9 |
| Liverpool | 5 | 4 | 5 | 6 | 7 | 6 | 8 | 12 | 15 |
| East Midlands | 4 | 3 | 4 | 5 | 6 | 4 | 5 | 10 | 14 |
| Other modelled UK | 17 | 18 | 24 | 29 | 37 | 24 | 35 | 47 | 64 |
| Non-London annual growth rate | | -0.0% | 2.4% | 2.1% | 2.4% | 3.3% | 3.3% | 2.6% | 2.3% |
| **UK total** | **217** | **217** | **262** | **304** | **352** | **275** | **338** | **391** | **453** |
| **UK annual growth rate** | | **0.0%** | **1.9%** | **1.5%** | **1.5%** | **2.7%** | **2.1%** | **1.5%** | **1.5%** |
| Paris CDG | 57 | 65 | 81 | 93 | 112 | 66 | 83 | 99 | 115 |
| Amsterdam | 41 | 46 | 57 | 69 | 84 | 47 | 59 | 73 | 111 |
| Frankfurt | 53 | 57 | 72 | 92 | 112 | 75 | 98 | 110 | 112 |
| Dubai | 46 | 54 | 66 | 82 | 107 | 60 | 75 | 92 | 121 |
| **Foreign hub total** | **198** | **221** | **276** | **336** | **416** | **248** | **314** | **374** | **460** |
| **Foreign hub annual growth rate** | | **1.2%** | **2.2%** | **2.0%** | **2.2%** | **2.5%** | **2.4%** | **1.8%** | **2.1%** |

**6.8** **Table 6.4** and the associated graphic use the capacity constrained forecasts shown in **Table 6.1** and relate throughput by area to the runway capacities given in **Table 4.3**. Note that the approach to the presentation of analysis in **Table 6.4** and subsequent tables simplify constraints by focusing primarily on runway capacity.

**6.9** They give percentage of the runway capacity used when there is no shadow cost at the airport. Once the airport has a shadow cost, either runway or terminal (such as occurs at Luton and Stansted), then the airport is marked as 100%. Outside London this produces occasional anomalies in the sequence over time: Bristol and Southampton airports appear to lose capacity rapidly in the 2040s. This is because both these airports have a terminal shadow cost by 2050, but up to 2040 only their runway usage is reported.[74]

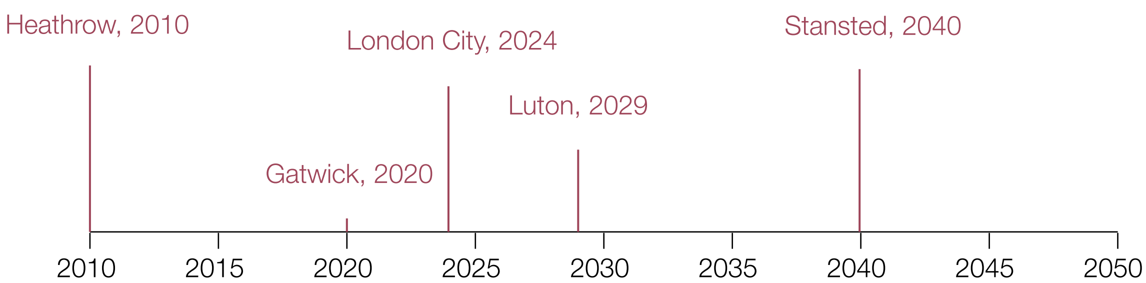
**6.10** The lack of available capacity in London and the South East has the impact of either suppressing demand or reallocating traffic to regional airports. This can be seen at airports such as Birmingham, Bristol and Southampton, which become constrained over the course of the modelled period when capacity is constrained in the London airport system. The impact of these and other capacity constraints are explored later in this section.

74 It is difficult to avoid this effect as modelled airports in congested conditions can have either runway or terminal shadow costs during the forecast period and some alternate. In the cases of Bristol and Southampton, terminal capacity is a relatively hard constraint

**Table 6.4: UK airports runway capacity used and airport at capacity timelines (carbon traded, capacity constrained, central demand)**

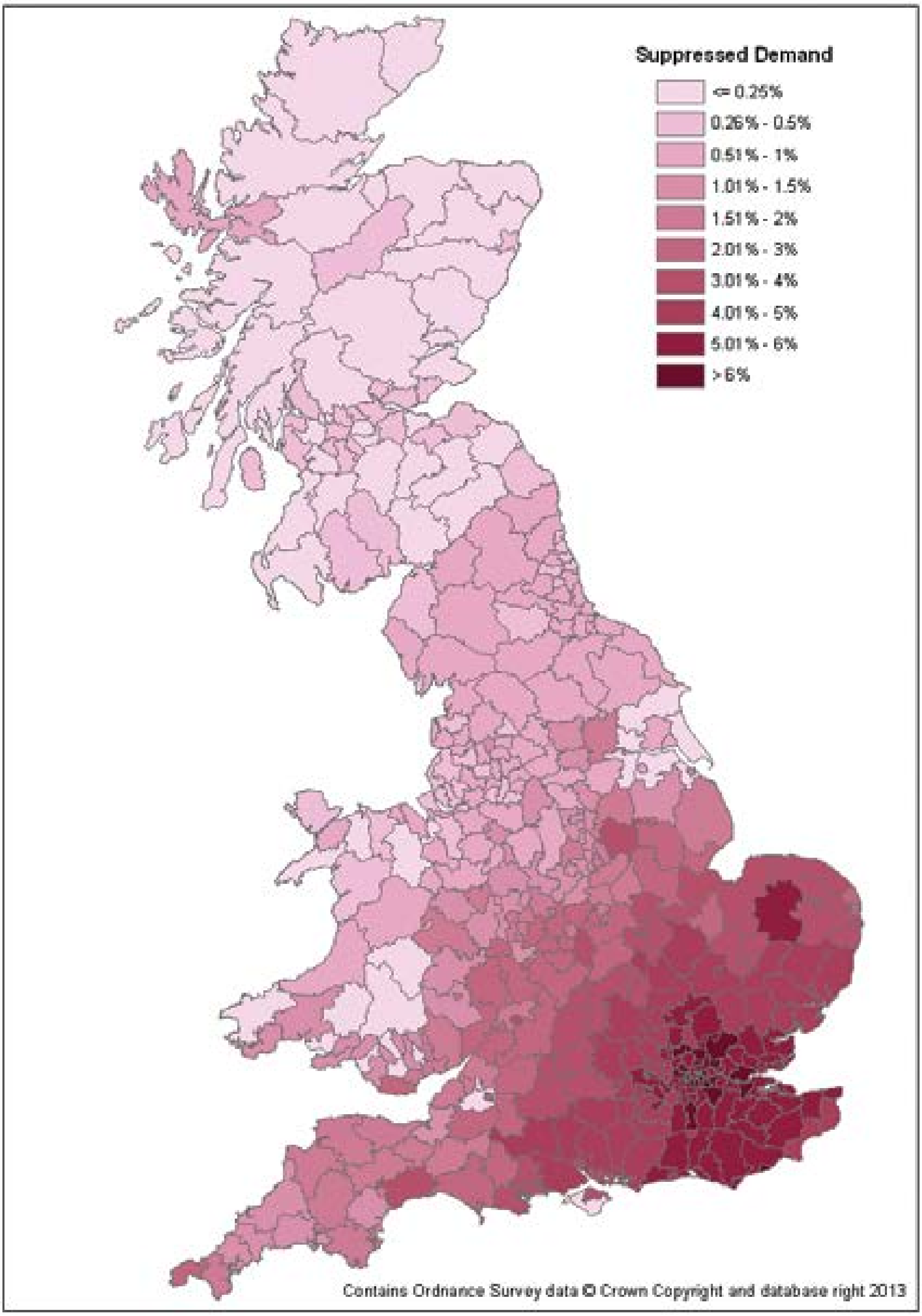
| Central | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 100% | 100% | 100% | 100% |
| Stansted | 62% | 55% | 67% | 100% | 100% |
| Luton | 62% | 58% | 100% | 100% | 100% |
| London City | 55% | 84% | 100% | 100% | 100% |
| **London** | **83%** | **85%** | **91%** | **100%** | **100%** |
| Manchester | 53% | 56% | 53% | 48% | 61% |
| Birmingham | 47% | 53% | 69% | 98% | 100% |
| Bristol | 34% | 30% | 26% | 31% | 100% |
| East Midlands | 18% | 17% | 18% | 21% | 47% |
| Southampton | 28% | 28% | 34% | 48% | 100% |
| Other modelled | 20% | 22% | 24% | 28% | 33% |
| **UK** | **38%** | **40%** | **42%** | **47%** | **52%** |
| Paris CDG | 65% | 64% | 75% | 86% | 100% |
| Amsterdam | 62% | 66% | 63% | 62% | 75% |
| Frankfurt | 84% | 66% | 80% | 95% | 100% |
| Dubai | 67% | 57% | 26% | 25% | 32% |
| **Foreign hubs** | **69%** | **63%** | **54%** | **55%** | **65%** |

100% = runway or terminal capacity exceeded, other %s refer to runway usage.
Mainland UK airports only.




**6.11** **Figure 6.3** shows the proportion of passengers in each local authority district who would have flown if there were no capacity constraints, but who do not fly in the constrained case. It is evident that most of the suppressed demand is in the South East. In other regions passengers are either able to continue to utilise their local airport (which may have new direct routes) or are able to route to their ultimate destination via one of the overseas hubs.

**Figure 6.3: Proportion of air passengers suppressed by district, 2050, carbon traded**[75]




75 When carbon is capped there is broadly similar demand between capacity scenarios

**6.12** The disparity between demand for travel and the currently assumed runway capacity at airports in the South East can be seen in **Figure 6.4** and **Figure 6.5**. When capacity constraints prevent an airport servicing all demand, shadow costs are incurred to either suppress passenger demand (as shown in **Figure 6.3**) or reallocate it to an alternative airport. The differences illustrated in **Figure 6.4** and **Figure 6.5** are indicative of the proportion of passengers who are unable to make their preferred travel choice.

**Figure 6.4: Unconstrained demand and forecast airport runway capacity in 2030, carbon traded**

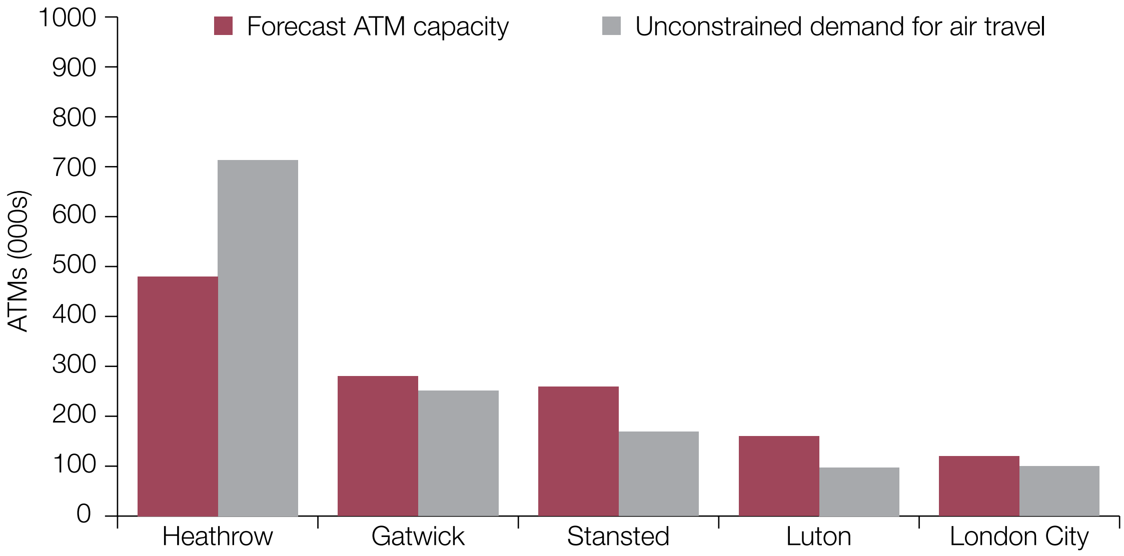
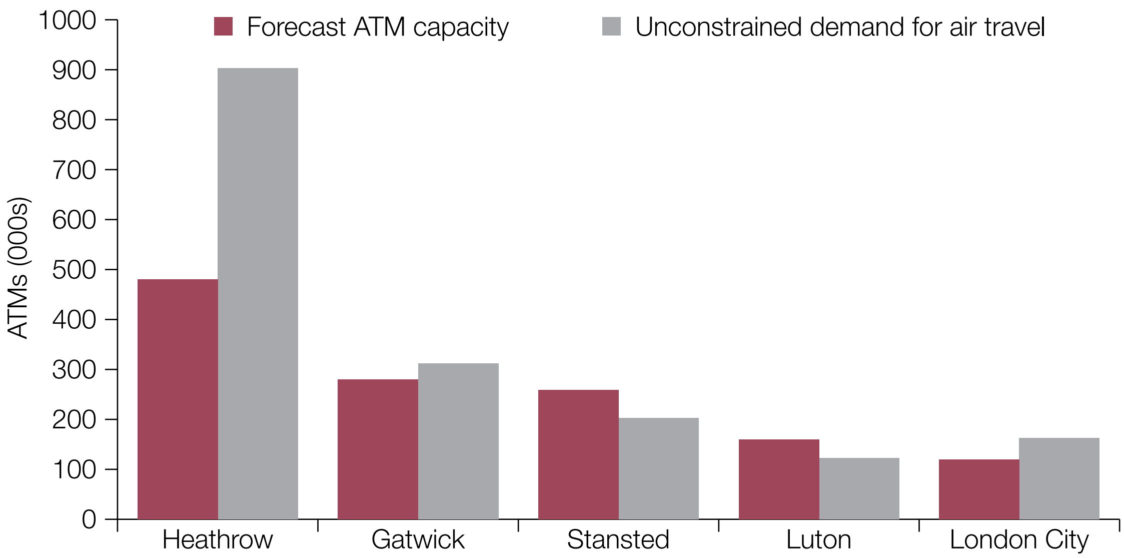



**Figure 6.5: Unconstrained demand and forecast airport runway capacity in 2050, carbon traded**

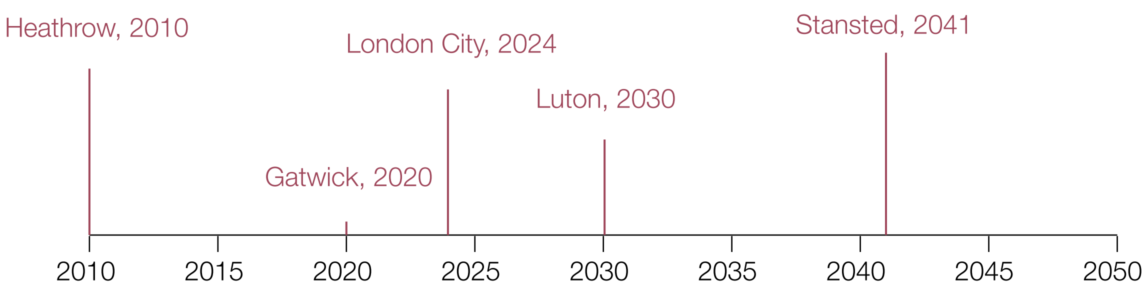


**6.13** **Table 6.5** below uses the carbon capped passenger forecasts shown in **Table 6.1** and relates throughput by area to the runway capacities given in **Table 4.3** to show when London and national capacity is reached, focusing primarily on runway capacity using the method described in paragraph 6.9.

**Table 6.5: UK airports runway capacity used (carbon capped, capacity constrained, central demand)**

| Central | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 100% | 100% | 100% | 100% |
| Stansted | 62% | 55% | 65% | 84% | 100% |
| Luton | 62% | 58% | 100% | 100% | 100% |
| London City | 55% | 84% | 100% | 100% | 100% |
| **London** | **83%** | **85%** | **90%** | **94%** | **100%** |
| Manchester | 53% | 56% | 52% | 47% | 58% |
| Birmingham | 47% | 53% | 68% | 95% | 100% |
| Bristol | 34% | 30% | 25% | 29% | 100% |
| East Midlands | 18% | 17% | 18% | 20% | 35% |
| Southampton | 28% | 28% | 33% | 43% | 100% |
| Other modelled | 20% | 22% | 24% | 27% | 32% |
| **UK** | **38%** | **40%** | **42%** | **46%** | **51%** |
| Paris CDG | 65% | 64% | 74% | 85% | 97% |
| Amsterdam | 62% | 66% | 61% | 60% | 73% |
| Frankfurt | 84% | 65% | 78% | 94% | 100% |
| Dubai | 67% | 57% | 27% | 25% | 31% |
| **Foreign hubs** | **69%** | **63%** | **53%** | **54%** | **63%** |

100% = runway or terminal capacity exceeded, other %s refer to runway usage.
Mainland UK airports only.



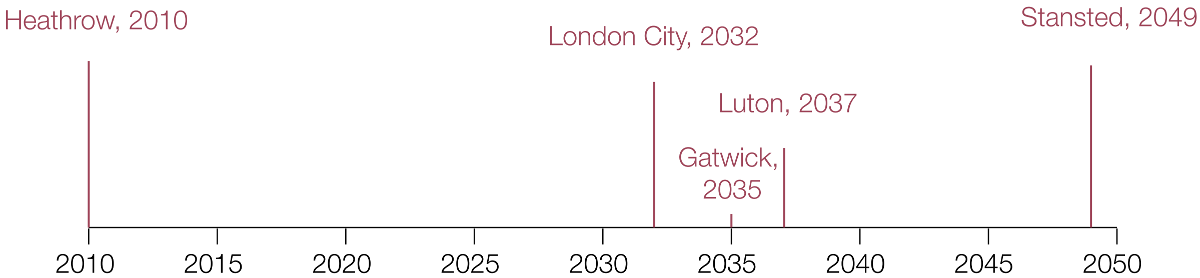

**6.14** Once again, the impact of capacity constraints in the London airport system can be seen at airports elsewhere. Note that the sudden exhaustion of capacity at Bristol and Southampton in the 2040s is explained in paragraph 6.9. This also affects Stansted, which has a terminal shadow cost from 2041 onwards.

6.15 **Table 6.6** and **Table 6.7** present a similar form of analysis for the low-high range. As this range has, by definition, little variation in the carbon capped scenario, only the capacity unconstrained forecasts are presented. They therefore present the range around the analysis reported in **Table 6.4**.

**Table 6.6: UK airports runway capacity used (carbon traded, capacity constrained, LOW demand)**

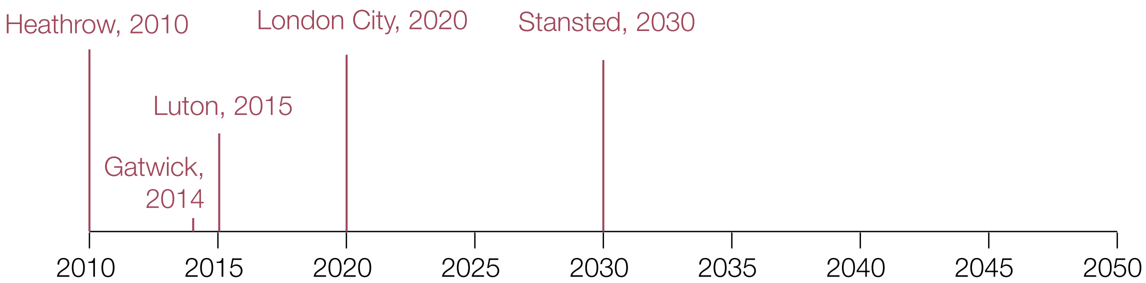
| Central | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 76% | 91% | 100% | 100% |
| Stansted | 62% | 49% | 56% | 65% | 100% |
| Luton | 62% | 51% | 64% | 100% | 100% |
| London City | 55% | 70% | 97% | 100% | 100% |
| **London** | **83%** | **76%** | **84%** | **90%** | **100%** |
| Manchester | 53% | 50% | 48% | 43% | 53% |
| Birmingham | 47% | 44% | 55% | 74% | 100% |
| Bristol | 34% | 25% | 18% | 20% | 28% |
| East Midlands | 18% | 16% | 17% | 18% | 22% |
| Southampton | 28% | 24% | 28% | 34% | 53% |
| Other modelled | 20% | 19% | 21% | 25% | 28% |
| **UK** | **38%** | **36%** | **38%** | **42%** | **47%** |
| Paris CDG | 65% | 64% | 75% | 85% | 96% |
| Amsterdam | 62% | 64% | 61% | 60% | 71% |
| Frankfurt | 84% | 56% | 69% | 86% | 100% |
| Dubai | 67% | 54% | 26% | 24% | 31% |
| **Foreign hubs** | **69%** | **60%** | **51%** | **53%** | **62%** |

100% = runway or terminal capacity exceeded, other %s refer to runway usage.
Mainland UK airports only.



| Table 6.7: UK airports runway capacity used (carbon traded, capacity constrained, HIGH demand) | | | | | |
|---|---|---|---|---|---|
| Central | 2011 | 2020 | 2030 | 2040 | 2050 |
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 100% | 100% | 100% | 100% |
| Stansted | 62% | 66% | 100% | 100% | 100% |
| Luton | 62% | 73% | 100% | 100% | 100% |
| London City | 55% | 100% | 100% | 100% | 100% |
| **London** | **83%** | **91%** | **100%** | **100%** | **100%** |
| Manchester | 53% | 62% | 59% | 57% | 100% |
| Birmingham | 47% | 66% | 97% | 100% | 100% |
| Bristol | 34% | 36% | 34% | 100% | 100% |
| East Midlands | 18% | 18% | 20% | 43% | 100% |
| Southampton | 28% | 33% | 42% | 100% | 100% |
| Other modelled | 20% | 24% | 27% | 31% | 38% |
| **UK** | **38%** | **44%** | **47%** | **52%** | **57%** |
| Paris CDG | 65% | 65% | 76% | 88% | 100% |
| Amsterdam | 62% | 66% | 63% | 63% | 93% |
| Frankfurt | 84% | 76% | 92% | 100% | 100% |
| Dubai | 67% | 57% | 27% | 26% | 34% |
| **Foreign hubs** | **69%** | **66%** | **57%** | **58%** | **68%** |

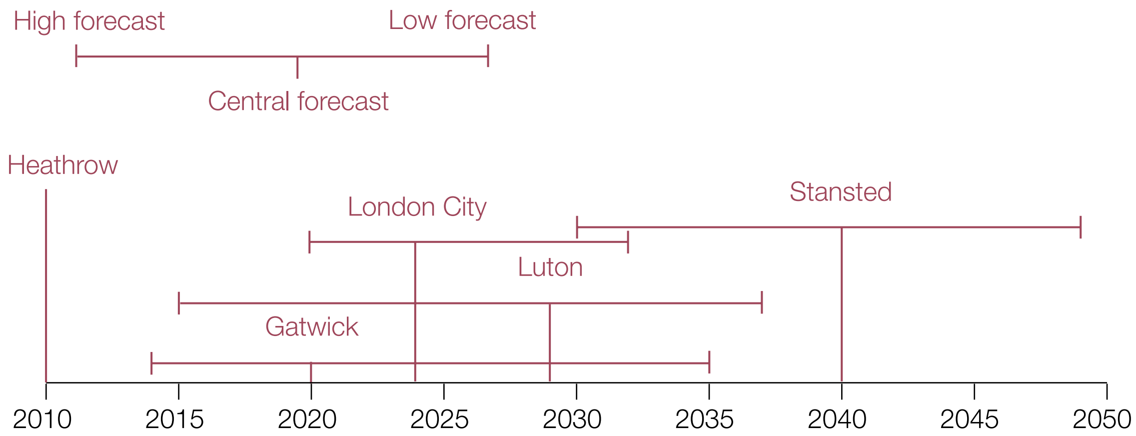
100% = runway or terminal capacity exceeded, other %s refer to runway usage.
Mainland UK airports only.



## Forecast range timelines

**6.16** The timelines of the range of years when the London airport system becomes full are shown in **Figure 6.6** below.

**Figure 6.6:** **Range of years when London airports become full, carbon traded**




## Destinations served and connectivity

**6.17** By comparing the forecasts of numbers of destinations served at major UK airports with capacity unconstrained and constrained, it is possible to estimate the number of routes being lost due to capacity constraints.

**6.18** **Table 6.8** and **Table 6.9** includes a threshold of daily services which is defined as being at least 365 daily scheduled departures a year, or 730 annual passenger ATMs (arriving and departing). The daily threshold applied is relatively stringent. This analysis excludes charter flights.

| Table 6.8: Implied route loss due to capacity constraint in 2050, carbon traded | | | |
|---|---|---|---|
| Carbon traded<br>2050 | Capacity unconstrained | Capacity constrained | Difference |
| Heathrow | 186 | 117 | -69 |
| Gatwick | 93 | 86 | -7 |
| Stansted | 69 | 68 | -1 |
| Luton | 32 | 34 | 2 |
| London City | 32 | 18 | -14 |
| **London*** | **247** | **230** | **-17** |
| Manchester | 74 | 75 | 1 |
| Birmingham | 46 | 62 | 16 |
| Glasgow | 17 | 14 | -3 |
| Edinburgh | 36 | 39 | 3 |
| Bristol | 27 | 36 | 9 |
| Newcastle | 22 | 22 | 0 |
| Other airports | 84 | 112 | 28 |

**Total destinations served in London, not the sum of destinations from London airports*

| Table 6.9: Implied route loss due to capacity constraint in 2050, carbon capped | | | |
|---|---|---|---|
| Carbon capped<br>2050 | Capacity unconstrained | Capacity constrained | Difference |
| Heathrow | 190 | 117 | -73 |
| Gatwick | 71 | 94 | 23 |
| Stansted | 64 | 70 | 6 |
| Luton | 31 | 33 | 2 |
| London City | 21 | 18 | -3 |
| **London*** | **244** | **232** | **-12** |
| Manchester | 65 | 76 | 11 |
| Birmingham | 36 | 66 | 30 |
| Glasgow | 16 | 14 | -2 |
| Edinburgh | 31 | 37 | 6 |
| Bristol | 24 | 40 | 16 |
| Newcastle | 20 | 22 | 2 |
| Other airports | 73 | 103 | 30 |

**Total destinations served in London, not the sum of destinations from London airports*

**6.19** In both carbon traded and carbon capped scenarios, the number of destinations served by the London airport system is much lower when capacity is constrained. In both cases Heathrow is most severely affected by capacity constraints. Airports with fewer capacity constraints, largely outside the South East, see the number of destinations served increase when capacity is constrained.

**6.20** Another useful measure of connectivity is provided by the quantity of available seat-km on scheduled services.[76] **Table 6.10** and **Table 6.11** show the change in available seat-km in each carbon scenario. The difference between the two capacity scenarios is indicative of the benefit that can be expected from removing capacity constraints. This is particularly noticeable in increasing the level of connectivity on routes serving long-haul destinations.

**Table 6.10: Change in modelled seat-km on scheduled, daily services, carbon traded (impact of releasing capacity)**

| Carbon traded | All destinations | | | Long haul destinations only | | |
|---|---|---|---|---|---|---|
| | Capacity unconstrained | Capacity constrained | % change | Capacity unconstrained | Capacity constrained | % change |
| 2020 | 841,462 | 785,210 | 7.2% | 546,835 | 503,170 | 8.7% |
| 2030 | 1,030,869 | 949,752 | 8.5% | 656,713 | 594,345 | 10.5% |
| 2040 | 1,231,921 | 1,087,594 | 13.3% | 800,113 | 680,562 | 17.6% |
| 2050 | 1,338,145 | 1,225,852 | 9.2% | 839,161 | 771,879 | 8.7% |

**Table 6.11: Change in modelled seat-km on scheduled, daily services, carbon capped (impact of releasing capacity)**

| Carbon capped | All destinations | | | Long haul destinations only | | |
|---|---|---|---|---|---|---|
| | Capacity unconstrained | Capacity constrained | % change | Capacity unconstrained | Capacity constrained | % change |
| 2020 | 837,087 | 784,298 | 6.7% | 544,292 | 502,473 | 8.3% |
| 2030 | 971,437 | 943,093 | 3.0% | 631,392 | 591,598 | 6.7% |
| 2040 | 1,082,156 | 1,060,902 | 2.0% | 713,478 | 668,462 | 6.7% |
| 2050 | 1,194,944 | 1,197,678 | -0.2% | 787,567 | 759,692 | 3.7% |

**6.21** This type of analysis can also be extended to explore the impact of releasing capacity on available seats. **Table 5.12** shows that again, the greatest benefit in releasing capacity constraints is in seat capacity available to long-haul destinations. The benefits are greater when there is no carbon cap.

76 As in previous analyses, this is limited to destinations served by an aggregate daily equivalent level of ATMs and excludes charter services

| Table 6.12: Change in modelled seats (millions) on scheduled, daily services, carbon traded (impact of releasing capacity) | | | | | | |
|---|---|---|---|---|---|---|
| | All destinations | | | Long haul destinations only | | |
| Carbon traded | Capacity unconstrained | Capacity constrained | % change | Capacity unconstrained | Capacity constrained | % change |
| 2020 | 306 | 288 | 6.2% | 72 | 67 | 7.5% |
| 2030 | 382 | 355 | 7.8% | 86 | 79 | 8.7% |
| 2040 | 446 | 402 | 11.0% | 107 | 91 | 18.1% |
| 2050 | 501 | 447 | 12.0% | 111 | 102 | 8.4% |

| Table 6.13: Change in modelled seats (millions) on scheduled, daily services, carbon capped (impact of releasing capacity) | | | | | | |
|---|---|---|---|---|---|---|
| | All destinations | | | Long haul destinations only | | |
| Carbon capped | Capacity unconstrained | Capacity constrained | % change | Capacity unconstrained | Capacity constrained | % change |
| 2020 | 304 | 288 | 5.7% | 72 | 67 | 7.2% |
| 2030 | 356 | 351 | 1.2% | 83 | 78 | 5.9% |
| 2040 | 386 | 391 | -1.3% | 94 | 89 | 5.2% |
| 2050 | 428 | 434 | -1.4% | 103 | 100 | 2.7% |

## Air transport movements (ATMs)

6.22 **Table 6.14** and **Table 6.15** show modelled ATMs.[77] ATMs are two way, comprising departing and arriving air transport movements. Data reported for 2011 uses modelled constrained figures rather than actual numbers. These are capacity unconstrained forecasts and, by their nature, the number of ATMs may exceed planning constraints (for example, at Heathrow).

77 Tables exclude freight and some miscellaneous movements such as positional flights, diplomatic flights, domestic charters and domestic flights from modelled UK airports to non-modelled UK airports

| Table 6.14: ATMs (thousands) at modelled airports, capacity unconstrained, carbon traded | | | | | |
|---|---|---|---|---|---|
| Airport | 2011 | 2020 | 2030 | 2040 | 2050 |
| Heathrow | 480 | 639 | 713 | 818 | 903 |
| Gatwick | 252 | 239 | 251 | 276 | 312 |
| Stansted | 152 | 157 | 169 | 183 | 202 |
| Luton | 80 | 70 | 97 | 112 | 122 |
| London City | 66 | 69 | 100 | 127 | 163 |
| **London total** | **1,031** | **1,174** | **1,331** | **1,516** | **1,703** |
| Manchester | 170 | 195 | 234 | 257 | 301 |
| Birmingham | 89 | 91 | 104 | 129 | 161 |
| Glasgow | 67 | 72 | 93 | 101 | 115 |
| Edinburgh | 93 | 100 | 122 | 144 | 165 |
| Bristol | 51 | 46 | 58 | 69 | 74 |
| Newcastle | 44 | 46 | 54 | 59 | 67 |
| Belfast International | 44 | 47 | 56 | 63 | 72 |
| Liverpool | 41 | 36 | 35 | 44 | 47 |
| East Midlands | 47 | 42 | 51 | 53 | 63 |
| Other modelled UK | 331 | 371 | 463 | 532 | 621 |
| **UK total** | **2,008** | **2,220** | **2,599** | **2,965** | **3,388** |
| **UK annual growth rate** | | **1.1%** | **1.6%** | **1.3%** | **1.3%** |
| Paris CDG | 427 | 444 | 513 | 579 | 652 |
| Amsterdam | 318 | 325 | 374 | 435 | 493 |
| Frankfurt | 401 | 406 | 487 | 584 | 692 |
| Dubai | 267 | 301 | 346 | 417 | 555 |
| **Foreign hub total** | **1,412** | **1,476** | **1,720** | **2,016** | **2,393** |
| **Foreign hub annual growth rate** | | **0.5%** | **1.5%** | **1.6%** | **1.7%** |

**Table 6.15: ATMs (thousands) at modelled airports, capacity unconstrained, carbon capped**

| Airport | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 480 | 636 | 697 | 762 | 847 |
| Gatwick | 252 | 236 | 221 | 226 | 228 |
| Stansted | 152 | 156 | 155 | 162 | 182 |
| Luton | 80 | 69 | 90 | 96 | 97 |
| London City | 66 | 68 | 88 | 106 | 132 |
| **London total** | **1,031** | **1,165** | **1,251** | **1,352** | **1,485** |
| Manchester | 170 | 194 | 216 | 234 | 256 |
| Birmingham | 89 | 90 | 86 | 106 | 122 |
| Glasgow | 67 | 72 | 88 | 94 | 106 |
| Edinburgh | 93 | 103 | 113 | 127 | 143 |
| Bristol | 51 | 46 | 52 | 51 | 58 |
| Newcastle | 44 | 45 | 49 | 52 | 56 |
| Belfast International | 44 | 47 | 51 | 56 | 63 |
| Liverpool | 41 | 36 | 31 | 30 | 33 |
| East Midlands | 47 | 41 | 47 | 50 | 53 |
| Other modelled UK | 331 | 368 | 432 | 491 | 557 |
| **UK total** | **2,008** | **2,208** | **2,418** | **2,643** | **2,933** |
| **UK annual growth rate** | | **1.1%** | **0.9%** | **0.9%** | **1.0%** |
| Paris CDG | 427 | 441 | 489 | 529 | 594 |
| Amsterdam | 318 | 323 | 352 | 387 | 432 |
| Frankfurt | 401 | 406 | 450 | 527 | 618 |
| Dubai | 267 | 299 | 325 | 376 | 502 |
| **Foreign hub total** | **1,412** | **1,470** | **1,616** | **1,818** | **2,146** |
| **Foreign hub annual growth rate** | | **0.4%** | **1.0%** | **1.2%** | **1.7%** |

6.23 **Table 6.16** and **Table 6.17** show ATM forecasts where there is capacity constraint, for each carbon scenario. In some cases an airport may incur a shadow cost (i.e. reach capacity) due to a terminal rather than runway constraint. This is a slightly different approach to the earlier analysis in this section (**Table 6.4** and **Table 6.5**) where an airport would have been considered to have reached capacity if a terminal shadow cost had been applied, even if spare runway capacity remained.

**Table 6.16: ATMs (thousands) at modelled airports, capacity constrained, carbon traded**

| Airport | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 480 | 480 | 480 | 480 | 480 |
| Gatwick | 252 | 280 | 280 | 280 | 280 |
| Stansted | 152 | 142 | 173 | 216 | 213 |
| Luton | 80 | 92 | 125 | 123 | 129 |
| London City | 66 | 101 | 120 | 120 | 120 |
| **London total** | **1,031** | **1,095** | **1,178** | **1,219** | **1,221** |
| Manchester | 170 | 180 | 210 | 242 | 306 |
| Birmingham | 89 | 109 | 142 | 202 | 206 |
| Glasgow | 67 | 73 | 88 | 98 | 108 |
| Edinburgh | 93 | 106 | 125 | 143 | 163 |
| Bristol | 51 | 46 | 60 | 71 | 92 |
| Newcastle | 44 | 46 | 55 | 59 | 63 |
| Belfast International | 44 | 45 | 55 | 64 | 71 |
| Liverpool | 41 | 39 | 48 | 54 | 66 |
| East Midlands | 47 | 45 | 49 | 56 | 125 |
| Other modelled UK | 331 | 402 | 495 | 603 | 734 |
| **UK total** | **2,008** | **2,187** | **2,505** | **2,812** | **3,155** |
| **UK annual growth rate** | | **1.0%** | **1.4%** | **1.2%** | **1.2%** |
| Paris CDG | 427 | 441 | 516 | 593 | 690 |
| Amsterdam | 318 | 338 | 398 | 462 | 563 |
| Frankfurt | 401 | 459 | 557 | 667 | 700 |
| Dubai | 267 | 318 | 360 | 442 | 562 |
| **Foreign hub total** | **1,412** | **1,556** | **1,831** | **2,164** | **2,515** |
| **Foreign hub annual growth rate** | | **1.1%** | **1.6%** | **1.7%** | **1.5%** |

| Table 6.17: ATMs (thousands) at modelled airports, capacity constrained, carbon capped | | | | | |
|---|---|---|---|---|---|
| Airport | 2011 | 2020 | 2030 | 2040 | 2050 |
| Heathrow | 480 | 480 | 480 | 480 | 480 |
| Gatwick | 252 | 280 | 280 | 280 | 280 |
| Stansted | 152 | 141 | 169 | 218 | 214 |
| Luton | 80 | 92 | 124 | 122 | 127 |
| London City | 66 | 101 | 120 | 120 | 120 |
| **London total** | **1,031** | **1,094** | **1,173** | **1,220** | **1,221** |
| Manchester | 170 | 180 | 209 | 235 | 292 |
| Birmingham | 89 | 109 | 141 | 195 | 206 |
| Glasgow | 67 | 73 | 87 | 99 | 111 |
| Edinburgh | 93 | 106 | 123 | 137 | 157 |
| Bristol | 51 | 46 | 55 | 64 | 99 |
| Newcastle | 44 | 46 | 54 | 58 | 61 |
| Belfast International | 44 | 45 | 55 | 63 | 72 |
| Liverpool | 41 | 39 | 47 | 51 | 64 |
| East Midlands | 47 | 45 | 49 | 53 | 94 |
| Other modelled UK | 331 | 401 | 486 | 565 | 711 |
| **UK total** | **2,008** | **2,184** | **2,479** | **2,742** | **3,088** |
| **UK annual growth rate** | | **0.9%** | **1.3%** | **1.0%** | **1.2%** |
| Paris CDG | 427 | 441 | 510 | 583 | 669 |
| Amsterdam | 318 | 335 | 386 | 451 | 545 |
| Frankfurt | 401 | 457 | 548 | 655 | 700 |
| Dubai | 267 | 317 | 361 | 434 | 548 |
| **Foreign hub total** | **1,412** | **1,550** | **1,805** | **2,123** | **2,463** |
| **Foreign hub annual growth rate** | | **1.0%** | **1.5%** | **1.6%** | **1.5%** |

**6.24** The use of a carbon cap means that overall passenger numbers do not change significantly between the capacity constrained and unconstrained scenarios. It is rather the allocation of demand between airports and market sectors which alters as capacity constraints are released.

## Passenger markets

**6.25** **Table 6.18** details the passenger numbers and growth rates for both carbon traded and carbon capped scenarios. The data is split by market: domestic, short-haul business and leisure, long-haul business and leisure, UK transfer and international transfer.

**6.26** There is significant growth in all markets with the exception of UK and international transfer passengers, which are forecast to decline markedly (by as much as 90%) by 2050. This is evident in both carbon traded and capped scenarios.

**6.27** In a carbon traded scenario, growth rates are equivalent or slightly higher when capacity is unconstrained than constrained. In the case of transfer passengers, a capacity constraint causes a decline, whereas removal of this constraint results in growth in both UK and international transfers.

**6.28** The implementation of a strict carbon limit on flights departing the UK results in lower growth in short-haul and long-haul markets, allowing growth in transfer passengers. This is most evident in the market for short-haul leisure, which sees the level of forecast growth drop from 87% in the constrained scenario to 60% in the unconstrained scenario.

**Table 6.18: Passenger numbers and growth rate by market**

| Scenario | | | Short-haul | | Long-haul | | Transfer | |
|---|---|---|---|---|---|---|---|---|
| | mppa | Domestic | Leisure | Business | Leisure | Business | UK | International |
| Base | 2011 | 28 | 99 | 24.7 | 31 | 8 | 5.9 | 20 |
| Carbon capped, capacity unconstrained | 2050 | 49 | 159 | 50 | 63 | 21 | 7.4 | 28 |
| | % growth | 73.6% | 60.4% | 102.4% | 103.6% | 166.7% | 25.4% | 38.4% |
| Carbon capped, capacity constrained | 2050 | 53 | 186 | 51.7 | 72 | 21 | 1.2 | 4 |
| | % growth | 89.3% | 87.4% | 109.3% | 134.7% | 167.9% | -79.7% | -81.8% |
| Carbon traded, capacity unconstrained | 2050 | 56 | 205 | 53.1 | 76 | 21 | 9 | 28 |
| | % growth | 100.7% | 106.1% | 115.0% | 146.8% | 167.9% | 52.5% | 37.9% |
| Carbon traded, capacity constrained | 2050 | 55 | 195 | 52.1 | 75 | 21 | 0.8 | 2 |
| | % growth | 94.6% | 96.3% | 110.9% | 143.5% | 167.9% | -86.4% | -90.6% |

Section 7:

# Alternative scenarios

**7.1** This section sets out the Commission's work on various alternative scenarios to test:

- connectivity outcomes for two potential future airport operating models;
- the potential to use taxation to better utilise airport capacity;
- how the London airport system might develop under four contrasting future paths of development for the global economy, and the air travel market in particular; and,
- how I-I interliners contribute to the diversity of routes at UK airports.

## Concentrated and dispersed hub capacity

**7.2** In addition to capacity constrained and unconstrained scenarios analysed in **Section 6**, two further capacity scenarios have been evaluated, and are presented in **Chapter 4** of the *Interim Report*. They are:

1) '**Concentrated London hub'**: in this scenario hub capacity is concentrated at one London airport, while the other airports mainly serve point-to-point traffic. To model this scenario Heathrow was assumed to be unconstrained. This was a modelling simplification rather than a specific scheme and was done because Heathrow had a full set of routes to all destinations without the need to 'seed' new frequencies. All other airports are limited to the capacities listed in **Table 4.3**.

2) **'Dispersed hub capacity'**: in this scenario hub capacity is dispersed across (mostly London) airports. Only Heathrow and London City airports are constrained. All other UK airports are given infinite capacity as in the unconstrained forecasts.[78]

**7.3** Even when airports are given unconstrained capacities, any relevant constraints are still applied in the modelling. For example, long-haul flights are prohibited at airports with unsuitable runways (e.g. airports such as London City and Southampton will

78 London City is constrained because compared to other London airports it is judged to be unrealistic to assume that it could ever have infinite capacity

be restricted to domestic and European flights). Similarly, low-cost carrier and charter airlines are not permitted to use Heathrow and London City in all cases.

**7.4** In these scenarios the analysis has included monitoring changes in the numbers of modelled destinations served within the region, rather than counting routes at individual airports. This form of analysis omits charter destinations.

**7.5** **Table 7.1** compares the number of passengers, ATMs and destinations served in the concentrated and dispersed hub case, under both carbon traded and carbon capped scenarios.

**7.6** The concentrated model serves slightly more destinations than the dispersed. The difference is less marked in the London airport system than it would be for many cities globally as London has the biggest OD market in the world; big enough to support independent hub operations from more than one airport.

**7.7** A concentrated system also serves slightly more passengers than a dispersed hub, under both carbon scenarios. By 2050 there are between 66,000 and 127,000 more ATMs under a concentrated system.

**Table 7.1: Passengers, ATMs and destinations served under dispersed and concentrated systems, carbon traded and capped, 2030, 2040 and 2050**

| | 2030 | | 2040 | | 2050 | |
|---|---|---|---|---|---|---|
| Daily threshold | $CO_2$ traded | $CO_2$ capped | $CO_2$ traded | $CO_2$ capped | $CO_2$ traded | $CO_2$ capped |
| Passengers (millions) | | | | | | |
| Dispersed | 149 | 142 | 173 | 161 | 205 | 183 |
| Concentrated | 164 | 153 | 194 | 172 | 223 | 198 |
| Difference | 15 | 11 | 21 | 11 | 18 | 15 |
| ATMs (000s) | | | | | | |
| Dispersed | 1044 | 1003 | 1163 | 1094 | 1344 | 1,225 |
| Concentrated | 1133 | 1071 | 1306 | 1161 | 1471 | 1,291 |
| Difference | 89 | 68 | 143 | 67 | 127 | 66 |
| Number of destinations served | | | | | | |
| Dispersed | 211 | 206 | 228 | 221 | 248 | 240 |
| Concentrated | 217 | 216 | 235 | 229 | 249 | 244 |
| Difference | 6 | 10 | 7 | 8 | 1 | 4 |

**7.8** Due to the nature of the DfT demand forecasts, the Commission was unable to test scenarios that would involve a step change in capacity or connectivity at any particular airport, for example, through the development of a substantial low-cost long-haul network or an alliance shift. The Commission intends to look in more detail in Phase 2 of its work programme at the viability of such step changes and their potential impacts.

## Congestion pricing

**7.9** The Commission has sought to investigate the potential for variable levels of APD to redistribute aviation demand to alleviate congestion at airports in the short term. APD rates currently vary according to journey distance and passenger class, and apply to all airline passengers beginning their journeys with a departure from a UK airport.[79] This policy was not modelled in the same level of detail as the core scenarios – in particular, the foreign hub airports were not included[80] – but the results are indicative of what might be expected from the implementation of such a policy.

**7.10** While there are several mechanisms by which APD could be varied, the Commission chose to do so according to the levels of congestion at airports, as this metric represents the ultimate aim of the policy.

**7.11** Analysis therefore focused on an APD congestion charge whereby a 10% surcharge is levied at airports operating above 90% of their maximum capacity. These were accompanied by decreases in APD at other, less congested airports, making the policy as a whole approximately revenue neutral. A 90% ratio of demand to capacity was chosen with the aim of forcing a resilience buffer into airport operating capacities. Although a 10% surcharge level is arbitrarily rounded, it serves as a general marker for the application of such a policy. The policy was implemented in the model from 2015 onwards.

**7.12** **Figure 7.1** and **Figure 7.2** demonstrate the difference in ATMs and total terminal passengers in 2020 between the carbon capped base and a 10% congestion levy at congested airports.[81]

**7.13** In this scenario, an increase in terminal passengers at regional airports is offset by a decrease at the more congested London airports, Heathrow and Gatwick.

79 APD does not apply to passengers interlining at a UK airport while en-route between two non UK airports, providing the stopover is no more than 24 hours. UK passengers making a transfer to an international flight at a UK hub airport pay for the international leg only. APD is only applied to passengers travelling on an aircraft weighing less than 5.7 tonnes
80 The model form used for this analysis is fully validated, but does not include the extensions described in this appendix
81 As the same carbon price in the base case is used in both APD scenarios, this does not constitute a fully carbon capped model – however, results are indicative of that expected from a carbon capped scenario

**Figure 7.1: Percentage change in ATMs as a result of 10% APD congestion charge relative to carbon capped baseline, 2020**

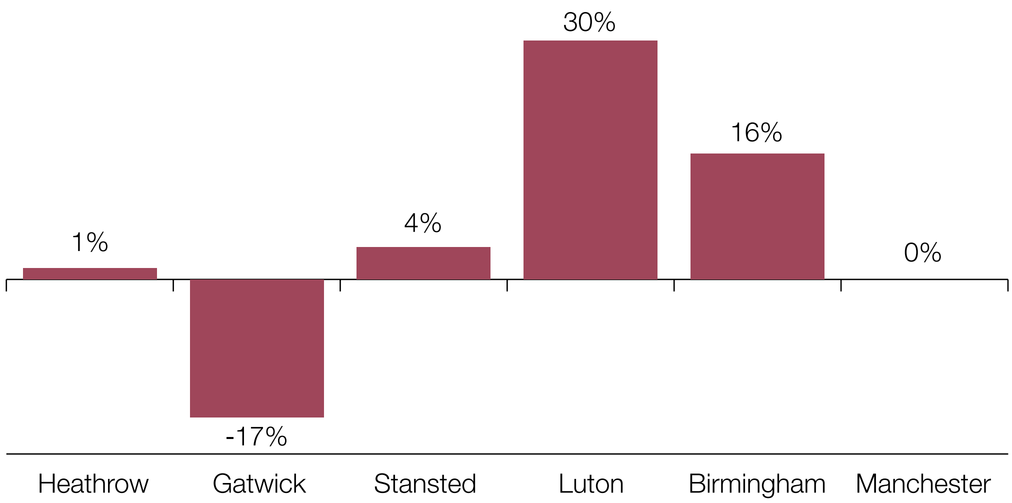
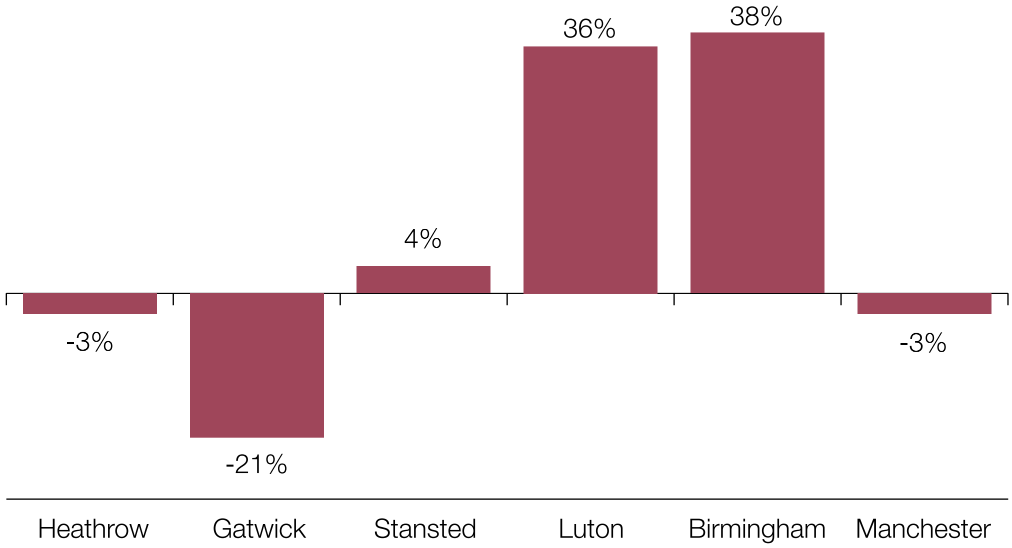



**Figure 7.2: Percentage change in passengers as a result of 10% APD congestion charge relative to carbon capped baseline, 2020**




7.14 **Table 7.2** shows the estimated change in destinations served as a result of a 10% APD congestion charge. The model predicts that there will be a particular loss in long-haul destinations available from London airports, which is not compensated for by other UK airports. Similarly, the modelling shows there would be a decrease in overall seat capacity on long-haul routes, as shown in **Table 7.3**.

**Table 7.2: Change in destinations served as a result of 10% APD congestion charge (daily services, relative to carbon capped baseline)**

| | Long haul | Short haul | Total |
|---|---|---|---|
| London | -6 | 1 | -5 |
| Other UK | 3 | -1 | 2 |
| All UK | -6 | 0 | -6 |

**Table 7.3: Change in available seats (millions) as a result of 10% APD congestion charge (daily services, relative to carbon capped baseline)**

| | Long haul | Short haul | Total |
|---|---|---|---|
| London | -7.3 | +1.0 | -6.3 |
| Other UK | +6.4 | -0.3 | +6.1 |
| All UK | -0.9 | +0.7 | -0.2 |

## Qualitative scenarios

7.15 The implications of four alternative scenarios to the baseline are discussed in **Chapter 4** of the *Interim Report*. Although the analysis is primarily qualitative, it has been supported by outputs from the modelling where possible. The modelling assumptions underpinning these scenarios, the results of these model runs and a comparison of results across scenarios are described here.

### Scenario A: Global growth

7.16 This scenario sees the role of hub airports enhanced, with an increased number of international transfer passengers (about 1% per annum cumulatively on top of the baseline level of growth). Associated with this is higher GDP growth (2% per annum in each year) in NICs and LDCs. Carbon is constrained to the extent that terminal passenger demand is 70% above the 2005 level, resulting in $CO_2$ emissions reaching 38Mt in 2050. This is a tighter constraint than in carbon traded scenarios, but not as tight as when carbon is capped to 2005 levels (37.5Mt).

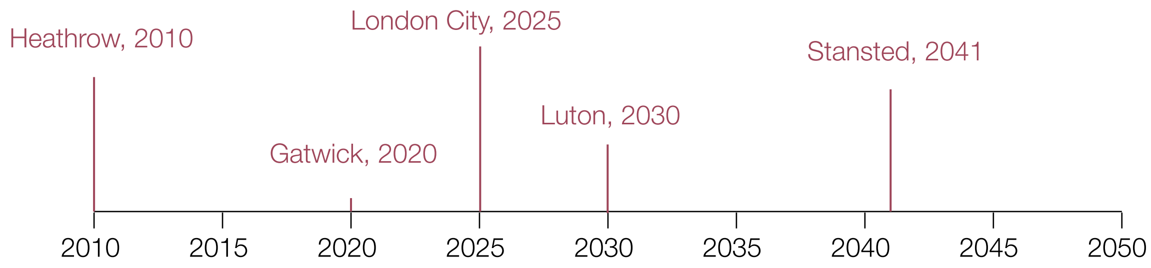
7.17 **Table 7.4** with its associated graphic shows a utilisation of UK capacity slightly below that forecast in the carbon capped baseline scenario. This is because long-haul flights make up a greater proportion of total traffic, and these result in a higher level of carbon per passenger. This reduces the number of passengers that can be accommodated within a given carbon cap.

**7.18** This scenario results in more use being made of the overseas hubs. This is a result of a combination of higher growth of I-I interliners and the prominence of Dubai International, for which a higher GDP growth rate was assumed.

**Table 7.4: Global scenario A airports runway capacity used**

| | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 100% | 100% | 100% | 100% |
| Stansted | 62% | 55% | 65% | 83% | 100% |
| Luton | 62% | 58% | 100% | 100% | 100% |
| London City | 55% | 85% | 100% | 100% | 100% |
| **London** | **83%** | **84%** | **90%** | **94%** | **100%** |
| Manchester | 53% | 56% | 51% | 46% | 54% |
| Birmingham | 47% | 54% | 68% | 94% | 100% |
| Bristol | 34% | 30% | 24% | 27% | 39% |
| East Midlands | 18% | 17% | 18% | 20% | 27% |
| Southampton | 28% | 29% | 33% | 48% | 100% |
| Other modelled | 20% | 22% | 23% | 26% | 31% |
| **UK** | **38%** | **40%** | **41%** | **45%** | **50%** |
| Paris CDG | 65% | 65% | 75% | 88% | 100% |
| Amsterdam | 62% | 66% | 64% | 65% | 91% |
| Frankfurt | 84% | 70% | 89% | 100% | 100% |
| Dubai | 67% | 58% | 29% | 30% | 41% |
| **Foreign hubs** | **69%** | **65%** | **57%** | **59%** | **71%** |

100% = runway or terminal capacity exceeded, other %s refer to runway usage.



### Scenario B: Relative decline of Europe

**7.19** In the second scenario it is assumed that Dubai International and Amsterdam[82] will successfully compete with Heathrow and other European hubs over interlining traffic.

**7.20** To model this assumption, 'hub penalties' are applied to Frankfurt, Heathrow and Paris CDG.[83] Again, NICs and LDCs are assumed to experience higher GDP growth rates. Carbon is fully capped to 2005 levels (37.5Mt).

**7.21** The scenario results in a shift in I-I transfer traffic to Amsterdam Schiphol and Dubai International. Amsterdam becomes the largest airport for such traffic, largely at the expense of Frankfurt. The impact on the UK is limited, as capacity constraints have resulted in little international transfer traffic in the UK in the baseline scenarios by 2040.

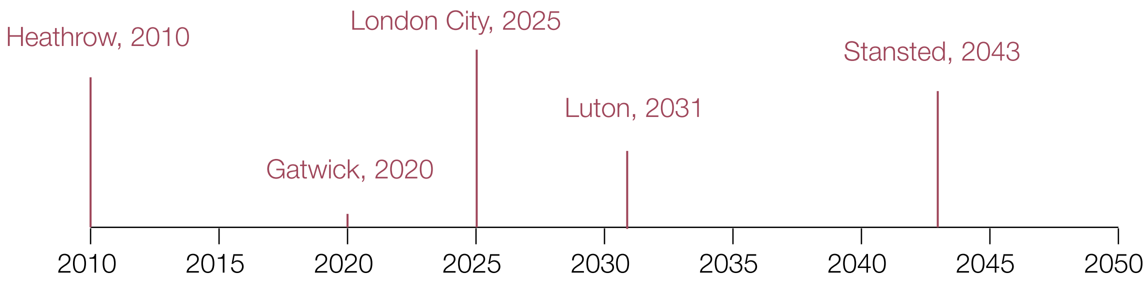
82 In this scenario, Amsterdam is arbitrarily assumed to have become the biggest European hub, as diminished passenger flows result in consolidation of hub capacity in Europe

83 Hub penalties are a modelling time measure to reflect the disbenefit or deterrent effect passengers perceive of interlining at a particular hub airport, over and above the penalty actually attached to waiting for their connection

**Table 7.5: Global scenario B airports runway capacity used**

| | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 100% | 100% | 100% | 100% |
| Stansted | 62% | 55% | 62% | 79% | 100% |
| Luton | 62% | 60% | 73% | 100% | 100% |
| London City | 55% | 84% | 100% | 100% | 100% |
| **London** | **83%** | **85%** | **90%** | **94%** | **100%** |
| Manchester | 53% | 56% | 50% | 46% | 57% |
| Birmingham | 47% | 53% | 63% | 91% | 100% |
| Bristol | 34% | 30% | 25% | 28% | 35% |
| East Midlands | 18% | 17% | 18% | 20% | 30% |
| Southampton | 28% | 28% | 30% | 42% | 100% |
| Other modelled | 20% | 21% | 23% | 26% | 30% |
| **UK** | **38%** | **40%** | **41%** | **45%** | **50%** |
| Paris CDG | 65% | 64% | 72% | 79% | 91% |
| Amsterdam | 62% | 69% | 73% | 82% | 98% |
| Frankfurt | 84% | 60% | 63% | 66% | 76% |
| Dubai | 67% | 58% | 29% | 29% | 39% |
| **Foreign hubs** | **69%** | **63%** | **53%** | **55%** | **66%** |

100% = runway or terminal capacity exceeded, other %s refer to runway usage.



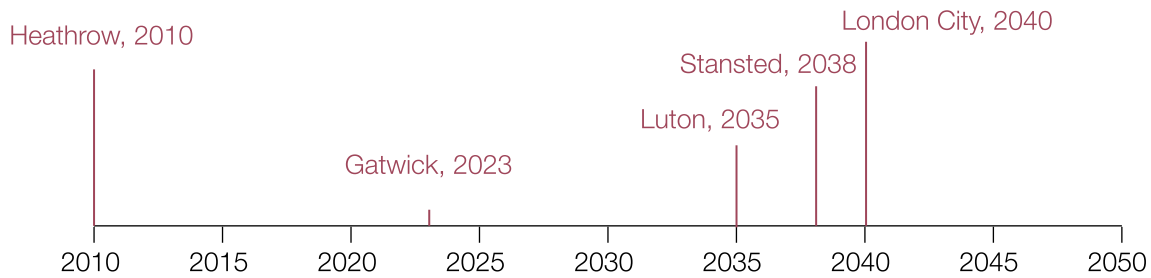
### Scenario C: Low-cost is king

**7.22** In this scenario low-cost carriers and charter flights are assumed to make up a larger proportion of total UK-based traffic as point-to-point connections increase their prominence. Their combined share rises from 38% in 2040 in the carbon capped baseline to 52%. There is also slower I-I transfer passenger growth. Low-cost carriers are able to operate a new generation of single aisle aircraft which will accommodate up to 220 passengers (A320neo and Boeing 737 MAX families). Big aircraft operated predominantly by legacy carriers on the thickest routes e.g. Boeing 747s and Airbus A380s, are replaced by the twin-engined, twin-aisle B787 Dreamliner and its Airbus rival, the A350. B787s and A350s can service both short-haul and long-haul routes. Larger, twin-engined aircraft such as the B777 continue to operate. Carbon is fully capped to 2005 levels (37.5Mt).

**7.23** This results in utilisation of UK runway capacity being slightly lower than in the previous two cases, although as the total volume of ATMs is similar to the baseline, the London airport system is still full by 2040. In the regions, those airports that have specialised in international low-cost traffic attract more traffic, but demand is not evenly dispersed. There are fewer I-I transfer passengers; their number falling by about 25% relative to the baseline.

| Table 7.6: Global scenario C airports runway capacity used | | | | | |
|---|---|---|---|---|---|
| | 2011 | 2020 | 2030 | 2040 | 2050 |
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 99% | 100% | 100% | 100% |
| Stansted | 62% | 61% | 70% | 100% | 100% |
| Luton | 62% | 58% | 69% | 100% | 100% |
| London City | 55% | 52% | 70% | 100% | 100% |
| **London** | **83%** | **83%** | **88%** | **100%** | **100%** |
| Manchester | 53% | 51% | 48% | 46% | 56% |
| Birmingham | 47% | 42% | 48% | 61% | 87% |
| Bristol | 34% | 32% | 27% | 32% | 100% |
| East Midlands | 18% | 19% | 21% | 23% | 35% |
| Southampton | 28% | 22% | 25% | 31% | 53% |
| Other modelled | 20% | 22% | 24% | 27% | 31% |
| **UK** | **38%** | **39%** | **40%** | **44%** | **49%** |
| Paris CDG | 65% | 65% | 74% | 84% | 95% |
| Amsterdam | 62% | 65% | 60% | 58% | 68% |
| Frankfurt | 84% | 59% | 68% | 80% | 96% |
| Dubai | 67% | 55% | 25% | 23% | 29% |
| **Foreign hubs** | **69%** | **61%** | **51%** | **51%** | **60%** |

100% = runway or terminal capacity exceeded, other %s refer to runway usage.



### Scenario D: Global stagnation and fragmentation

**7.24** In scenario D economies close themselves off by adopting more conditional and interventionist national policy models. It is thus assumed that the UK experiences GDP growth consistent with the bottom end of the OBR forecast range, which is around 0.5% per annum lower than the central forecast used in the baseline scenarios. Alongside this, GDP growth for all other countries is lower by 1% per annum (relative to the baseline scenarios). I-I transfer traffic falls back to 2011 levels by 2040 and Dubai International becomes a less attractive airport for international to international interliners. Carbon emissions remain at the level of the carbon traded scenario.

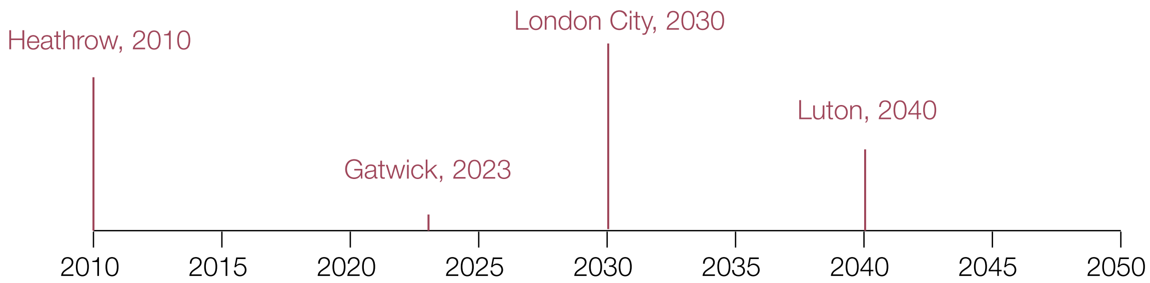
**7.25** Utilisation of capacity is lower as the assumed weaker economic growth lowers passenger demand growth relative to the baseline scenarios. Consequently, some runway capacity remains at Stansted by 2050, although the London airport system is 92% full. There is substantial capacity still available at regional airports.

**7.26** International transfer traffic is significantly lower compared to the baselines, such that its total is similar to that modelled in scenario C. Despite this, Heathrow sees an increase in the number of international transfers. This is because the lower aggregate demand reduces the shadow cost at Heathrow, attracting more price sensitive international transfer passengers.

**Table 7.7: Global scenario D airports runway capacity used**

| | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Heathrow | 100% | 100% | 100% | 100% | 100% |
| Gatwick | 93% | 88% | 97% | 100% | 100% |
| Stansted | 62% | 51% | 55% | 59% | 77% |
| Luton | 62% | 54% | 60% | 100% | 100% |
| London City | 55% | 76% | 100% | 100% | 100% |
| **London** | **83%** | **80%** | **86%** | **89%** | **92%** |
| Manchester | 53% | 51% | 47% | 41% | 46% |
| Birmingham | 47% | 47% | 52% | 61% | 79% |
| Bristol | 34% | 27% | 20% | 23% | 28% |
| East Midlands | 18% | 16% | 17% | 18% | 22% |
| Southampton | 28% | 25% | 28% | 29% | 39% |
| Other modelled | 20% | 20% | 21% | 23% | 26% |
| **UK** | **38%** | **37%** | **38%** | **40%** | **44%** |
| Paris CDG | 65% | 59% | 65% | 72% | 77% |
| Amsterdam | 62% | 59% | 53% | 49% | 54% |
| Frankfurt | 84% | 60% | 64% | 74% | 88% |
| Dubai | 67% | 51% | 22% | 18% | 22% |
| **Foreign hubs** | **69%** | **57%** | **45%** | **43%** | **50%** |

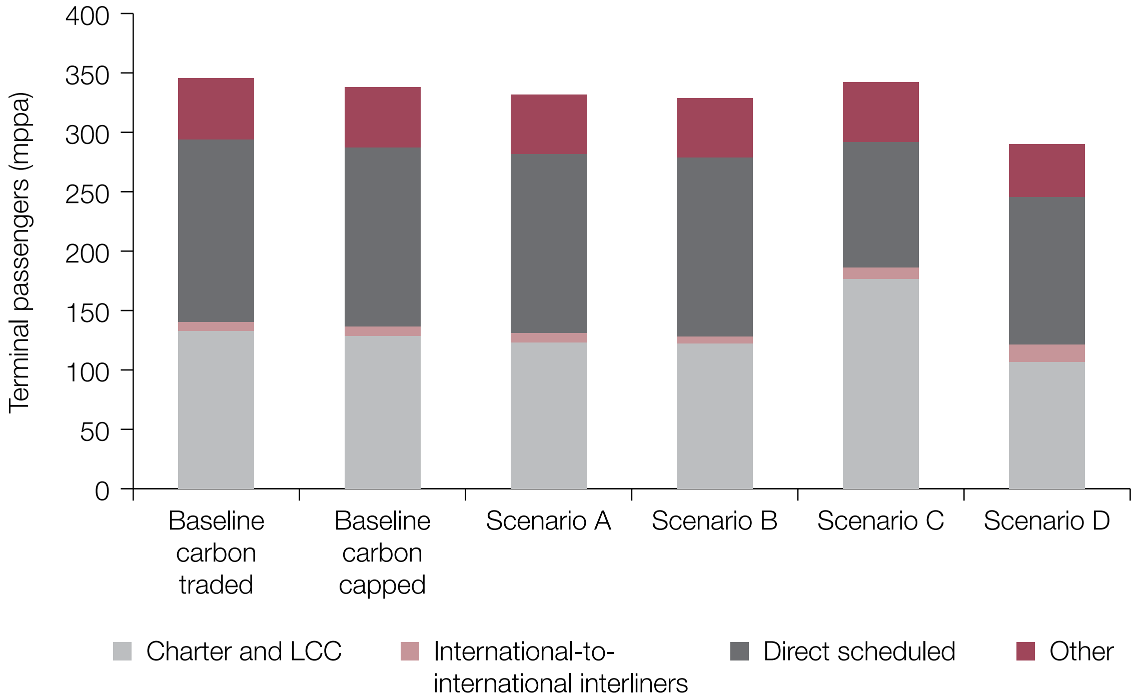
100% = runway or terminal capacity exceeded, other %s refer to runway usage.



### Comparison between scenarios

7.27 **Figure 7.3** shows the total number of terminal passengers in UK airports, split by type, across the two baseline capacity constrained scenarios and the four qualitative scenarios.

**Figure 7.3 UK Terminal passenger demand across scenarios in 2040**

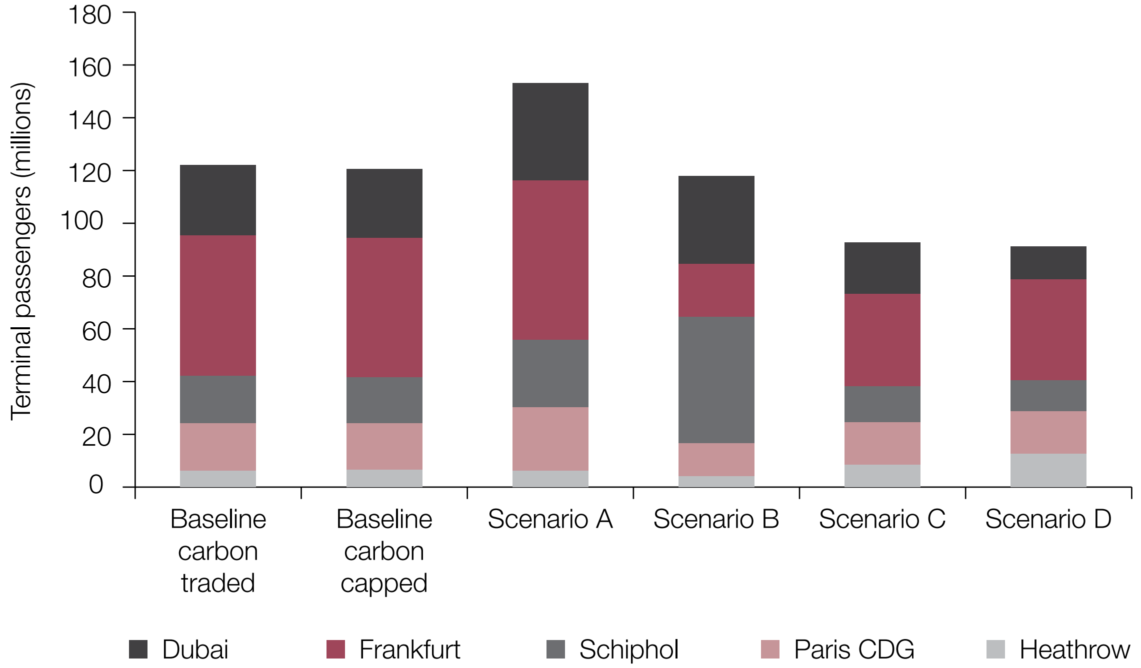



*Note 1: all scenarios shown are capacity constrained*
*Note 2: 'Other' traffic relates to all domestic flights, and passengers making indirect international trips originating or ending in the UK*

7.28 Total demand is similar across scenarios A, B and C, mainly due to the fact that demand is already constrained by the carbon target. Demand in scenario D is lower due to a very pessimistic GDP growth assumption. The composition of demand is quite different in scenario C because low-cost carriers and charter operators make up a much bigger share of the market. Across scenarios A, B and D the composition of demand remains broadly similar.

7.29 **Figure 7.4** shows the impact of the scenarios on I-I traffic at Heathrow and the four overseas hubs.

**Figure 7.4: International-International transfer traffic in 2040**

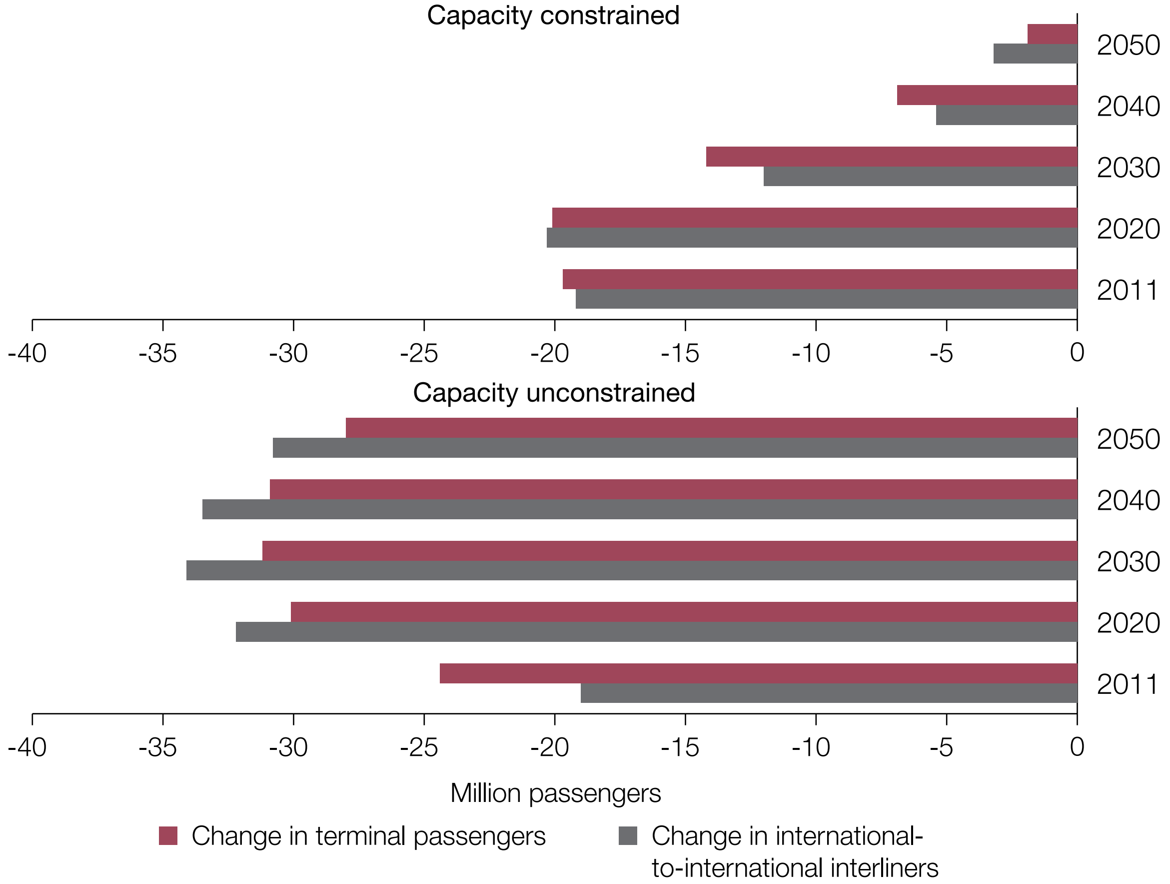



## No international to international transfers

**7.30** A test has been conducted where all I-I transfer passengers are removed from the modelling in both the UK and overseas.[84] As **Figure 7.5** demonstrates total throughput tends to fall by a similar volume to the number of I-I passengers removed (i.e. the released capacity is not all taken up).

84 Only scheduled I-Is were removed. Residual self-interliners using low cost carriers and therefore banned from Heathrow were allowed to remain. These only amounted to 0.6mppa

**Figure 7.5: Impact of removing I-I interliners from modelling, carbon traded**




7.31 The number of destinations served by the key hubs and the principal competing London and regional airports is analysed below in **Table 7.8**. This analysis looks at changes in destinations reached by services on at least daily schedules for the capacity constrained scenarios. As illustrated by **Figure 7.5**, the loss of passengers and therefore destinations, is lower in the capacity constrained scenarios because the number of I-I interliners were eroded in the baseline case by rising shadow costs as the forecasting period progressed.

7.32 **Table 7.8** shows that with capacity constrained the net loss of long-haul destinations at Heathrow is not compensated by gains in long-haul at other airports in either the carbon capped or traded scenarios. In both carbon scenarios there are also net losses of short-haul routes as these also attract passengers as feeders for transfers to long-haul routes. The pattern of route loss is similar for both the carbon capped and traded scenarios.

7.33 It should be noted that in **Table 7.8**, destinations should not be totalled for the London airport system or nationally because it may be the same destination that is lost at different airports.

**Table 7.8: Changes in number of destinations served in 2030 at each airport when I-I interliners are removed, capacity constrained, daily services**

| | Change in destinations served, carbon capped | | | | | |
|---|---|---|---|---|---|---|
| 2030 | Dom | Europe | OECD | NIC | LDC | Total |
| Heathrow | 2 | -6 | -14 | -6 | -1 | -25 |
| Gatwick | 0 | -5 | 7 | 4 | 0 | 6 |
| Stansted | -1 | 3 | 0 | 0 | 0 | 2 |
| Luton | -1 | -6 | 0 | 0 | 0 | -7 |
| London City | 0 | 8 | 0 | 0 | 0 | 8 |
| Manchester | 0 | -4 | 0 | 0 | 0 | -4 |
| Birmingham | 0 | 0 | 1 | 0 | 0 | 1 |
| Edinburgh | -2 | 0 | 0 | 0 | 0 | -2 |
| Glasgow | 2 | 0 | 0 | 0 | 0 | 2 |
| Bristol | 0 | 1 | 0 | 0 | 0 | 1 |
| Newcastle | 0 | 0 | 0 | 0 | 0 | 0 |
| Other airports | 0 | -1 | 1 | 0 | 0 | 0 |
| | Change in destinations served, carbon traded | | | | | |
| 2030 | Dom | Europe | OECD | NIC | LDC | Total |
| Heathrow | 2 | -5 | -14 | -6 | 0 | -23 |
| Gatwick | 0 | -8 | 7 | 3 | 0 | 2 |
| Stansted | 0 | 0 | 0 | 0 | 0 | 0 |
| Luton | 0 | -4 | 0 | 0 | 0 | -4 |
| London City | 0 | 8 | 0 | 0 | 0 | 8 |
| Manchester | 0 | -1 | 0 | -1 | 0 | -2 |
| Birmingham | 0 | -1 | 1 | 0 | 0 | 0 |
| Edinburgh | -1 | 0 | -1 | 0 | 0 | -2 |
| Glasgow | 2 | 0 | 0 | 0 | 0 | 2 |
| Bristol | 0 | 0 | 0 | 0 | 0 | 0 |
| Newcastle | 0 | 0 | 0 | 0 | 0 | 0 |
| Other airports | 0 | 1 | 1 | 0 | 0 | 2 |

7.34 **Table 7.9** below repeats the analysis of lost destinations when I-I interliners are removed for the unconstrained capacity case. As **Figure 7.5** illustrates, the loss of routes in this scenario is greater, because without capacity constraints and shadow costs there were more routes to lose. 2030 is shown as it has the peak loss of passengers in the forecasting period. As with the constrained case, long-haul routes lost at Heathrow are not fully replaced elsewhere. However, unlike in both capacity constrained cases, there is a small gain in the number of short-haul routes in the carbon capped case, although there is a loss of routes when there is no carbon capping.

**Table 7.9: Changes in number of destinations served in 2030 at each airport when I-I interliners are removed, traded carbon, capacity unconstrained, daily services**

| 2030 | 'Change in destinations served, carbon constrained | | | | | |
|---|---|---|---|---|---|---|
| | Dom | Europe | OECD | NIC | LDC | Total |
| Heathrow | -1 | -34 | -14 | -6 | -6 | -61 |
| Gatwick | 0 | 11 | 6 | 5 | 4 | 26 |
| Stansted | 0 | 2 | 0 | 0 | 0 | 2 |
| Luton | 1 | 5 | 0 | 0 | 0 | 6 |
| London City | 0 | 7 | 0 | 0 | 0 | 7 |
| Manchester | 0 | -2 | 2 | 0 | 0 | 0 |
| Birmingham | 0 | 12 | 0 | 1 | 0 | 13 |
| Edinburgh | -1 | 2 | 1 | 0 | 0 | 2 |
| Glasgow | 2 | 1 | 0 | 0 | 0 | 3 |
| Bristol | 0 | 1 | 0 | 0 | 0 | 1 |
| Newcastle | 1 | 0 | 0 | 0 | 0 | 1 |
| Other Airports | 0 | 9 | 0 | 1 | 0 | 10 |
| 2030 | Change in destinations served, carbon unconstrained | | | | | |
| | Dom | Europe | OECD | NIC | LDC | Total |
| Heathrow | -1 | -34 | -14 | -5 | -5 | -59 |
| Gatwick | 1 | 3 | 6 | 5 | 4 | 19 |
| Stansted | 0 | -1 | 0 | 0 | 0 | -1 |
| Luton | 1 | 3 | 0 | 0 | 0 | 4 |
| London City | 0 | 7 | 0 | 0 | 0 | 7 |
| Manchester | 0 | -5 | 0 | 0 | 0 | -5 |
| Birmingham | 0 | 4 | 0 | 0 | 0 | 4 |
| Edinburgh | 0 | 1 | 0 | 0 | 0 | 1 |
| Glasgow | 3 | 0 | 0 | 0 | 0 | 3 |
| Bristol | 0 | -4 | 0 | 0 | 0 | -4 |
| Newcastle | 0 | 0 | 0 | 0 | 0 | 0 |
| Other Airports | 0 | 4 | 0 | 0 | 0 | 4 |

Section 8:

# Next steps

**8.1** The results presented in this report are the result of extensive model development and utilisation. The Commission will continue to develop this and other modelling techniques to support future analytical work in Phase 2, where appropriate looking beyond the modelling framework currently used. In the case of the DfT's modelling suite, this will be taken forward alongside some already planned improvements and updates such as reviewing the models geographic zones.

# Glossary

| | |
|---|---|
| Aircraft km | The number of kilometres travelled by an aircraft |
| AMS | Amsterdam Schiphol Airport (IATA code) |
| APD | Air Passenger Duty |
| ATM | Air Transport Movement |
| ATM Demand Model | Part of NAPAM which calculates the number and size (seats) of ATMs needed to serve the demand allocated to the route |
| CAA | Civil Aviation Authority |
| Capacity constrained | Future passenger and ATM demand is limited to airport capacity where no significant additional runway or terminal capacity is added |
| Capacity unconstrained | Passenger and ATM demand is not limited by runway or terminal capacity |
| Carbon capped | Modelling scenario where $CO_2$ emissions are limited to 2005 level through an ETS and higher carbon prices |
| Carbon traded | Modelling scenario where $CO_2$ emissions are part of an ETS, but not limited to any target |
| CCC | UK Committee on Climate Change |
| CDG | Paris Roissy-Charles De Gaulle Airport (IATA code) |
| CGE model | Computable General Equilibrium model, a dynamic model of a whole economy |
| $CO_2$ | Carbon dioxide |
| DECC | Department for Energy and Climate Change |
| Demand Allocation Routine | Part of NAPAM which models the impact of future UK airport capacity constraints on air transport movements and passengers at the UK and four foreign hub airports |
| DfT | Department for Transport |
| DXB | Dubai International Airport (IATA code) |
| EC | European Commission |
| ECM | Error correction model |
| EEA | European Economic Area |
| Enerdata | Independent energy research and consulting firm |
| EU ETS | European Union Emissions Trading System |
| Eurostat | Statistical office of the European Union |

| | |
|---|---|
| FDI | Foreign direct investment |
| FRA | Frankfurt Airport (IATA code) |
| GDP | Gross domestic product (National Income) |
| GMM | Generalised method of moments, an econometric method for estimating parameters |
| Gravity model | (in this context) a trade model which predicts bilateral trade flows based on the economic sizes of and distance between two units |
| GVA | Gross value added |
| HMRC | Her Majesty's Revenue and Customs |
| HS2 | High Speed Two |
| IATA | International Air Transport Association (airline trade body) |
| IEA | International Energy Agency |
| I-I | International to International interliners i.e. passengers whose are transferring via a UK airport with their origin and destination outside the UK |
| IMF | International Monetary Fund |
| International-interliners | Passengers starting or finishing their journey in the UK but using a foreign hub |
| IV | Instrumental variable, an econometric method which allows consistent estimation when the explanatory variables are correlated with the error terms in a regression |
| Larame | A term referring to the relationships between passenger demand, aircraft size and load factors, and flight frequency that have been derived statistically from historical data |
| LCC | Low-cost carrier |
| LDC | Less Developed Country |
| LHR | Heathrow Airport (IATA code) |
| London airport system | For the purposes of this report, the London airport system refers to the following airports: Heathrow, Gatwick, Stansted, Luton and London City. |
| MM | Method of moments |
| Monte Carlo analysis | A method of forecasting where inputs are randomly varied within a distribution to calculate the probability of a particular outcome |
| mppa | Million passengers per annum |
| $mtCO_2$ | Million tonnes of carbon dioxide |
| NAPAM | The DfT's National Air Passenger Allocation Model |
| NAPDM | The DfT's National Air Passenger Demand Model |

| | |
|---|---|
| NIC | Newly Industrialised Country |
| NPV | Net present value |
| OAG | Official Airline Guide |
| OBR | Office for Budgetary Responsibility |
| OD | Origin and destination |
| OECD | Organisation for Economic Co-operation and Development (used in this report to refer to members outside the European Union) |
| Passenger Airport Choice Model | Part of NAPAM that models how national passenger demand splits between the UK airports |
| PaxIS | Passenger Intelligence Services, which in this context comes from ticket data obtained from the IATA |
| PLANET | Rail model used by HS2 Ltd to forecast passenger flows |
| Point-to-point | Direct connection between two destinations |
| PPML | Poisson pseudo-maximum likelihood estimator, an approach to estimating gravity models |
| PV | Present value |
| PwC | PricewaterhouseCoopers LLP |
| Sabre ADI | Sabre airport data intelligence, travel transaction processing company. |
| SDG | Steer Davies Gleave |
| SE | South East |
| Seat-km | The number of kilometres travelled by an aircraft multiplied by the number of seats |
| Shadow cost | The extra cost of flying required to reduce passenger demand from above an airport's runway or terminal capacity, to a level that is back within capacity |
| Suppression | The process whereby passengers respond to a shadow cost by deciding not to fly rather than using a 'less preferred' airport |
| Terminal passenger | A person joining or leaving an aircraft at a reporting airport, as part of an ATM. More detail is included in DfT's January 2013 publication[1] |
| WE | Western Europe |
| WebTAG | The DfT's transport appraisal guidance |

85 DfT UK Aviation forecasts, January 2013, particularly paragraphs 2.6 to 2.8, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013