Department for Transport

UK Aviation Forecasts

Moving Britain Ahead

October 2017

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Glossary

Term	Description
Aircraft-kilometres, Aircraft-km	The number of kilometres travelled by an aircraft
AEM	Advanced Emission Model
APD	Air Passenger Duty
ATAG	Air Transport Action Group
ATM	Air Transport Movement - landings or take-offs of aircraft
ATM Demand Model	Part of NAPAM which calculates the number and size (seats) of ATMs needed to serve the demand allocated to the route
Baseline	Case where no new runways are added
Bellyhold	Cargo hold of a passenger aircraft used for freight
BEIS	Department for Business Energy and Industrial Strategy
CAA	Civil Aviation Authority
CAEP	The Committee on Aviation Environmental Protection
Capacity constrained	Modelling case where passenger and ATM demand must fit available future capacity where no significant additional runway or terminal capacity is added
Capacity unconstrained	Modelling case where passenger and ATM demand is not limited by runway or terminal capacity
CCC	UK Committee on Climate Change
CH4	Methane
Charter	As determined by the CAA, flights sold in holiday packages and not operating to a schedule
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DfT	Department for Transport
Domestic interliners	Passengers who start or end the journey in the UK and change to an international flight at a UK hub airport
Domestic passengers	Passengers who complete an end to end journey within the UK
EC	European Commission
EEA	European Environment Agency
EMEP/EEA	The European Monitoring Evaluation Programme (EMEP) / European Environment Agency (EEA) air pollutant emission inventory guidebook (formerly called the EMEP CORINAIR emission inventory guidebook) provides guidance on estimating emissions from both anthropogenic and natural emission sources.
EMME	Transport modelling software used in NAAM2
EU ETS	European Union Emissions Trading System
EUROCONTROL	The European Organisation for the Safety of Air Navigation
FMM	Fleet Mix Model
Foreign passengers	Foreign residency as defined in CAA passenger interview surveys

GIS	Geographic Information System
GDP	Gross Domestic Product (national income)
GHG	Greenhouse gas
GMBM	Global Market Based Measures
HMRC	Her Majesty's Revenue and Customs
HS2	High Speed Two
IATA	International Air Transport Association (airline trade body)
ICAO	International Civil Aviation Organization
International-international	International-international interliners / transfer passengers; i.e. passengers who are transferring via a UK airport or one the four overseas hubs in the model with their origin and destination outside the UK
IMF	International Monetary Fund
IPS	International Passenger Survey
Kg/nm	Kilogram per nautical mile
LCC	Low-cost carrier: low-cost carriers apply a business model that relies on reducing operating costs to provide passengers with relatively cheap tickets – only includes easyJet, Ryanair, Jet 2 and scheduled Thomsonfly services in the department's model.
LDC	Less Developed Country, a NAPDM long-haul forecasting region
Lei	Leisure Passengers
LGW 2R	Gatwick Airport Second Runway, the option promoted by Gatwick Airport Limited
LHR NWR	Heathrow Airport North West Runway, the option promoted by Heathrow Airport Limited
LHR ENR	Heathrow Airport Extended Northern Runway, the option promoted by Heathrow Hub Limited
LRTAP	Long Range Transboundary Air Pollution
Load factor	The proportion of seats on an ATM utilised by passengers
Long-haul	'Long-haul' depicts a destination (or route) to or from an overseas country that is not listed as part of the group of countries defined as 'Western Europe' (or 'short-haul')
MACC	Marginal abatement cost (MAC) curves
Model base year	The year from which the majority of underlying model data is taken, and the first year of model output - 2016 in these forecasts
mppa	Million passengers per annum
$MtCO_2$	Million tonnes of carbon dioxide.
$MtCO_2e$	Million tonnes of carbon dioxide equivalent – a metric which can include other greenhouse gases converted to the warming equivalent of carbon dioxide.
N_2O	Nitrous Oxide
NAAM2	National Airport Accessibility Model, generation 2, a model used to extract travel costs by road and rail from all district to all mainland UK airports

NAEI	National Atmospheric Emissions Inventory
NAPAM	National Air Passenger Allocation Model, a model within the department's aviation demand modelling suite. NAPAM allocates the unconstrained demand output from NAPDM to airports, taking into account capacity constraints
NAPDM	National Air Passenger Demand Model, a model within the department's aviation demand modelling suite. NAPDM forecasts the aggregate national demand for air travel before allocating to airports in NAPAM and taking account of airport capacity constraints
NIC	Newly Industrialised Country, a forecasting region in NAPDM
nm	Nautical Mile
NMF	Network Modelling Framework (DfT rail model)
NPS	National Policy Statement
NTEM	National Trip End Model (DfT model)
OBR	Office for Budget Responsibility
OECD	Organisation for Economic Co-operation and Development. In this report, this grouping refers to countries in the OECD but outside of Western Europe, as defined in NAPDM
OSGR	Ordnance Survey Grid Reference
Passenger-kilometres	The number of kilometres travelled by an aircraft multiplied by the number of passengers on board, sometimes referred to as RPK (Revenue passenger kilometres).
PIANO	An aircraft engine fuel-burn modelling tool
PFM	PLANET Framework Model used by HS2 Ltd
Point-to-point	Direct connection between two destinations
Runway capacity	The annual number of aircraft movements that are able to use an airport's runways and supporting airside infrastructure
Scheduled (Sch)	In the department's aviation demand modelling suite, scheduled carriers refer to only those carriers operating to a schedule, have been defined as such by the CAA and do not fall in the DfT definition of low-cost carriers
Seat-kilometres, seat-km	The number of kilometres travelled by an aircraft multiplied by the number of seats
SESAR	Single European Sky ATM Research
Shadow cost (also referred to as fare premia or congestion premium)	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
Short-haul	'Short-haul' has been defined as 'Western Europe', which comprises the following groups of countries: Andorra; Austria; Belgium; Bosnia and Herzegovina; Cape Verde; Channel Isles, Croatia, Cyprus, Czech Republic; Denmark; Estonia; Faroe Islands; Finland; France; Germany; Gibraltar; Greece; Greenland; Hungary; Iceland; Ireland; Italy; Latvia; Lithuania; Luxembourg; Macedonia; Malta; Republic of Moldova; Monaco; Montenegro; Netherlands; Norway; Poland; Portugal; San Marino; Serbia; Slovakia; Slovenia; Spain; Sweden; Switzerland; and Turkey. This is consistent with the definition of 'Western Europe' used in the department's aviation model suite

Suppression	The process whereby passengers respond to a shadow cost by deciding not to fly rather than using a 'less preferred' airport
Surface access	Land-based forms of transport used to access airports
Terminal passenger	A person joining or leaving an aircraft at a reporting airport, as part of an ATM.
Transfer traffic	Passengers connecting between their origin airport and destination airport through an intermediate airport
tCO2	tonnes Carbon Dioxide
Terminal capacity	The annual number of terminal passengers that are able to use an airport's terminals including its supporting landside infrastructure
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VFR	Visiting Friends and Relatives
WE	Western Europe, the short-haul forecasting region in NAPDM
WEO	World Economic Outlook
WebTAG	Department for Transport Appraisal Guidance

Executive summary

Introduction

1 This document sets out the Department for Transport (DfT) 2017 forecasts for air passengers, aircraft movements and CO_2 emissions at UK airports. The department's forecasts are a long term strategic look at UK aviation and are used for a number of purposes:

- informing future aviation strategy and policy
- informing decisions around the need and location of airport expansion
- providing emissions information for use in international discussions
- feeding into other government departments and the wider aviation sector

2 In October 2016 the Government accepted the conclusions of the Airports Commission, confirming the need for new runway capacity in the South East of England and announced that its preferred scheme for adding the capacity was a Northwest Runway at Heathrow ('LHR NWR'). A draft Airports National Policy Statement (NPS) was published in February 2017 and from February to May 2017, the department undertook a consultation on the draft Airports NPS which included assessments of all three options for additional capacity in the South East of England shortlisted by the Airports Commission.[1] The department has published a revised draft Airports NPS taking account of the updated evidence base and has launched a public consultation on that document. It is therefore appropriate for this document to include new forecasts for all the shortlisted capacity options.

3 This document comprehensively updates the last DfT forecasts of January 2013, describes how the forecasts are prepared and includes the forecasts for the shortlisted capacity options. The evaluation and appraisal of these options is considered in a separate document.[2]

The aviation market

4 The aviation market has undergone some significant changes since the department last published forecasts in 2013.[3] Passenger demand has grown significantly at UK airports, averaging 4.2% per annum since 2011. In 2016 passenger movements reached an historic high of 267 million at the airports for which the department forecast[4]. Aircraft movements (ATMs) have grown nationally by 10%, despite average load factors being higher and airlines using bigger aircraft.

[1] *Draft Airports National Policy Statement: new runway capacity and infrastructure at airports in the South East of England*, DfT, February 2017.
[2] *Updated Appraisal Report*, DfT, October 2017.
[3] In 2013 the department used base data relating to 2011. The base data used for these forecasts is 2016.
[4] There were a further 1m passenger movements at airports not included in the model.

Passengers mppa	2011	2016	growth	per year
London	134	162	22%	4.0%
Outside London	84	105	25%	4.5%
National	218	267	23%	4.2%

ATMs (000s)	2011	2016	growth	per year
London	991	1107	12%	2.2%
Outside London	971	1042	7%	1.4%
National	1962	2149	10%	1.8%

Seats (million)	2011	2016	growth	per year
London	176	206	17%	3.3%
Outside London	113	131	15%	2.9%
National	289	337	17%	3.1%

5 Short-haul flights have also increased noticeably over the past five years. Both 'full service' scheduled and low cost carrier (LCC) sectors have grown strongly, in part through a marked drop in the market served by charter airlines. Overall, both domestic and long-haul passenger flights increased by 12% over the five year period, compared to a 29% growth in short-haul flights.

6 The pattern of ground origins of passengers has also shifted significantly in the last five years. The majority of recent national growth was concentrated in London, which has seen demand increase by 36%. Passengers at Heathrow grew from 69 million to 76 million - its runways are now effectively full and running at or about its planning cap of 480,000 aircraft movements a year. Gatwick grew from 34 million to 43 million passengers and now operates at capacity over increasingly long periods. The other three London airports, Stansted, Luton and London City, saw a combined increase of 13 million passengers in the five years. Outside London, the larger airports performed the most strongly, led by Manchester with growth from 19 million to 26 million passengers a year over the same time period.

The aviation model

7 The department continues to develop, maintain and operate a comprehensive aviation model. It comprises a suite of interrelated components to produce forecasts for demand at the national level, passengers and aircraft at the larger UK airports and the CO_2 emissions associated with aircraft departures from UK airports.

8 The model was used extensively in the Airports Commission's analysis, when the Commission was appraising their shortlisted capacity options. As the department adopts a policy of continuous improvement to its analytical models, the current model version builds on the technical changes used in that analysis, including the full modelling of competing overseas hubs. In addition it has undergone a significant number of further updates and improvements since 2015, most notably:

- updating all the base demand data to 2016
- validating the model with detailed 2016 statistics of aviation activity
- updating all the macroeconomic inputs on the main drivers of passenger demand (economic activity and fares) with the latest sources on GDP, consumer spending, oil prices and carbon costs available from the OBR, IMF, BEIS and others
- refreshing the aircraft fleet turnover model and fuel burn models with the latest data, a new peer review of this and information about aircraft from the latest version of European Environment Agency's emissions inventory guidebook

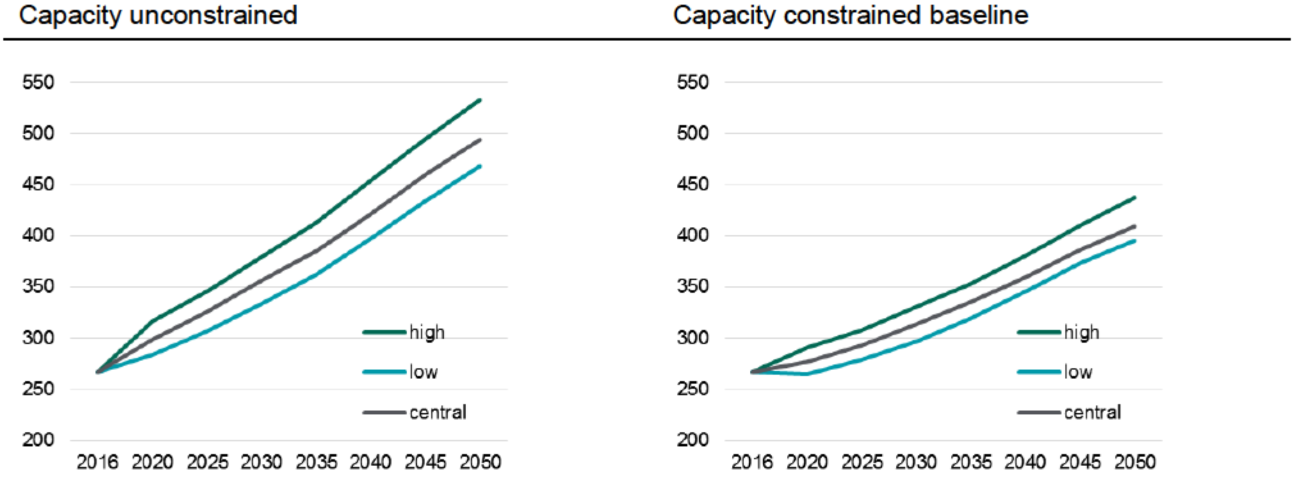
9 The purpose of these forecasts is primarily in informing longer term strategic policy rather than in providing detailed forecasts at each individual airport in the short term - commercial and local information not reflected in these national strategic forecasts could be significant at airport level in the short term.

National air passenger forecasts

10 The presentation of the air passenger forecasts as demand growth scenarios reflects the inherent uncertainty in forecasting to 2050. A series of supporting sensitivity tests on the key economic inputs provide further evidence on the potential variability around the underlying economic inputs.

11 Forecasts are made for both unconstrained demand and demand constrained by airport capacity limitations. Unconstrained forecasts give a picture of underlying demand while capacity constrained forecasts form the primary basis of the department's appraisal and decision making processes.

Capacity constraints are forecast to reduce demand growth



Demand is expressed in million passengers per annum (mppa)

12 Without constraints to airport growth, demand is forecast to rise to 355 million by 2030 (central scenario) and 495 million passengers in 2050 within a range of 480 to 535 million. When capacity constraints are taken into consideration, and no new runways are added, national demand is forecast to rise to 315 million by 2030 (central scenario) and 410 million passengers in 2050 within a range of 395 to 435 million passengers. This is a marked slowing of the rate of annual growth, with the new forecasts suggesting annual growth of 1.2-1.5% compared to an annual rate averaging 3.8% since 1990. This is as a result of market maturity, lower long term economic forecasts, capacity constraints and a significant rise in carbon prices.

Airport passenger forecasts

13 In addition to the baseline, the new forecasts take account of the three options for additional capacity in the South East of England shortlisted by the Airports Commission and included as part of the consultation on the Government's revised draft Airports National Policy Statement. The table below shows the capacity constrained forecasts in million terminal passengers per annum in the central demand case.

	Baseline	LGW 2R	LHR ENR	LHR NWR
London airports				
2016	162	162	162	162
2030	187	192	216	222
2040	199	220	235	241
2050	205	249	239	248
Airports outside London				
2016	104	104	104	104
2030	126	124	122	121
2040	160	150	147	146
2050	204	183	190	187
Total demand				
2016	267	267	267	267
2030	313	317	337	343
2040	360	370	382	387
2050	410	432	429	435

Figures relate to million passengers per annum (mppa)

London airports refer to Gatwick, Heathrow, London City, Luton and Stansted

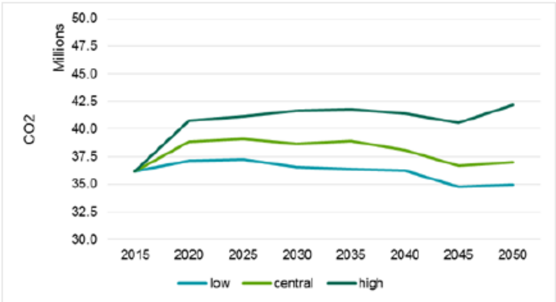
Baseline: no new runways; LGW 2R: London Gatwick Second Runway; LHR ENR: London Heathrow Extended Northern Runway; LHR NWR: London Heathrow North West Runway

14 Without additional new runways much of the growth is forecast to occur at airports outside London as airports in London become constrained. Adding a new runway at either Gatwick or Heathrow facilitates faster national growth, with more of it focussed in London, while other airports continue to grow. More information on the forecasts are provided elsewhere in this document, particularly in Chapter 7.

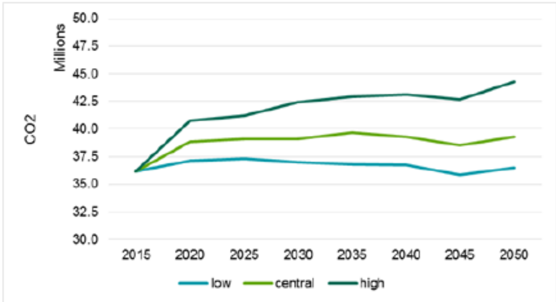
CO_2 emissions

15 Under the central demand forecast with no new runways, annual CO_2 emissions are forecast to be 37.0Mt by 2050. Adding a runway is estimated to result in an additional 1.5 to 2.9MtCO_2 across the range of demand growth scenarios assessed.

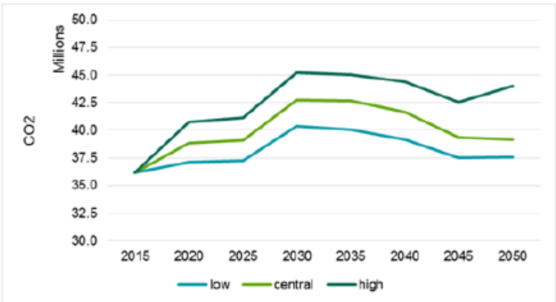
Baseline



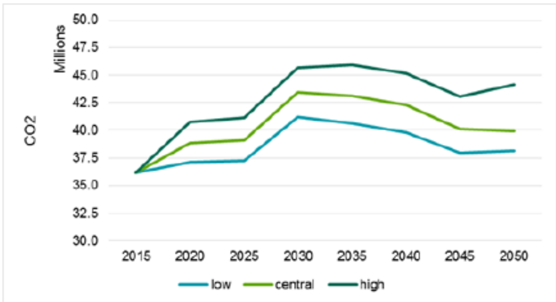
LGW Second Runway



LHR Extended Northern Runway



LHR Northwest Runway



National MtCO_2 emissions, departing flights

1. Introduction

1.1 This document sets out the Department for Transport (DfT) 2017 forecasts for air passengers, aircraft movements and CO_2 emissions at UK airports. The forecasts have a base of 2016 and extend out to 2050. They supersede the last set of forecasts published by the department in January 2013.[5]

Nature and purpose of forecasts

1.2 The DfT forecasts serve a number of purposes. They:

- take a view on a range of expected passenger demand and aircraft movements to inform the future aviation strategy and a range of policies
- can be used to inform decisions on the need for and location of new airport capacity and environmental assessments associated with such decisions
- provide estimates for the expected range of aviation greenhouse gas emissions which are used by the UK government in international negotiations
- are also used across other Government departments, their agencies and others working independently within the aviation sector

1.3 The purpose of these forecasts is primarily in informing longer term strategic policy rather than in providing detailed forecasts at each individual airport in the short term; the uncertainty reflected by future demand growth scenarios at the national level is compounded at the level of the individual airport. At the airport level the department's forecasts may also differ from local airport forecasts. The latter may be produced for different purposes and may be informed by specific commercial and local information – such information is particularly relevant in the short-term. For example, an airport may have reached an agreement with an airline to increase frequencies or routes in the short-term and for some airports, one route may make up a large proportion of their traffic. Nevertheless, for both continuity with previous publications and transparency of the forecasting methodology, airport level forecasts are included in this document.

1.4 While the department aims to accurately reflect existing planning restrictions on the expansion of airports, the forecasts should not be considered a cap on the development of individual airports. In some circumstances more recent airport specific data and forecasts might be used, in conjunction with additional relevant information, to inform local planning decisions.

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[5] *UK Aviation Forecasts*, DfT, 2013, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013.

Context of these forecasts

1.5 The forecasts inform a number of areas of aviation policy. On 2 February 2017, the Government published *Draft Airports National Policy Statement: new runway capacity and infrastructure at airports in the South East of England* (draft NPS).[6] supported by an appraisal of sustainability.[7] A public consultation on the Draft Airports National Policy Statement was held between February and May 2017.

1.6 In the consultation document on the draft Airports National Policy Statement,[8] the government explained it was undertaking further work to update the evidence base, including its passenger demand forecasts, and that it would publish this information as soon as possible during the consultation. The department continued to develop the aviation model taking the opportunity to incorporate the latest market data for 2016 to produce this updated set of demand forecasts. The department has published a revised draft Airports NPS taking account of the updated evidence base and has launched a public consultation on that document. The UK aviation forecasts 2017 (this document) includes new forecasts for the capacity options shortlisted by the Airports Commission, but does not update the evaluation and appraisal of the options - that has been undertaken separately.[9]

1.7 In July 2017 the Government also announced plans to develop a new UK Aviation Strategy to help shape the future of the aviation industry to 2050 and beyond. In August 2017 a call for evidence was published and a series of public consultations on the six objectives of the strategy was announced.[10] The aim of the strategy is to set the direction of long term aviation policy out to 2050 and beyond. These forecasts cover all commercial passenger aviation activity at the UK's most significant passenger airports. They therefore also supplement and inform future consultations on the six objectives of the strategy.

Scope of these forecasts

1.8 This report details the results of the new updated version of the department's aviation model with a base year of aviation demand in 2016. For the period 2016-2050 it includes forecasts of:

- underlying national air passenger demand 2016-2050 (unconstrained demand)
- national air passenger demand 2016-2050 allowing for airport constraints
- passengers predicted to use selected UK airports[11]
- aircraft movements (ATMs) at selected UK airports

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[6] https://www.gov.uk/government/publications/draft-airports-national-policy-statement.

[7] *Appraisal of Sustainability: Draft Airports National Policy Statement* (AoS), DfT, February 2017, https://www.gov.uk/government/publications/appraisal-of-sustainability-for-the-draft-airports-national-policy-statement

[8] Consultation on *Draft Airports National Policy Statement: new runway capacity and infrastructure at airports in the South East of England, DfT, February* 2017, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/589082/consultation-on-draft-airports-nps.pdf

[9] *Updated Appraisal Report*, DfT, 2017.

[10] *Beyond the horizon: The future of UK aviation*, DfT, July 2017, https://www.gov.uk/government/consultations/a-new-aviation-strategy-for-the-uk-call-for-evidence. The six stated objectives are to (1) help the aviation industry work for its customers (2) ensure a safe and secure way to travel (3) build a global and connected Britain (4) encourage competitive markets (5) support growth while tackling environmental impacts (6) develop innovation, technology and skills

[11] A list of the airports included in the forecasts is given in the box on page 27. Blackpool and Coventry airports were included in previous set of DfT forecasts but at present, and in the forecasts, are now effectively closed to passenger traffic and the total active UK airports in the modelling is 29.

- passenger and ATM activity at four competing overseas hub airports[12]
- measures of airline activity (distances flown and seats delivered)
- CO_2 emissions of aircraft departing the UK

1.9 Demand forecasts are presented for three demand growth scenarios: central, low and high. Sensitivity tests are also conducted varying the key demand drivers of the forecast growth scenarios.[13]

1.10 The airport capacity options for which forecasts are presented are the baseline and the three options shortlisted by the Airports Commission (Commission) and consulted on in the revised draft Airports National Policy Statement:

- baseline (no new runways)
- a Northwest Runway at Heathrow Airport (LNR NWR)
- an Extended Northern Runway at Heathrow airport (LHR ENR)
- a Second Runway at Gatwick (LGW 2R)

1.11 This report presents the forecasts for these options, plus a capacity unconstrained case. These forecasts are used in further downstream analysis and option appraisal, and that analysis and appraisal is included as information supporting a consultation on the revised draft Airports National Policy Statement.

Airports Commission forecasts

1.12 These are the first DfT forecasts since those published in January 2013, four months after the Airports Commission was set up in September 2012.

1.13 In February 2013 the Commission issued an aviation demand forecasting discussion paper seeking views on the most appropriate methods and tools for producing independent forecasts for their work. That paper recognised that the department's aviation model produced the most detailed national level forecasts available. However, it did raise some requirements which the Commission considered important and that the existing DfT model at that point did not fully meet. These included the need to deal effectively with the inherent uncertainty in any long term forecasts and to take better account of competition between UK and international hub airports. The Commission's interim report detailed the model developments undertaken to meet these requirements.[14] The Commission then used the department's aviation model with its own assumptions to produce, with technical support from the department, its own independent set of forecasts.

1.14 The forecasts presented by the Commission were considered by the department as part of the evidence base used in their final report.[15] The department's *Further Review and Sensitivities Report* concluded that the Commission's report was a sound and robust piece of evidence.[16] However, this did not mean that the department owned or adopted the forecasts used in the Commission's analysis. Hence this

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[12] Amsterdam (Schiphol), Paris (Charles de Gaulle), Frankfurt and Dubai International.
[13] UK and foreign GDP, oil prices, carbon prices, total fuel costs and levels of market maturity.
[14] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271231/airports-commission-interim-report.pdf
[15] For the Airports Commission final report, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/440316/airports-commission-final-report.pdf and for the Commission's final forecasts themselves, see the report *Strategic Fit: Forecasts* at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/439687/strategic-fit-updated-forecasts.pdf
[16] *Further review and sensitivities report*: airport capacity in the south-east, DfT, 2016, https://www.gov.uk/government/publications/airport-expansion-further-review-and-sensitivities-report.

document sets out the first official DfT forecasts since 2013. Developments to the model since 2013 are described in Chapter 2 of this report.

Uncertainty in forecasting

1.15 The forecasts are presented as demand growth scenarios to reflect the inherent uncertainty in forecasting to 2050. There are also supporting sensitivity tests on the key economic inputs. The growth scenarios have been informed by evidence on the potential variability around the economic inputs expected to drive future air passenger growth. The assumptions around the market maturity inputs also allow for past relationships between economic inputs and aviation activity to change, and variations on this relationship are considered among the sensitivity tests.

1.16 This document mainly presents unrounded forecasts. This is primarily to give transparency to modelling outputs - the use of unrounded figures does not reflect the underlying level of certainty around individual results.

This document

1.17 The rest of this report is set out in the following way:

- **Chapter 2** describes the models and methodology used to produce these forecasts and explains how these have changed since forecasts were last published.
- **Chapter 3** describes how the CO_2 emissions forecasts are produced and how the underlying models have been updated.
- **Chapter 4** examines how the UK aviation market has changed in the past five years, and the validation of the model.
- **Chapter 5** sets out the input assumptions used to produce these forecasts.
- **Chapter 6** describes the range of forecasts for underlying demand growth, unconstrained by any limits on UK airport capacity.
- **Chapter 7** describes the range of forecasts where demand is constrained by capacity considerations; four sets of capacity constraints are considered: the 'do minimum' baseline and the three capacity options shortlisted by the Airports Commission.
- **Chapter 8** presents the CO_2 emissions forecasts associated with the demand growth scenarios and the baseline and three capacity options.
- **Chapter 9** reports a number of sensitivity tests carried out to investigate the effect of key demand input assumptions.

1.18 A series of data annexes provide a breakdown of results in a more detailed form which are supplemented by a separate spreadsheet file of many of the tables that appear in this document. And, in addition to the data presented in this report, data files are available which provide fully disaggregated passenger and ATM outputs for the forecast years of 2030, 2040 and 2050.

2. The aviation forecasting model

Overview of model structure

2.1 This chapter describes the methodology and assumptions used to produce forecasts of UK air passengers and air transport movements (ATMs).

2.2 The complete model forecasts passenger demand from UK ground origin/destination to domestic and international zones, including information on which UK airport(s) or overseas hubs passengers use. Passengers are divided into two journey purpose groupings – business and leisure – and also whether they are UK or overseas residents.

2.3 The modelling is split into three main phases. First, demand is forecast nationally on a capacity unconstrained basis. Next, this demand is allocated to UK airports and overseas hubs using the relative total cost of travel associated with each route option including the effects of capacity constraints. It simultaneously calculates the frequency of ATMs needed to meet that demand. Finally, the allocation of passengers and ATMs is used to generate a series of downstream outputs including disaggregate information about passenger movements and costs as well as more detailed forecasting of aircraft and CO_2 emissions.

2.4 The modelling framework consists of a number of sub-models as shown in Figure 2.1. Each key model which determines the passenger and ATM forecasts is summarised in this chapter.

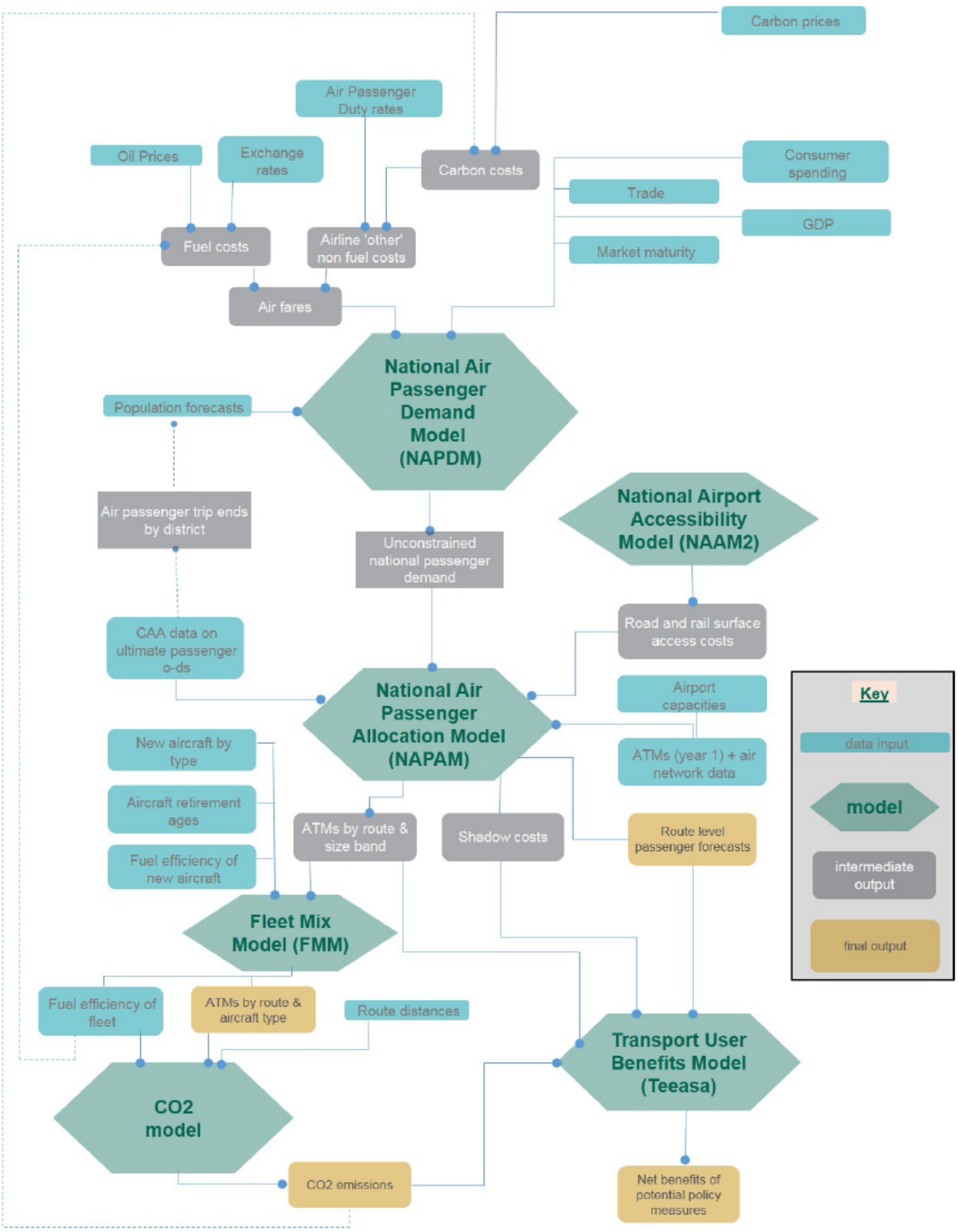

Figure 2.1 Aviation forecasting model

Forecasting aviation

Terminal passengers and air transport movements

2.5 The model forecasts the number of passengers passing through UK airports ('terminal passengers') and four competing overseas hubs each year. This covers UK and foreign residents travelling to, from or within the UK and those passengers passing through the UK and transferring at a UK or major competing overseas hubs. As part of the process to account for the impacts of airport capacity on passenger demand, the number of air transport movements (ATMs) and destinations served are also forecast.

2.6 The primary units of the forecasts are terminal passengers and ATMs. The Civil Aviation Authority (CAA) records the number of passengers and the number of aircraft take-offs and landings at UK airports each year.

2.7 The CAA defines an ATM as a landing or take-off of an aircraft engaged in the transport of passengers, cargo or mail on commercial terms (excluding 'air taxi' movements, and empty positioning flights). As it does not include non-commercial movements, it also excludes private, aero-club and military movements. These forecasts are consistent with the department's definition.

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

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

- a direct, one way trip from the UK to an overseas destination would count as one terminal passenger
- a domestic, direct, one way trip would count as two terminal passengers (one departing from an airport and one arriving at an airport)
- a one way trip from the UK to an overseas destination via a UK connection (or hub transfer) would count as three terminal passengers (one departing from the 'ground origin' airport, one arriving at the hub airport and one departing the hub airport)
- a one way trip between two overseas countries via a connection in the UK would count as two terminal passengers (one arriving at the hub and one departing the hub on a different connecting flight)

2.10 Terminal passengers and ATMs reported here refer to those attributable to modelled UK airports. They are two-way so a round trip would involve double the terminal passengers of the one-way trips given as examples above. The full definitions of terminal passengers and air transport movements and the way that the statistical data is assembled are available on the CAA website.[17]

National Air Passenger Demand Model (NAPDM)

Overview

2.11 The NAPDM forecasts demand that is unconstrained by airport capacity at the national level. It consists of a series of econometric models modified to take account of market maturity assumptions. These econometric models, combined with forecast data of the key inputs taken from external sources, provide aggregate passenger demand forecasts by NAPDM market. The key drivers are incomes and associated economic activity and air fares - NAPDM includes a module which forecasts fares. The markets are split by:

- whether a passenger has an international or domestic destination

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17 http://www.caa.co.uk/uploadedFiles/CAA/Content/Standard_Content/Data_and_analysis/Datasets/Airport_stats/Airport_data_2016_annual/Foreword.pdf

- the global region an international passenger is travelling to or from
- whether the passenger is a UK or foreign resident
- the journey purpose (leisure or business)
- whether the passenger is coming to the UK or just passing through the UK (or a modelled competing overseas hubs) to connect between international flights

NAPDM markets

Four global regions representing international passengers are included.

Market (abbreviation)	Name	Note
WE	Western Europe	Excludes the UK itself but in addition to the EU-27 includes non-EU countries in Europe, the Channel Islands, Iceland and all of eastern Europe including Russia
OECD	OECD	Long-haul OECD countries outside Europe: primarily USA, Canada, Mexico, Japan and Australasia
NIC	Newly industrialised countries	The definition has been broadened to include more long-haul emerging economies such as the Indian, sub-continent, south America, and Indonesia*
LDC	Less developed countries	Primarily Saharan and sub-Saharan Africa (excluding South Africa).

* The wider definition of NIC adopted by the Airports Commission is, retained, which also impacts other markets, particularly LDC.

International markets of passengers who have an origin or destination in the UK make up 16 markets with international-international transfers and internal two domestic markets bringing the total of econometrically modelled markets to 19.

International passengers

UK residents	Business WE	Business OECD	Business NIC	Business LDC
	Leisure WE	Leisure OECD	Leisure NIC	Leisure LDC
Foreign residents	Business WE	Business OECD	Business NIC	Business LDC
	Leisure WE	Leisure OECD	Leisure NIC	Leisure LDC
Transfer passengers	WE, OECD, NIC, LDC international - international combined			
Domestic passengers	Business UK	Leisure UK		

Econometric models

2.12 Econometric analysis is used to derive estimated relationships between passenger demand and their key drivers, with a different econometric model estimated for each market. The equations derived are then applied to projections of the explanatory variables to produce national level forecasts for each market.

2.13 The econometric models use analysis of a continuous time series from 1984-2008 drawn mainly from the International Passenger Survey (IPS) to estimate the 19 models. These model were peer reviewed, successfully explained past demand movements, have intuitive explanatory variables, and parameter values in line with economic theory.[18]

2.14 This analysis, along with independent academic research[19] highlighted that the key drivers for long term aviation demand have been the changes in incomes and associated economic activity, and the changes in air fares.

2.15 Figure 2.2 shows the long term growth in passengers at UK airports over the past 26 in the context of key world events which had a major impact on economic activity and air fares.

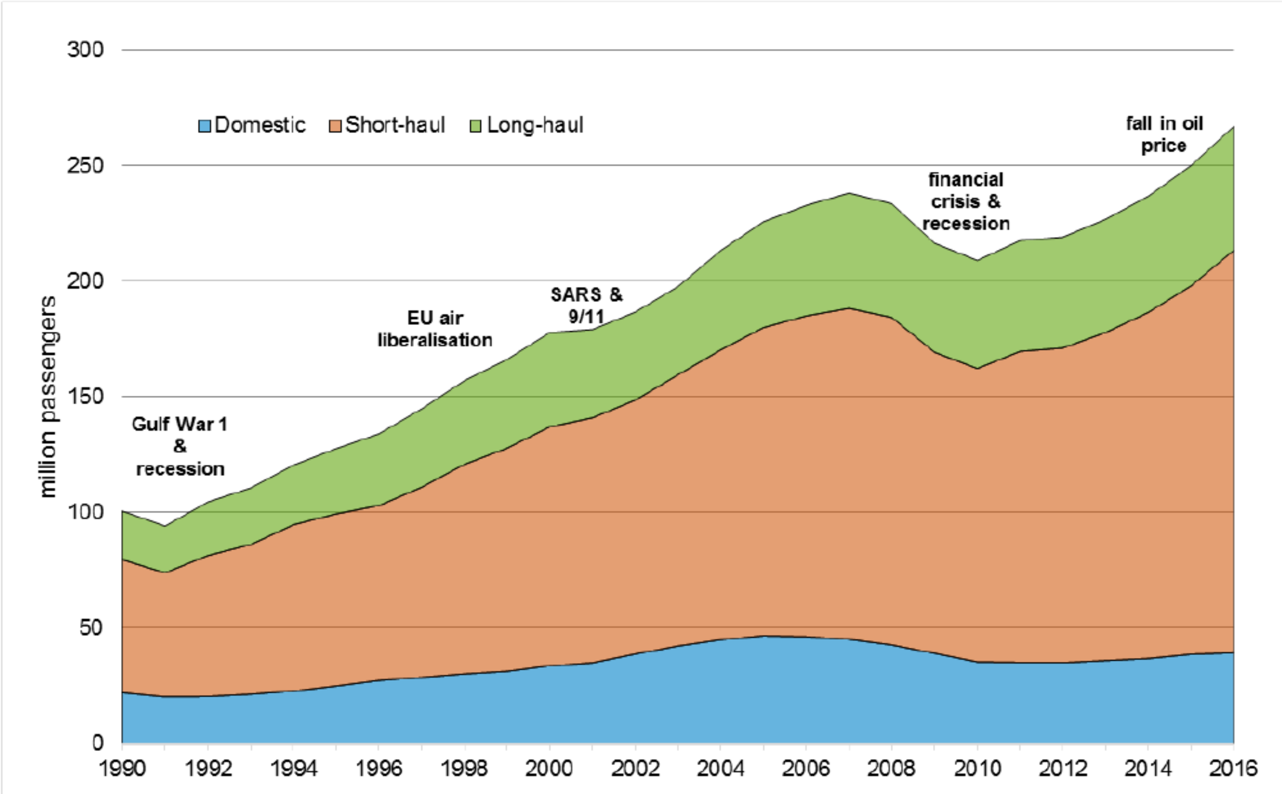

Figure 2.2 Historic UK passenger demand and key political and economic events

2.16 NAPDM starts with passenger outturns in the 2016 base year. The econometric equations are then applied to the projections of the explanatory variables, described in Chapter 5, to produce national forecasts for each of the 19 market sectors. Chapter 9 reports 'market maturity' sensitivity tests which test the impact of these relationships changing in different ways to the central case considered in this document.

2.17 Details of the econometric techniques used are set out in both the 2011 and 2013 forecast publications. These documents give details of the underlying datasets, model forms, modelling methodology, model performance and the peer review process. The 2011 forecasts additionally include supporting technical papers and

[18] The peer review is available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4508/peer-review-econometrics.pdf.

[19] The academic research into the drivers of air demand and comparisons of income and fares elasticities is included on page 19 of the 2013 forecasts, https://www.gov.uk/government/publications/uk-aviation-forecasts-2013.

provide notes on instances where elasticities were imposed instead of being taken from the econometric analysis.[20]

2.18 Table 1 summarises the starting level of the elasticities of air passengers with respect to income and fare used in the forecasts[21]. It shows that income (which in the form of the GDP forecasts includes a measure of population growth) is a strong driver of demand across the sectors. More disaggregate elasticities are provided in Chapter 9.

		Elasticity with respect to	
Sector	**Share of base year demand**	**Income**	**Air fares**
UK business	7%	1.2	-0.2
UK leisure	47%	1.4	-0.7
Foreign business	6%	1.0	-0.2
Foreign leisure	19%	1.0	-0.7
International to international transfers	9%	0.5	-0.5
Domestic	12%	1.1	-0.5
Total	100%	1.2	-0.6

The Airports Commission change to the international to international transfer fares elasticity has been retained. The elasticity changed from -0.7 to -0.5, reflecting that it now relates to a broader market, following the inclusion of overseas hubs.

Table 1 Starting level of income and price elasticities of demand

2.19 That air fare elasticities are relatively low is to be expected. Air fares are often only a relatively small proportion of the overall journey cost: duration of stay, costs of getting to the airport, convenience and many other factors all influence choice. It is intuitive that fare responsiveness is some way below unity, because passengers may also have other options besides not travelling in their response to an increase in fare. For example, passengers might reduce the cost of their trip by travelling to a less expensive destination, or by using a less expensive class of travel or airline. This overall fare elasticity is also in keeping with the findings for other modes that UK transport demand is price inelastic (i.e. it has a price elasticity below unity).

Market maturity

2.20 The econometrics is supplemented by a number of assumptions relating to 'market maturity'. This term is often used to refer to the process by which the demand for a product becomes less responsive to its key drivers through time. Air travel demand has shown very strong growth for several decades and while it would seem reasonable to start from the premise that the drivers of demand in the past will continue to drive demand in a similar way in the future, this can only be the starting point. Any exercise to forecast the future must also consider how the relationships observed in the past might change in the future.

2.21 In the NAPDM, market maturity is reflected by assuming that income elasticities decline over time. The central demand assumption is that the elasticities decline linearly to no more than 0.6 by the end of the maturity process which is assumed to

[20] In particular, see *Re-estimating the National Air Passenger Demand Model Econometric Equations*, August 2011, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4512/re-estimating-napdmee.pdf

[21] For the market maturity sensitivities, these values sometimes differ as set out in set out in Chapter 9.

span 70 years.[22] Sensitivity tests have been conducted (see Chapter 9) recognising the degree of uncertainty around these assumptions.

2.22 In defining the range of assumptions, the 19 market segments for which separate econometric models have been estimated are split into 3 groups. Broadly, the groups bring together markets on the basis of how soon they are expected to show signs of market maturity. These are set out in Table 2.

Maturity of markets	Markets included	Maturity starts
Most mature	DMB, DML	2010
Fairly mature	UBW, UBO, ULW, ULO, FBW, FBO, FLW, FLO, ULN, ULL	2015
Least mature	UBN, UBL, FBN, FBL, FLN, FLL	2025

Domestic journeys within the UK: DMB: Domestic business; DML: Domestic leisure.
Journeys between the UK and other countries: First letter denotes UK resident (U), or Foreign resident (F).
Second letter denotes Business (B), or Leisure (L).
Third letter denotes foreign origin or destination:W: Western Europe; O: OECD excluding Western Europe;
N: Newly Industrialised Countries (NICs); L: Less Developed Countries (LDCs).

Table 2 Maturity of different forecasting markets

2.23 The market maturity process is assumed to extend over 70 years while the demand forecasts used in the passenger to airport allocation and ATM modelling cover the period 2016-2050. Therefore by 2050 the declining of income elasticity in the maturity process is assumed to be incomplete. Table 3 sets out the income elasticities at the start and end of the forecasting period in the central demand case.

Market sector	Income elasticity in 2016	Income elasticity in 2050
UK business	1.2	0.9
UK leisure	1.4	1.0
Foreign business	1.0	0.8
Foreign leisure	1.0	0.8
International to international transfers	0.5	0.5
Domestic	1.1	0.8
Total	1.2	0.9

Table 3 Change in income elasticities over time

Updated fares module

2.24 A major component of the NAPDM is the fares module, which forecasts air fares by NAPDM market. It is a significant part of the model as changes in air fares are a key driver of changes in demand. It breaks out the components of fare into:

- fuel costs
- carbon costs
- Air Passenger Duty (APD)

[22] Unless the starting elasticity is already below 0.6 in which case the elasticity is unchanged throughout the modelled period. In contrast to the version used in the previous DfT publication, the fares elasticity is no longer assumed to decline in line with the income elasticity.

- airline 'other' costs

2.25 All fare inputs, except Air Passenger Duty (APD), are estimated on a per seat-kilometre basis. This is because the primary driver of airline costs, and ultimately fares, relate to aircraft usage and its associated costs rather than to the passengers carried. These seat-kilometre cost components are then multiplied by distance (on a geographical market basis) and finally APD is added to derive a total fare. As the forecast components change over time, so does the forecast fare.

2.26 An overview of the bottom-up methodology for forecasting fuel costs in every year is set out in the box below.

Modelling of airline fuel costs

Oil price ($ per barrel)

Oil price projections in $ per barrel are taken from the Department for Business, Energy and Industrial Strategy.

Spot fuel price ($ per litre)

Regression analysis suggests the following relationship between the spot fuel price and the oil price:

Price ($) = 0.03 + 0.007 x oil price ($)

Spot fuel price (£ per litre)

These are converted into sterling using exchange rate projections from the OBR.

Hedged fuel price (£ per litre)

Based on a review of airline accounts, the effective fuel price forecast to be paid in a given calendar year is assumed to be based on spot prices in the most recent three calendar years. It is weighted as follows: 50% of the spot price in the given year, 33% the previous year, and 17% the year before that.

Fuel cost (pence per seat km)

This is turned into a cost per seat km using fuel efficiency outputs from the Fleet Mix and CO_2 models. It is assumed that any changes in fuel costs feed through to changes in air fares.

2.27 This approach revises the methodology underpinning the fuels cost modelling used in previous forecast publications. Previous forecasts used CAA airline account data to determine the base year level of fuel costs per seat-kilometre. This approach has been revised to bring it into line with the modelling of carbon costs, with base year fuel consumption driven by outputs from the CO_2 model.

2.28 This revised approach has two main advantages. It:

- allows fuel consumption rates to vary by NAPDM market, taking into account the different fleet mix (and therefore fuel efficiency) associated with different markets
- ensures consistency with the way carbon costs are modelled

2.29 The result is a lower estimate of fuel costs than in previous model versions, even before taking account of the reduction in oil prices. This change of approach does not affect the methodology of forecasting changes in fuel costs over time, and so overall has relatively little impact on forecast demand growth.

2.30 Previous forecasts made no allowance for the practice of airline hedging strategies. Following the large movements in oil prices towards the end of 2014, the department undertook an analysis of such strategies, using airlines' published annual reports. This confirmed that, as is well known, many airlines hedge a proportion of their fuel costs, so such costs often do not change simultaneously with the price of oil. Strategies vary by airline, with the common aim of protecting themselves against sudden changes in fuel prices. Airlines do this through a variety of mechanisms which determine the price of fuel in advance. As the model does not include specific airlines within it, it is necessary to assume a representative hedging strategy across the sector. The analysis of airline annual reports concluded that the effective fuel price that airlines would be predicted to pay in a given calendar year should be based on:

- 50% of the spot jet fuel price in the given year
- 33% of the spot price in the previous calendar year and
- 17% of the spot price in the calendar year before that

2.31 This change has the advantage of better reflecting airline practices, resulting in a profile of fuel cost forecast changes that are more robust. The impact on demand growth depends on the profile of fuel prices in the two years preceding the base year. Under the fuel and oil price assumptions used in these forecasts, this revised methodology results in higher forecast demand growth, although its impact is very small. The resulting fuel cost estimates are set out in Chapter 5.

2.32 Airline 'other' (non-fuel) costs are calculated as the difference between the quantified components of airline costs and the air fare. More detail on the data used, and resulting estimated costs, is provided in Chapter 5.

Geographical composition of demand

2.33 The data and approach taken to estimate the distribution of passenger traffic growth across UK districts has been revised since the last DfT and Airports Commission forecasts using the model. This affects the geographical composition of a given level of demand growth across UK districts, but not the total demand by NAPDM market. In tandem with these changes, as Figure 2.1 illustrates, this part of the model has become subsumed in the NAPDM.

2.34 In previous versions of the department's model, changes in the local district composition of demand over time were driven by a series of regressions, with the most important drivers being forecast population and local income growth. The revised approach has been simplified so that the sole driver is each district's projected share of population growth. Trip rates grow by the same percentage as the population in each district within each NAPDM market. This ensures that districts with faster forecast population growth receive a higher share of each market's forecast demand growth.

2.35 Previous model versions also assumed each district's share of non-UK resident traffic (by NAPDM market) was fixed over time. This has been revised such that the same assumptions on demand distribution apply to foreign residents as well, implicitly assuming that foreign residents are more likely to visit areas that have a fast-growing population. This assumption is supported by the growing significance of the visiting friends and relatives (VFR) market for the aviation industry.

2.36 The department has taken this approach because of the absence of official local or regional Gross Value Added (GVA) forecasts. There is also tentative empirical evidence suggesting that regional GVA variations do not play a particularly significant role in determining the composition of aviation passenger demand. Furthermore, the revised approach helps to simplify the modelling and update process, improving model transparency and usability.

2.37 These changes do not affect the level of overall national trip growth forecasts, but they do lead to a greater concentration of passenger traffic growth in London and the South East.

National Air Passenger Allocation Model (NAPAM)

2.38 The National Air Passenger Allocation Model (NAPAM) forecasts passenger demand at 31 UK airports plus four competing overseas hubs.[23] It forecasts how passengers might choose between the airports in reaction to their relative estimated attractiveness. As part of this process, it forecasts ATM demand by airport and the fare premia (often termed 'shadow costs') for passengers wishing to use airports operating at capacity. The NAPAM takes as an input the demand growth over time by market forecast by the NAPDM.[24]

2.39 The box below shows the airports in the model (with IATA codes) arranged by forecasting region.

[23] Blackpool and Coventry airports are included in this total but at present and in the forecasts are now effectively closed to passenger traffic, so there are currently only 29 mainland UK airports, plus the four overseas hubs in the model. A 32nd UK slot reserved for new airport sites is unused in these forecasts.

[24] The way in which this is done has changed from the last DfT forecast publication, with the developments made while the Airports Commission was using the model retained. See *Airports Commission: Interim Report, Appendix 3, Technical Appendix*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266670/airports-commission-interim-report-appendix-3.pdf, pages 49-51, for more details.

Airports in the National Air Passenger Allocation Model

London	South West and Wales	Scotland
Gatwick (LGW)	Bournemouth (BOH)	Aberdeen (ABZ)
Heathrow (LHR)	Bristol (BRS)	Edinburgh (EDI)
London City (LCY)	Cardiff (CWL)	Glasgow (GLA)
Luton (LTN)	Exeter (EXT)	Inverness (INV)
Stansted (STN)	Newquay (NQY)	Prestwick (PIK)
Other South East and East	**North**	**Northern Ireland**
Southampton (SOU)	Doncaster-Sheffield (DCS)	Belfast City (BHD)
Southend (SEN)	Durham Tees Valley (MME)	Belfast International (BFS)
Norwich (NWI)	Humberside (HUY)	
Midlands	Leeds-Bradford (LBA)	**Overseas hubs**
Birmingham (BHX)	Liverpool (LPL)	Amsterdam Schiphol (AMS)
East Midlands (EMA)	Manchester (MAN)	Dubai (DBX)
(Coventry - closed)	Newcastle (NCL)	Frankfurt (FRA)
	(Blackpool - closed)	Paris Charles de Gaulle (CDG)

Modelling the passenger's choice of airport

2.40 NAPAM generates the forecast passenger demand at each modelled UK airport. The airport allocation model has been built to explain and reproduce passengers' current choice of airport, as recorded in CAA passenger interview surveys.

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

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

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

Allocating passengers between airports

Modelling and forecasting how people choose between a set of discrete options is an established practice in statistics and transport modelling. NAPAM contains an application of the standard multinomial logit formulation commonly used in this context. The model estimates the proportion P of passengers with journey purpose p travelling to/from UK zone i to foreign destination j, that use airport A, can be represented by the following flexible functional form (the example is the simplest form):

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

where

i = zone of origin

j = zone of destination

p = journey purpose

A = airport

R = route

Cost(i,j,A) = generalised cost of travelling from zone i to zone j using airport A

β = parameter to be estimated during calibration

The process of model calibration involves using statistical data to select the set of values for the unknown parameters which lead to the model's predictions best fitting the data.

The strength of different drivers of passengers' airport choice is likely to vary between passenger groups - for example, business passengers may be more affected by the frequency of flights offered. Therefore separate allocation models are estimated for the following markets:

- international scheduled[25] and charter (package holiday) passengers
- domestic passengers beginning and ending their journeys in the UK
- transfer passengers 'interlining' by changing planes at a hub airport[26]
- UK and foreign passengers
- business and leisure passengers
- short-haul and long-haul passengers

Some of these markets have more complicated functional forms than the generic equation shown in this box.

[25] A further distinction is currently drawn between conventional scheduled and Low Cost Carriers (LCC) in the allocation as the calibration results showed a difference in parameter estimates. However, these markets have become less clearly differentiated over time, and this distinction is not made at all parts of the forecasting (e.g. the econometric models of unconstrained demand). The distinction has also been withdrawn in the model of internal domestic flights.

2.43 The strength of each factor in driving an airport's share of demand is determined by calibrating logit models with data on passenger airport choices drawn from CAA passenger interview surveys.[27] This involves using techniques by which the weighting on each factor is estimated so as to maximise the model's accuracy in predicting current choices. This means that the model aims to represent passengers' actual, observed, airport choice behaviour.[28] The current model uses the choice parameters which were calibrated and documented at the time of the independent peer review undertaken in 2010. A variety of other parameters including aircraft size graphs and route level generalised cost constants are adjusted to validate route level forecasts against actual route level passenger allocations in the base year of 2016.

2.44 The model splits the UK into 455 zones (see Figure 2.3). It assumes that the share of travellers originating in, or destined for, each zone potentially travelling via each of the up to 32 modelled airports[29] depends on:

- the time and money costs of accessing that airport by road or public transport based on the network of road and rail services (illustrated in Figure 2.6); this uses the standard transport modelling approach of combining journey time, including waiting and interchanging, and money costs into a single 'generalised cost' measure
- flight duration and the frequency of the service at each airport
- travellers' preferences for particular airports
- travellers' value of time (which varies by journey purpose)

2.45 The ultimate destination of internal UK passengers is one of the 455 zones illustrated in Figure 2.3. The zoning follows 1991 census geography rather than current administrative boundaries. This is deliberate to retain sufficient granularity in regions such as Scotland, Durham, Northumberland, Shropshire and Wiltshire where current unitary administrative boundaries are now too broad to allow accurate passenger allocation between neighbouring airports.

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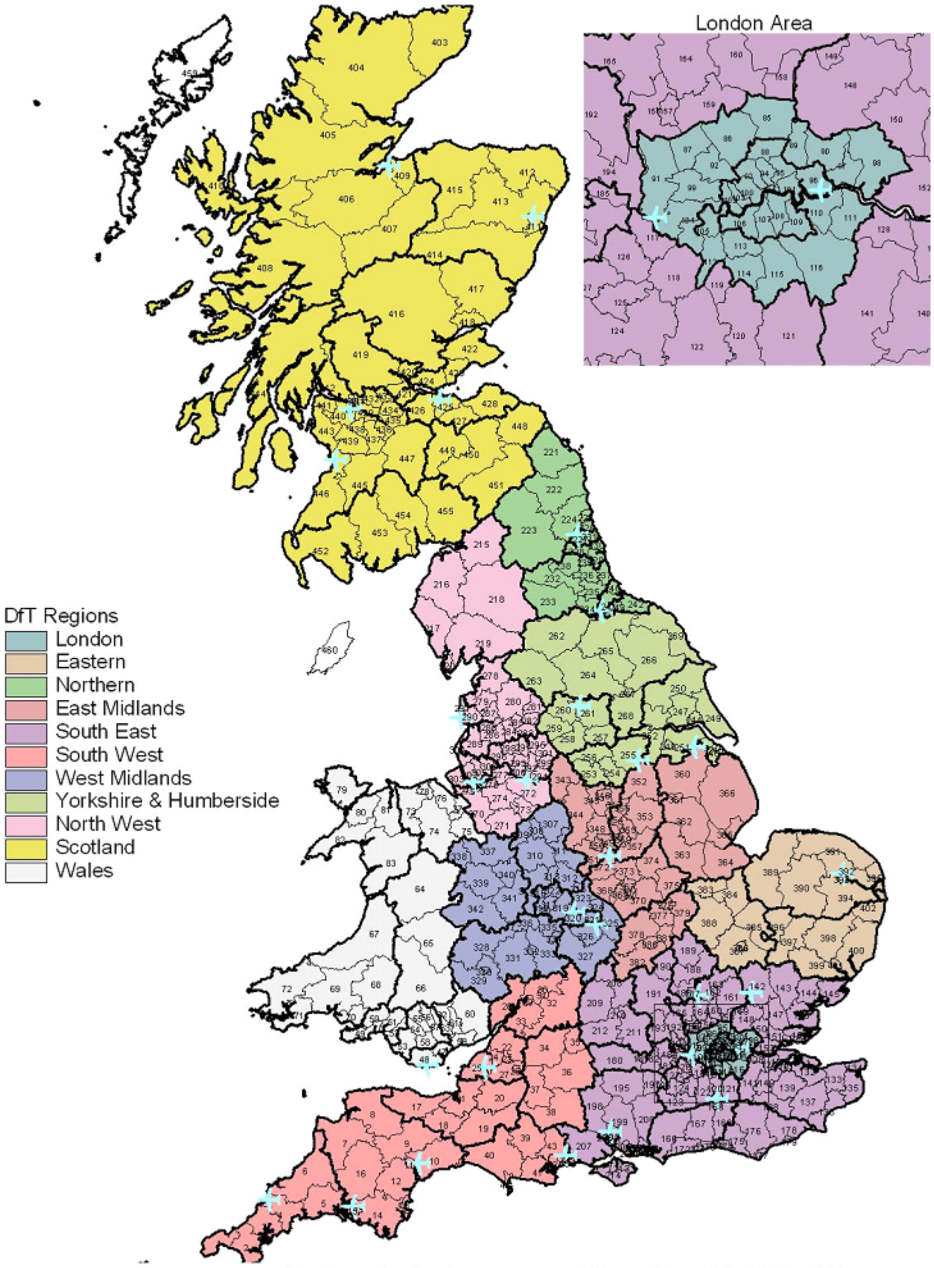
[26] These include passengers with UK origins or destinations changing at a UK hub airport ('domestic interliners'); passengers with UK origins or destinations changing at an overseas hub airport such as Amsterdam Schiphol; or, passengers with no ground origin or destination within the UK but who use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

[27] Passengers are interviewed by the CAA at Heathrow, Gatwick, Stansted, Luton and Manchester every year with all but the smallest regional airports in the model being rotated on an annual basis normally on a 3-5 year cycle. The 2008 choice data used in the estimation exercise included the nine airports surveyed by the CAA in 2008 with data from other airports not surveyed during that period taken from the most recent survey and updated to 2008 traffic levels from published CAA activity statistics.

[28] The Peer Review report (*Peer Review of NAPALM*, John Bates Services, October 2010) (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4506/review-napalm.pdf) provides a useful introduction to the re-estimation. Note that NAPAM used to be called 'NAPALM'.

[29] The 31 airports were selected when NAPAM was first developed in 2000 and were the busiest 27 mainland UK airports for passenger activity plus the two Belfast airports. In 2006 Coventry and Blackpool were added and Doncaster-Sheffield replaced Sheffield City to reflect then current activity. In the 2013 version Southend replaced Plymouth which closed in 2011. In these forecasts Coventry and Blackpool have now ceased regular passenger operations, but remain in the model without any traffic. Two airports now busier than the smallest of the current modelled set, Isle of Man and Derry, are both 'offshore'. The 32nd airport slot was reserved for assessing new airport sites.



National Air Passenger Allocation Model: UK Zones

Figure 2.3 NAPAM UK district zones

2.46 International passengers are defined as those that travel to one of 27 international route group zones or one of the 21 largest European airports (which are modelled as separate destinations) as their ultimate destination.. The model explicitly includes the option for passengers to transfer at a hub airport either in the UK or abroad, including Amsterdam, Frankfurt, Dubai or Paris Charles de Gaulle.

2.47 The definition of 'route group zones' and the identity of separately modelled European airports are shown in Figure 2.4 and listed in the next text box.

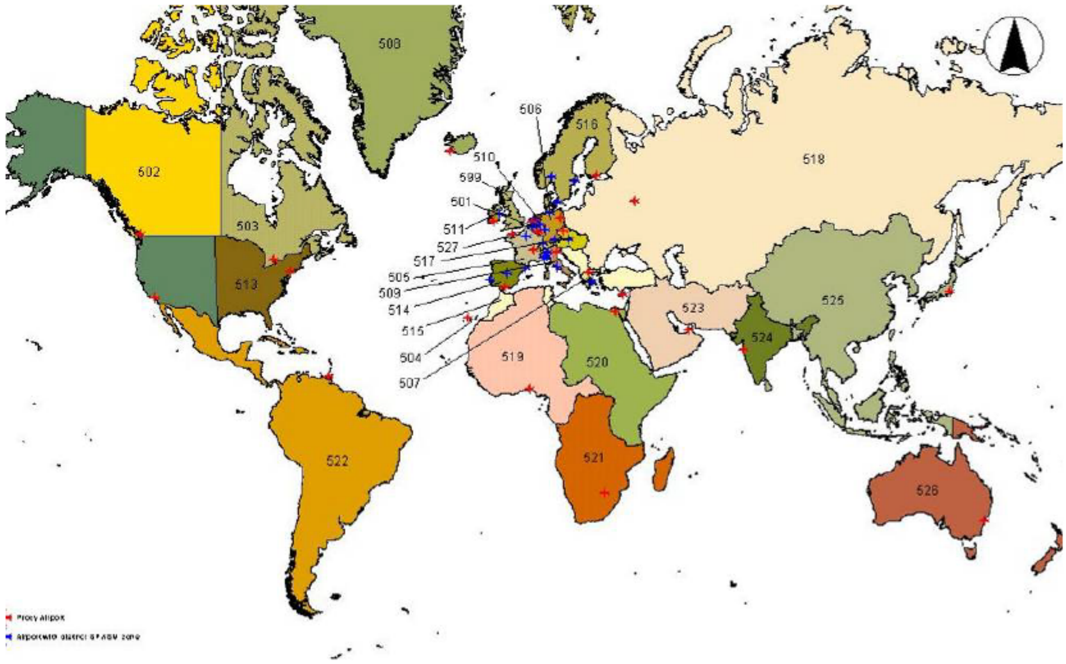


Figure 2.4 NAPAM international destination zones

2.48 The share of a zone's demand an airport will attract will be greater the lower the time and money costs of accessing and using that airport is, and the greater the frequency of service is.

2.49 Air fares are an important part of forecasting aviation growth in the national demand model (NAPDM). However, it has not been possible to include fares in the list of factors driving choice between individual airports. An extensive exercise to re-estimate the factors driving airport choice failed to find a statistically significant relationship between fares for particular routes and passengers' choice of airport. This is partly attributable to the difficulty in deriving reliable mean fares with the increasingly wide spread of fares for each route available with web based ticketing and modern yield management systems. It is also likely to be because the variability of the aggregated fares data between different airports in the same market is often low.

2.50 The decision to omit fares as an airport choice variable was supported by the peer review process in 2010.[30] However, as the previous section has described, fares remain a key driver of the underlying unconstrained demand forecasts and play a part in determining the overall decision on whether to travel by air. At the personal level, at particular times and for particular journeys, it is to be expected that comparison of fares play a key part in individual choices of airport (especially for those which are geographically close), even though statistically robust relationships cannot be derived for the whole market.

2.51 Summing forecast demand for each airport across all the zones and passenger markets gives the total forecast demand for each airport, unconstrained by airport capacity.

[30] *Peer Review of NAPALM*, John Bates Services, October 2010, pp. 25-26. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4506/review-napalm.pdf

NAPAM international zones and route groups

Route group zones, length of haul, NAPDM region			Route group zones, length of haul, NAPDM region	
1.Belgium/Luxembourg	S	WE	15.Other Mediterranean states	WE
2. Canada (west)	L	OECD	16.Scandinavia/Baltics	WE
3. Canada (east)	L	OECD	17.Central Europe	WE
4. Canary Islands	S	WE	18.Eastern Europe	WE
5. France	S	WE	19.West Africa	LDC
6. Germany	S	WE	20.East Africa	LDC
7. Greece	S	WE	21.South Africa	NIC
8. Iceland	S	WE	22.Caribbean & South America	NIC
9. Italy	S	WE	23.Middle East	NIC
10.Netherlands	S	WE	24.India Sub-Continent	NIC
11.Ireland	S	WE	25.Far East	NIC
12.United States (west)	L	OECD	26. Australasia	OECD
13.United States (east)	L	OECD	27.Channel Isles	WE
14.Iberian Peninsula	S	WE		
Individual airports, all short-haul and WE				
28. Paris Charles de Gaulle (CDG)			39. Milan Linate (LIN)	
29. Dublin (DUB)			40. Stockholm Arlanda (ARN)	
30. Amsterdam (AMS)			41. Vienna (VIE)	
31. Frankfurt (FRA)			42. Oslo (OSL)	
32. Brussels (BRU)			43. Barcelona (BCN)	
33. Zurich (ZRH)			44. Athens (ATH)	
34. Dusseldorf (DUS)			45. Hamburg (HAM)	
35. Copenhagen (CPH)			46. Lisbon (LIS)	
36. Madrid (MAD)			47. Geneva (GVA)	
37. Munich (MUC)			48. Nice (NCE)	
38. Rome Fiumicino (FCO)				

Some international zones do not map exactly to one of the four NAPDM regions; in such cases, the NAPDM region with the most traffic within the zone is used.

The 27 'route group zones' are each further subdivided into up to 20 possible destinations. NAPAM analyses the level of demand between a UK airport and a route group zone to forecast how many destinations within the zone are served by a particular UK airport. This facility is calibrated to provide accurate baseline forecasts of the number of individual destinations served by each UK airport and is included in the model validation process.

Modelling ATMs

2.52 The ATM model forecasts the number of ATMs by aircraft size band and route for each airport. It is important to understand the demand in terms of numbers of aircraft flights (ATMs) as well as the number passengers for four reasons:

1. A key determinant of passenger choices is the frequency of service provided at different airport options. As such the projection of the number of flights influences passenger decisions.
2. As demand is forecast to grow, forecast demand exceeds capacity at some airports. The limiting capacity could be the airport terminal, runway, or planning constraint. Runway capacity is measured not by passenger numbers, but by the number of ATMs. The ATM model within NAPAM translates passenger demand into ATM demand at each airport, to allow comparison of demand with both passenger and ATM capacity constraints.
3. It is important to predict when new routes will become available at particular airports, creating a new option for passengers to consider.
4. Finally, predictions of ATMs and aircraft-kilometres by aircraft type on each route are required for estimating future aviation carbon emissions.

2.53 The ATM model in NAPAM simulates the introduction of new routes by testing in each forecast year whether sufficient demand exists to make new routes viable from each airport. Effectively this assumes that supply of routes will respond to demand, subject to airport capacity and a minimum passenger threshold to make a new route commercially viable. The test is two-way, so routes can be both opened and withdrawn year by year. Airports are tested jointly for new routes, allowing them to compete with each other.

2.54 For each route from each airport, the ATM model in NAPAM then forecasts the size of aircraft, load factor, and frequency of operation used to meet forecast passenger demand based on relationships between these factors derived statistically from historical data. The box on page 35 provides further detail on the modelled relationship between capacity, demand, aircraft size and how this is affected by capacity constraints.

2.55 Forecasts of CO_2 emissions and environmental assessments require more detailed assumptions to be made about the specific aircraft types that make up the stock of aircraft in each forecast year. These are generated in the Fleet Mix Model (FMM), which is explained in the next chapter.

Freight ATMs

2.56 Freight is not modelled in detail. An assumption about the number of freighter ATMs is nevertheless required in the model as freighters potentially affect the space for passenger ATMs available where capacity constraints exist and, as discussed in Chapter 3, CO_2 emissions.[31] At the airport level the number of freighter movements has been volatile with some evidence of overall national decline in recent decades. In the absence of clear trends for individual airports, the modelling now assumes that the number of such movements will remain unchanged from 2016 levels at airport level across the system.

[31] For capacity constraints in the London area, this mainly affects Stansted as freighter numbers are insignificant elsewhere. At Heathrow, freighters now represent under 0.5% of ATMs.

Shadow costs and constraining passengers and ATMs to airport capacity

2.57 As illustrated in Figure 2.5, NAPAM forecasts both passenger and ATM demand at each airport with ATM demand being a function of passenger demand, load factors and the modelled size of the aircraft on individual routes. Aircraft sizes in seats and load factors evolve over time as the model rolls forward.

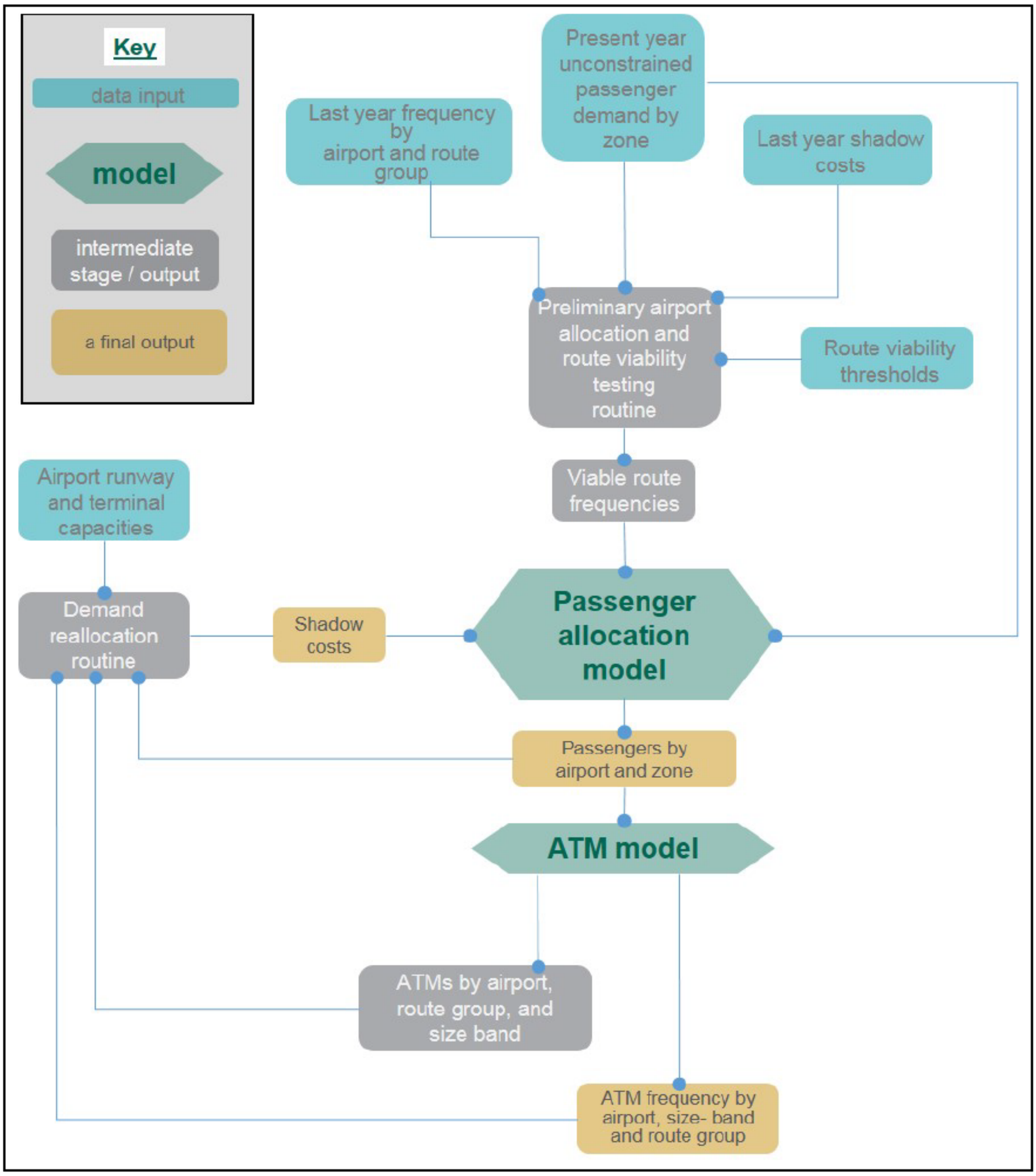


Figure 2.5 NAPAM internal allocation, ATM and shadow cost models

2.58 The demand allocation components of NAPAM iteratively model the impact and interactions of capacity constraints on the numbers of air passengers, ATM numbers and their passenger loads at each UK airport. Where unconstrained passenger demand wanting to use an airport exceeds capacity, the demand reallocation process increases the cost of using the airport until its demand falls to within its maximum capacity. This cost is known as a 'shadow cost', or 'congestion premium' and performs the function of limiting the number of passengers to capacity.

2.59 As discussed in the box below, one of two types of shadow cost may be applied when an airport becomes congested. It may be a runway slot shadow cost, representing a charge per aircraft, which is shared between all the passengers, with its value depending on the average aircraft size for each route in a given year. Alternatively, a terminal shadow cost represents a charge levied equally on every passenger passing through the airport and not varying by route. Shadow costs can also be seen as representing the value a marginal passenger would place on flying to/from that airport, if extra capacity were available. It is therefore a key input to the appraisal of potential additional capacity.

Relationship between capacity, demand and aircraft size

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

However, a shortage of runway capacity can also favour the use of larger aircraft, to maximise the number of passengers using scarce slots. In the model this is represented when a runway shadow cost rather than terminal shadow cost is applied. The Demand Reallocation Routine tests for breaches of both runway and terminal capacity with runway constraints regarded as more 'binding' than terminal where both are becoming overloaded. All shadow costs are ultimately added to the individual passenger's overall cost of travel. But a runway constraint will stimulate the use of larger aircraft and higher passenger loads because airlines can better meet demand with larger more fully loaded aircraft and because the charge levied on the use of the runway is lower on a per passenger basis for more fully loaded aircraft. Conversely a terminal shadow cost will not penalise the use of smaller aircraft, usually found on shorter haul routes.

The range of business models adopted by different airlines will play a part - the full extent of which is hard to replicate exactly in this type of model. For example, some airlines may place greater emphasis on frequency and having services conveniently timed throughout the working day and may maximise profits on certain routes with more frequent services operated by smaller aircraft.

Overall, the most prevalent effect in the ATM Demand Model is in line with the underlying historic data of aircraft loads tending to increase as demand rises. However, the capacity response effect also occurs, and in practice the response to capacity limits varies between airlines depending on their differing business models and commercial objectives.

2.60 In the iterative demand reallocation process, the shadow cost is added to the other costs of using each over-capacity airport, before repeating the passenger allocation element. When a shadow cost solution is found which fits all airports within user specified bounds of their input runway and terminal capacities, the ATM models are re-calculated to check ATM numbers still fit runway constraints. If they do the model is said to have converged for that year, if not the iterative process continues until a solution is found in which both types of capacity are not exceeded at any airport, or in practice not allowed to exceed the user input tolerances allowed to ensure model convergence is achieved.

2.61 This process means that forecasts of passenger numbers at airports under capacity constraints takes into account capacity at all airports. These forecasts are also based on passengers' observed airport choice behaviour.

2.62 Shadow costs have two significant effects on the allocation of demand:

a. some passengers in the model will be re-allocated to an alternative, less-congested airport but such 'less-preferred' airports may also in turn experience changes in shadow costs and affect further airports; and

b. some passengers in the model will decide not to fly, reducing the total amount of passenger traffic travelling through UK airports - this is discussed further below.[32]

2.63 Higher shadow costs increase the total cost of travel, leading some passengers to decide not to travel by air at all: this process is known as 'suppression'. The modelling reflects this by adding shadow costs to the generalised cost and applying the NAPDM fare elasticities described earlier in this chapter.

2.64 This version of the model uses a refined suppression process introduced in the model used by the Airports Commission. This involves a revised functional form (relative to that used in the last set of published DfT forecasts) in line with the 2011 peer review recommendations.[33] It ensures a more rigorous set of elasticities are used, as well as providing greater consistency between NAPDM and NAPAM. The impact has been to slightly increase the extent of the suppression, but the overall impact on the forecasts is small, particularly when compared to the impact of allowing reallocation from UK airports to the overseas hubs now included in NAPAM.

[32] In the latest version of the model total volumes of international-international transfers may have been significantly reduced because of shadow costs at the UK hub airports. Despite appearances at the UK airport level, this is usually not trip suppression but re-allocation to overseas hubs which are now fully incorporated into the modelling following the Airports Commission's required improvements - see the box on page 37.

[33] *Peer Review of NAPALM*, John Bates Services, This change was incorporated in the Airports Commission forecasts, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4506/review-napalm.pdf

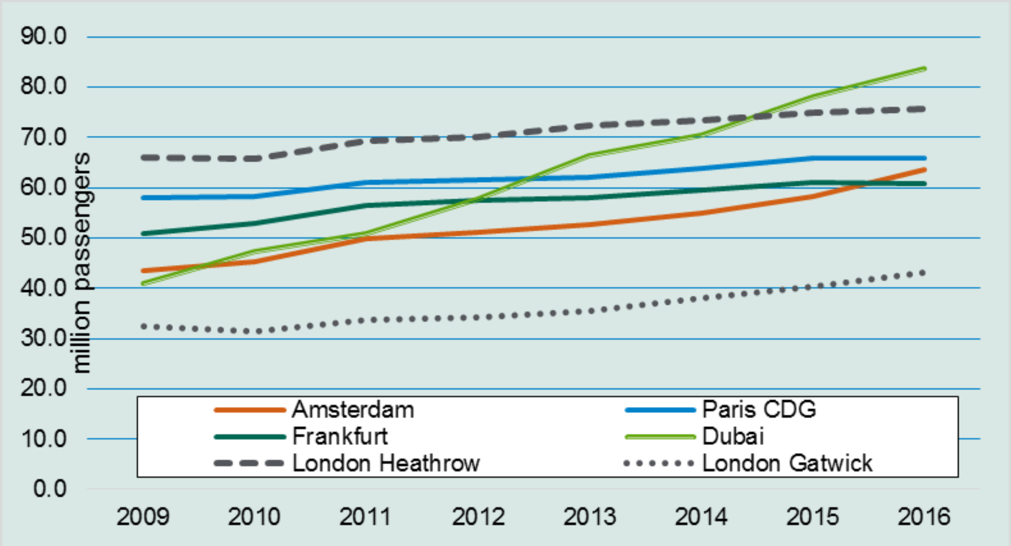
The overseas hub airports in the UK aviation model

Previous DfT versions of NAPAM had allowed passengers with origins and destinations in the UK to reach their destinations by making transfers at either a UK hub airport (principally Heathrow, Gatwick or Manchester) or routeing via an overseas hub airport (Amsterdam, Paris Charles de Gaulle, Frankfurt or Dubai). However, while the UK hubs potentially had capacity constraints and shadow costs together with dynamically modelled route networks, the costs of using competing overseas hubs was relatively fixed.

The Airports Commission wanted to examine this issue. Connected to this, they also wished to look at the potential for demand for currently deterred international-international transfers from UK hubs to be attracted by expanded capacity in UK.

Demand at some competing hubs, notably Dubai, has been growing strongly which makes them relatively more attractive to passengers.

Growth at hub airports competing for international transfer passengers



Amsterdam, Paris Charles de Gaulle, Frankfurt and Dubai were consequently fully integrated into NAPAM, using a methodology consistent with that used for UK airports. This meant:

- full capacity constraint modelling and the potential for shadow costs at the overseas hubs
- collecting data on current international-international transfers at all these airports and allocating this combined demand pool around all the modelled hub airports
- filling in and forecasting the rest of each airport's non-transfer (local) demand
- allowing the dynamic modelling of ATMs and route networks

All these features have been retained in the department's current version of NAPAM.

Demand data

2.65 This new model version and forecast replaces all previous international demand data, rebuilding the base demand matrix with a new CAA passenger interview set for 2011-2016. The data is controlled at route level (scheduled/charter/LCC) to 2016 passenger flows on individual routes. In total over 1.1m interviews collected at 81 separate CAA surveys over the period have been processed and used to build the origin-destination base demand matrices by airline type and journey purpose.[34] The average sample rate across all 81 surveys was 1 in every 1200 passengers. Table 4 shows when the surveys were undertaken and the number of interviews collected at each survey.

		2011	2012	2013	2014	2015	2016	Total
ABZ	Aberdeen	0	0	6,619	0	0	0	6,619
BHX	Birmingham	11,575	10,323	11,395	14,102	8,326	9,113	64,834
BRS	Bristol	0	9,585	0	0	9,126	0	18,711
CWL	Cardiff	0	6,611	0	0	7,863	0	14,474
EMA	East Midlands	6,739	7,030	6,616	7,537	7,132	8,217	43,271
EDI	Edinburgh	0	0	13,817	0	0	0	13,817
EXT	Exeter	0	6,253	0	0	0	0	6,253
LGW	Gatwick	24,695	29,524	28,747	28,442	26,640	25,495	163,543
GLA	Glasgow	0	0	15,138	0	0	0	15,138
LHR	Heathrow	53,351	67,868	60,036	60,240	62,916	55,859	360,270
INV	Inverness	0	0	3,662	0	0	0	3,662
LBA	Leeds/Bradford	0	0	0	6,423	0	0	6,423
LPL	Liverpool	0	0	0	7,406	6,117	5,558	19,081
LCY	London City	0	9,470	10,592	8,104	8,956	6,998	44,120
LTN	Luton	7,769	7,935	8,393	8,460	9,432	9,531	51,520
MAN	Manchester	27,904	30,348	30,158	30,466	32,238	25,927	177,041
NCL	Newcastle	0	0	15,432	0	0	0	15,432
STN	Stansted	24,225	28,134	27,395	25,263	25,888	23,176	154,081
DSA	Doncaster Sheffield	0	0	0	3,267	0	0	3,267
		156,258	213,081	238,000	199,710	204,634	169,874	1,181,557

Table 4 Number of CAA survey interviews feeding into model's base year demand

2.66 Earlier model versions had used the CAA's coding to district ground origins. But the CAA district definition now follows more aggregate current administrative district boundaries which are not compatible with the 1991 census based boundaries used in the allocation model. As a result, the new demand data is coded with GIS to the original NAPAM district zones by using postcodes and OSGR centroids.

2.67 Prior to assignment to airports a preload is undertaken to reflect the assumption that the presence in the 2016 base of capacity constraints is now deterring some demand and CAA surveys and statistics can only capture demand that has not been priced off by congestion costs at the London airports. The base year model calibration and validation process now involves the model applying shadow costs in the base year to suppress sufficient traffic to accurately represent observed 2016 national total traffic, as reported later in Chapter 4.

[34] Time constraints required the use of a pre-release version of the CAA 2016 survey (the summation of the four quarterly data sets) but this does not affect the process as all the interview sample weightings were recalculated and controlled to finalised 2016 route level statistics.

Surface access inputs

2.68 Surface access costs from each district (zone) to each airport in the model are a key part of predicting future airport usage. Passengers, when choosing their preferred airport within NAPAM, take into account the time and money costs of accessing each airport.[35] The detailed road and rail transport networks used to extract travel costs connecting all zones to all to airports are now more fully integrated into the department's aviation modelling suite; this new tool is called the National Airport Accessibility Model (NAAM2).

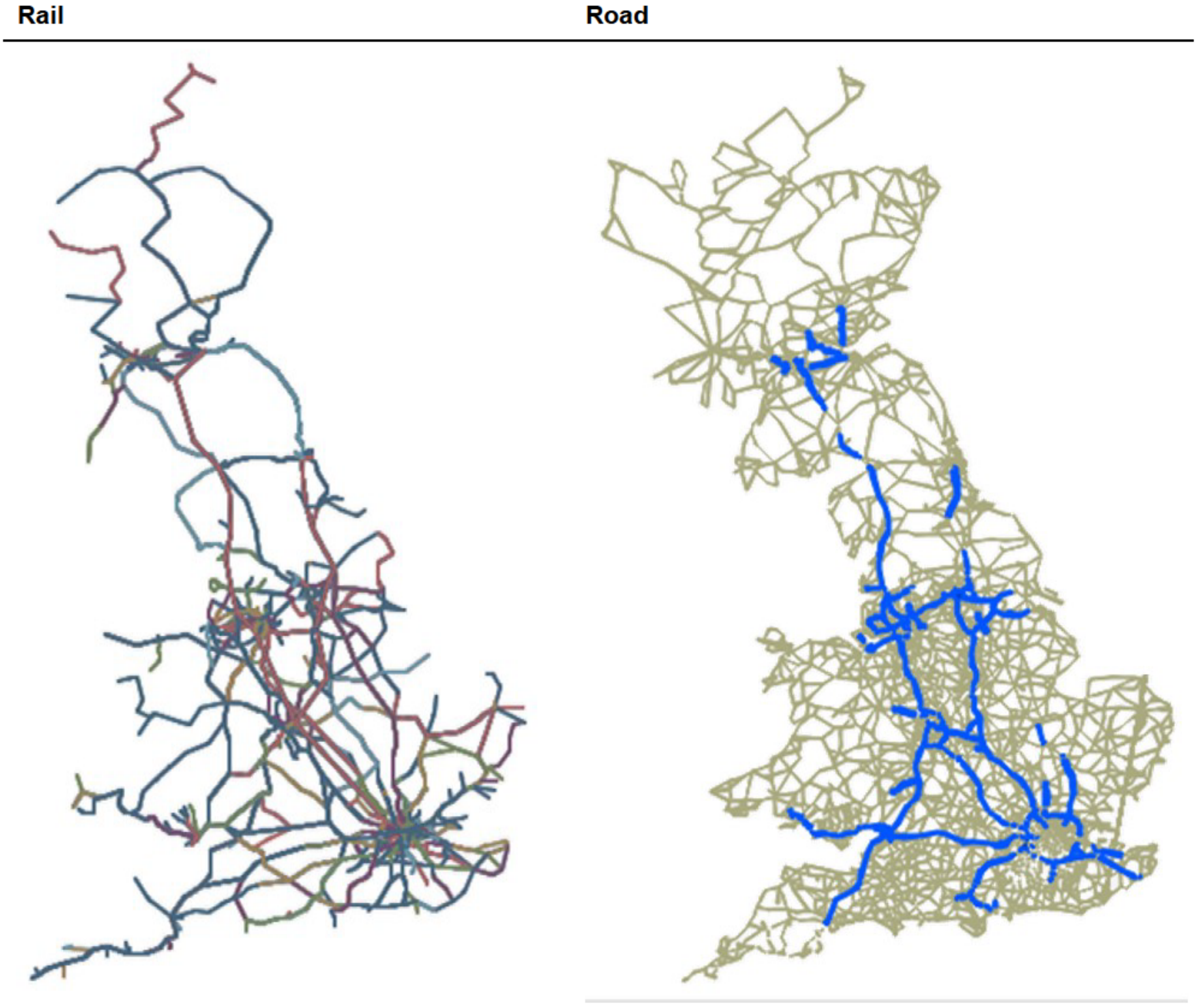


Figure 2.6 NAAM2 rail and road networks

2.69 The most significant development relating to surface access since the department's last forecasts has been modernising NAAM2's software platform.[36] This has improved the usability and transparency of the modelling and provided outputs for other separate analyses.

2.70 There has been improved disaggregation in some regions, particularly in Scotland, which allows for a better representation of how passengers access both the road and rail networks and improves the allocation of passengers to Scotland's airports.

[35] The travel costs represent inter-peak conditions.
[36] NAAM2 now uses EMME transport modelling software.

Model changes made on behalf of the Airports Commission

2.71 The Airports Commission instigated a number of changes to the department's model prior to preparing their own forecasts. These followed a consultation on aviation forecasting which received submissions from airport operators, industry groups, the CAA and environmental and other groups.[37] The most significant of the changes introduced that have been retained in the department's current version of the aviation model are:

- modelling of overseas hubs (Amsterdam, Paris Charles de Gaulle, Frankfurt and Dubai) in the same detail as the principal UK airports
- new definitions of Newly Industrialised Countries (NIC) in NAPDM to include countries such as Brazil and Indonesia which had previously been classified as Less Developed countries (LDC)
- improved modelling of trips suppression - see the description earlier in this chapter
- improved modelling of aircraft loads - initial load factors could be entered for every route rather than groups of routes
- updating of the distribution of traffic within the 27 zones which contained groups of routes
- mode shifts of passengers on internal domestic journeys consistent with HS2 Ltd's forecasts
- development of the NAAM2 surface access model - as described in the preceding section

2.72 Full details of the modelling changes instigated by the Airports Commission can be found in their document *Strategic Fit Forecasts*.[38]

Summary of modelling changes since the Airports Commission

2.73 The department adopts a policy of continuous improvement to its analytical models, and this new model version builds on the changes instigated at the request of the Airports Commission. The updated model essentially follows the overall methodology outlined in the last DfT forecasts from 2013[39] combined with changes outlined above and reported in the final Airports Commission forecasts. In addition to routine software and model maintenance the most significant changes are:

- base demand data has been updated to 2016 with more accurate geographical coding of UK ground origin districts - this process has been described earlier in this chapter
- the information on passengers and transfers at the main competing overseas hubs (Amsterdam, Paris Charles de Gaulle, Frankfurt and Dubai) has been updated with ticket data from these airports from 2014, replacing the 2011 dataset used in the Airports Commission forecasts

[37] *Aviation Demand Forecasting discussion paper*, Airports Commission, February 2013, https://www.gov.uk/government/publications/discussion-paper-on-aviation-demand-forecasting.
[38] *Strategic Fit: Updated Forecasts*, Airports Commission, July 2015, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/439687/strategic-fit-updated-forecasts.pdf.
[39] DfT, *UK Aviation Forecasts, 2013* https://www.gov.uk/government/publications/uk-aviation-forecasts-2013

- the model validation year has been moved forward from 2011 (used in both the department's last and the Airports Commission's forecasts) to 2016, with a new detailed validation check against CAA reported actuals for 2016 - these updates are described in full in Chapter 4
- macroeconomic inputs to the demand model (NAPDM) have been brought fully up to date with the latest available inputs - these updates are described in full in Chapter 5
- improved modelling of fuel costs - as described earlier in this chapter
- a simplified approach to modelling local district level UK variation within the national growth forecasts – as described earlier in this chapter
- values of time and surface access generalised costs have been updated in line with the latest WebTAG data book values[40]
- the forecast scheduled/LCC/charter market shares have been reviewed and updated - these updates are described further in Chapter 5
- baseline airport capacities have been reviewed and updated - these updates are described further in Chapter 5
- the modelling of future aircraft fleet turnovers and the introduction of new types in the FMM has been significantly updated and reviewed with the fleet composition base year moved forward from 2008 to 2015 - this update is described further in Chapter 3
- the CO_2 emissions modelling has been significantly updated using new reported aircraft fuel-burn rates for a wider range of current aircraft and the emissions modelling re-calibrated to 2015 BEIS reported outturn ('bunker fuel') - this update is described further in Chapter 3

[40] https://www.gov.uk/government/publications/webtag-tag-data-book-july-2017

3. CO_2 emissions modelling

Introduction

3.1 This chapter comprises three parts. These set out:

1. the nature, purpose, context and interpretation of the forecasts of carbon dioxide (CO_2) emissions from UK aviation, including information on the methodology and assumptions used in forecasting UK aviation CO_2 emissions;
2. the department's Fleet Mix Model and
3. the department's aviation CO_2 model

Nature and purpose of the CO_2 forecasts

3.2 There is currently no internationally agreed way of allocating international aviation CO_2 emissions to individual countries. However, the United Nations Framework Convention on Climate Change (the UNFCCC) do provide a recommended approach which these forecasts follow. This means that DfT forecast CO_2 emissions produced by all flights departing UK airports from the aviation model base year of 2016 out to 2050. The modelling covers passenger and freighter ATMs departing all the UK airports in the department's model, but does not quantify CO_2 emissions at overseas hubs or flights to the UK. The forecasts therefore include CO_2 emitted from all domestic flights within the UK, and all international flights which depart UK airports, irrespective of the nationality of passengers or carriers. Emissions from UK airports not included in the model are unlikely to be significant as they are small and offer only short range services.

3.3 The scope of aviation CO_2 could cover many possible sources of emissions. For example, some might argue that emissions from journeys to and from an airport are 'generated' by the existence of the airport and its services. However, this would cause double-counting of emissions in different parts of the UK national inventory where surface transport emissions are accounted separately.[41]

3.4 The sources of emissions covered in the forecasts in this chapter are set out in Table 5. The approach used is consistent with the BEIS outturn estimates and the UNFCCC recommended approach for reporting on CO_2 emissions from international aviation, assuming the quantity of aviation fuel consumed from UK bunkers is a reasonable approximation to amount of fuel used on flights within and departing the UK.[42]

[41] The CO_2 forecasts in this report relate specifically to aircraft both on the ground and in the air. However, in appraising potential policy measures affecting capacity/level of activity at specific airports the DfT also considers the potential for significant impacts on CO_2 emissions from airport surface access, construction and operations. See *Updated Appraisal Report*, DfT, 2017.for more details.

[42] In *BEIS GHG Emission National Statistics* UK domestic aviation CO_2 emissions are reported in the UK total and international aviation emissions are reported as a memo item. See https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015.

Emissions source	Included in the forecasts?
All domestic passenger flights within the UK	✓
All international passenger flights departing UK airports	✓
All passenger aircraft while on the ground in the UK e.g. taxiing	✓
All domestic freighter aircraft departing UK airports	✓
All international freighter aircraft departing UK airports[43]	✓
All freighter aircraft while on the ground in the UK e.g. taxiing	✓
General aviation (non-commercial flights) in UK airspace	×
Surface access, i.e. passenger and freight journeys to and from a UK airport	×
Non-aircraft airport sources, e.g. terminal lighting and airfield vehicles	×
UK registered aircraft flying from airports not in the UK	×
International flights arriving in the UK	×
Overflights passing through UK airspace	×

Table 5 Definitions and sources of carbon emissions included in the forecasts

3.5 It is important to recognise that actions or events that reduce UK inventory aviation CO_2 emissions do not necessarily reduce global aviation CO_2 emissions (and *vice versa*), as the scope of the CO_2 emissions modelling reported relates to aircraft departing UK airports. For example, constraining activity at UK hub airports could result in some passengers making transfers via neighbouring continental hub airports instead of the UK, thereby offsetting the reduction in the UK emissions inventory with increases in emissions elsewhere.

3.6 The department's UK aviation CO_2 emission forecasts are used to help monitor and inform long term strategic UK aviation and climate change policy. The updated forecasts have been central to carbon abatement analysis that the department recently commissioned external experts to undertake. This analysis has formed the baselines against which a range of policy options for reducing CO_2 emissions from UK aviation have been assessed. These forecasts will also inform the development of the Government's forthcoming Aviation Strategy.

Aviation carbon emissions in the context of global CO_2 reduction

3.7 This section sets out how aviation's greenhouse gas (GHG) emissions have grown historically, and how they currently compare to total greenhouse gas emissions, at the national and global level.

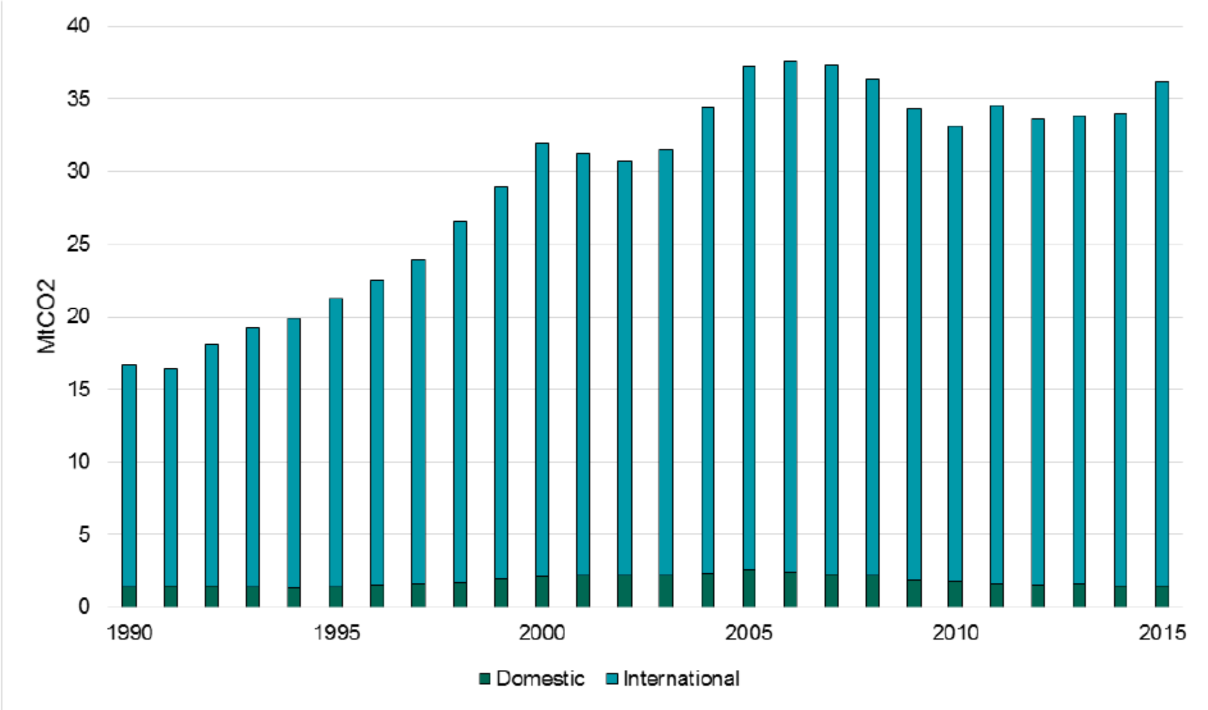
3.8 CO_2 makes up about 99 per cent of the Kyoto greenhouse gas emissions from UK aviation, with the other 1% coming from Nitrous Oxide (N_2O).[44]

3.9 Figure 3.1 shows UK aviation emissions since 1970 and demonstrates that in keeping with the global growth in demand for air travel in that time, CO_2 emissions have tended to grow strongly. Some deviations from the trend are evident, and these are explained by demand variations, such as those resulting from the oil price shocks in the 1970s, recessions, terrorism threats or fears of global pandemics. The

[43] Emissions from freight carried in the bellyhold of aircraft are captured in the passenger aircraft emissions.
44 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

reduction in aviation CO_2 emissions following the financial crisis and economic recession is clearly visible.

3.10 Figure 3.1 also shows that international travel from the UK, as opposed to domestic flights, has been the main source of emissions growth, consistently accounting for over 90% of aviation emissions.



Source: https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

Figure 3.1 Historic aviation CO_2 emissions from UK departing aircraft

3.11 While aviation at present remains a relatively small contributor to total greenhouse gas emissions (both at the UK and global levels), aviation's proportional contribution is likely to increase significantly in the coming decades as other sectors decarbonise more quickly over time.

3.12 Available evidence indicates that the aviation sector is responsible for approximately one to two per cent of global greenhouse gas emissions.[45] At the UK level, Table 6 shows that domestic aviation accounts for 0.3% of UK greenhouse gas emissions. If internal shipping and aviation emissions are added to the total in 2015, UK aviation (domestic and international) accounted for 6.5% of UK GHG emissions and total transport accounted for 30%.

[45] See *Reducing Transport Greenhouse Gas Emissions: Trends & Data*, International Transport Forum, 2010, https://www.itf-oecd.org/sites/default/files/docs/10ghgtrends.pdf and *Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies*, Prepared for the Pew Center on Global Climate Change by David McCollum, Gregory Gould and David Greene, 2009, http://www.c2es.org/docUploads/aviation-and-marine-report-2009.pdf.

BEIS UK greenhouse gas (GHG) statistics 2015	million tonnes of CO2e equivalent	% of total UK greenhouse emissions
Total UK emissions excluding international aviation and shipping	495.7	92.4%
Total UK emissions including international aviation and shipping	536.4	100.0%
Total UK transport emissions including international aviation and shipping	160.7	30.0%
Of which		
• road	111.5	20.8%
• rail	1.9	0.4%
• shipping	9.9	1.8%
• aviation	34.8	6.5%
– domestic	1.5	0.3%
– international	33.3	6.2%

Table 6 UK greenhouse gas emissions in 2015[46]

Interpreting the forecasts

3.13 The forecasts of UK aviation CO_2 emissions should be interpreted within the context of broader UK and international climate change policy. The Climate Change Act (2008) commits the UK government by law to reducing greenhouse gas emissions by at least 80% of 1990 levels by 2050.[47] The UK has also signed up to the Paris Agreement that aims to hold the increase in global average temperature to well below 2°C of pre-industrial levels.[48] In addition, aviation's entry into the EU ETS in 2012 and the forthcoming implementation of the Carbon Offsetting and Reduction Scheme for International Aviation agreed at the International Civil Aviation Organisation mean that any growth of the CO_2 emissions in scope of these schemes above the level of the caps set under these schemes will be exactly offset by emission reductions from other sectors, paid for by the aviation sector.[49] [50] These schemes are accounted for in the modelling through the inclusion of carbon price in air fares in the demand forecasts. For more information see Chapters 2 and 5.

3.14 The forecasts are intended to capture the long term trend in UK aviation CO_2 emissions. While they can capture some short term effects to the extent that the factors driving changes in aviation (e.g. economic growth) can be accurately forecast, they are not primarily intended to predict short term deviations from the trend, as could be caused by an unforeseen recession or other external shock.

3.15 There are significant uncertainties about the future path of the factors driving changes in aviation CO_2 emissions. As with the air passenger forecasts, this uncertainty is reflected by presenting the CO_2 forecasts as a set of demand growth

[46] UK Greenhouse Gas Emissions, BEIS, https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015
[47] https://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/the-climate-change-act/
[48] http://unfccc.int/paris_agreement/items/9485.php
[49] See https://ec.europa.eu/clima/policies/transport/aviation_en for more details.
[50] See https://www.icao.int/environmental-protection/Pages/market-based-measures.aspx for more details.

scenarios and by performing sensitivity tests to illustrate the sensitivity of the forecasts to changes in key drivers. The assumptions underpinning the overall demand growth scenarios and sensitivity tests are set out in Chapters 5 and 9.

3.16 A further uncertainty is that the total climate change impacts of aviation are greater than its CO_2 emissions alone. This issue is discussed further in the box below.

Non-CO_2 climate effects

Although aviation does not emit significant quantities of any other Kyoto greenhouse gases, it results in other emissions that have both cooling and warming effects on the climate. These effects come about as a direct result of the atmospheric conditions in which they are emitted. Non-CO_2 emissions with climate impacts include water vapour and nitrogen oxides (NOx). Emissions of NOx result in the production of ozone, an air pollutant with harmful health and ecosystem effects and a greenhouse gas. But ozone in the atmosphere has benefits as it reduces ambient methane and has a cooling effect. However, the current understanding is that the overall balance of NOx is warming.

The last major international assessment of these impacts was made by the Intergovernmental Panel on Climate Change (IPCC) in 1999. A comprehensive updated assessment of aviation emissions was undertaken by Lee et al in 2009.[1] The Committee on Climate Change (CCC) report on aviation in 2009 summarised the findings of Lee et al (2009), including its estimates of the different climate effects of aviation.[2] For example, the estimated 100-year Global Warming Potentials from Lee et al (2009) indicate that, once the non-CO_2 climate effects of aviation are taken into account, aviation's overall climate effects could be up to double the climate effect of its CO_2 emissions alone. However, as this work recognises, the magnitude of the impacts are unclear.

So while scientific advances since the 1999 assessment have reduced key uncertainties, considerable scientific uncertainty still remains and the view of the 2009 CCC report about non-CO_2 climate effects has not been revised.

[1] Lee et al. (2009) Aviation and global climate in the 21st century, Atmospheric Environment.
[2] Committee on Climate Change (2009) Meeting the UK aviation target – options for reducing emissions to 2050
See also:
Lee, D. et al., 2010. Transport impacts on atmosphere and climate: Aviation. Atmospheric Environment,
Brasseur, G. p. et al., 2016. Impact of Aviation on Climate: FAA's Aviation Climate Change Research Initiative (ACCRI) Phase II. American Meteorological Society

Methodology and assumptions

3.17 Aviation CO_2 emissions are directly related to the amount and type of aviation fuel consumed. There are therefore three key drivers of aviation CO_2 emissions:

- **Total distance flown**: this comprises the volume and average distance of flights from the UK, in turn driven by passenger and freight demand after accounting for airport capacity constraints.
- **Fuel efficiency of aircraft**: the fuel required to fly a given total distance will fall as aircraft efficiency driven by technological and operational improvements improves.
- **Type of fuel used by aircraft**: the CO_2 emissions are associated with a given amount of fossil fuel burn by aircraft; they will fall as the penetration of alternative fuels increases.

3.18 Chapter 2 explains how the passenger demand forecasts are obtained, and how they are converted into a forecast of air transport movements (ATMs) from each airport in the UK to destinations around the world. This section sets out how the ATM forecasts are converted into CO_2 forecasts. Figure 3.2 provides an overview of the modelling components and key assumptions that together produce the forecast of CO_2 emissions to 2050. Below each step is explained in more detail.

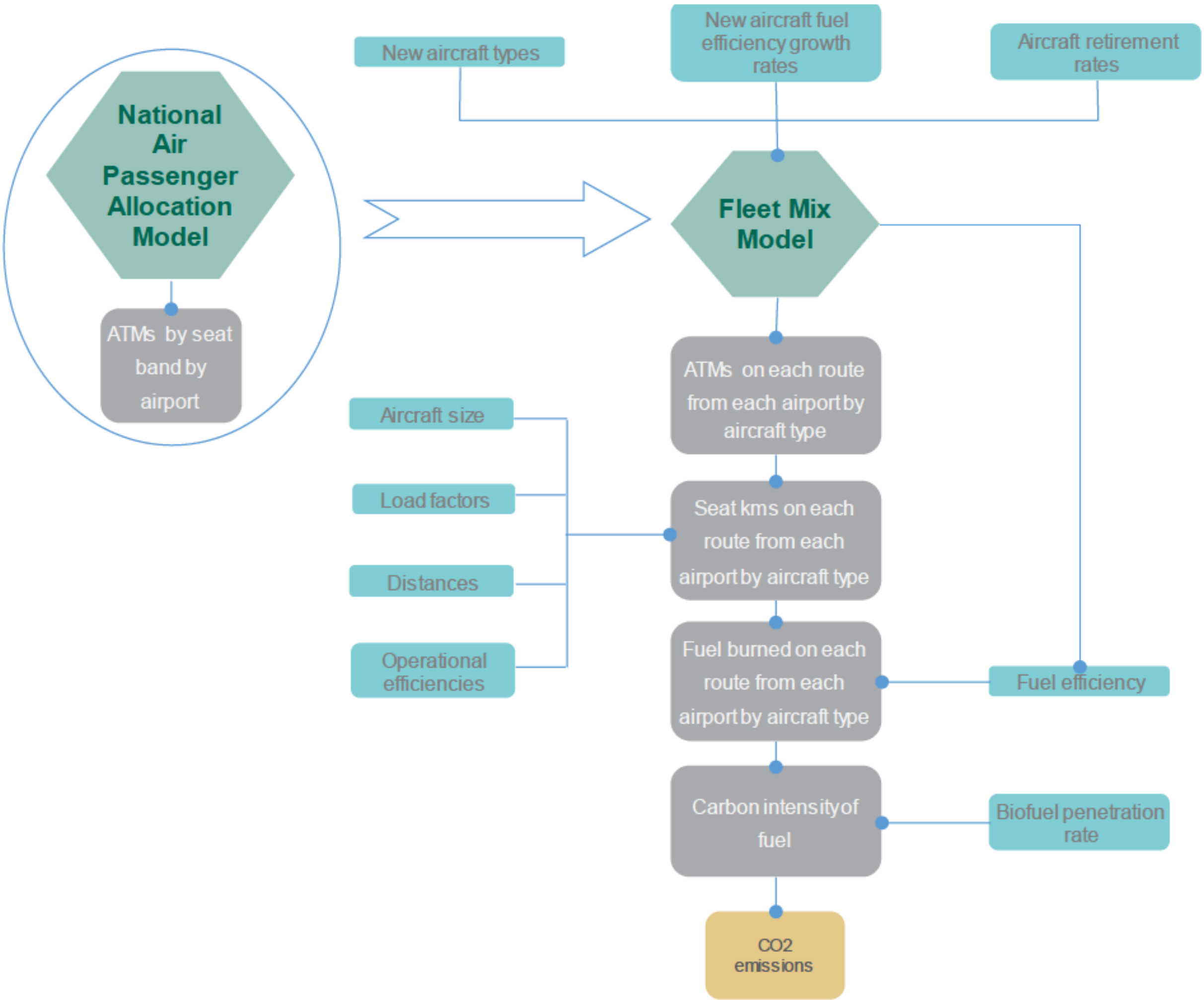


Figure 3.2 Forecasting aviation CO_2 emissions

3.19 Details of the Fleet Mix Model (FMM) and CO_2 models are given below. These were recently reviewed by Ricardo Energy & Environment as part of their work, commissioned by the department, to produce cost and carbon abatement data for use in developing MACCs (marginal abatement cost curves) for the UK aviation sector.[51] Any changes since the department last produced forecasts in 2013 are highlighted in the relevant section and the box below.

[51] *A Review of the DfT Aviation Fleet Mix Model*, and *Carbon abatement in UK aviation*, both Ricardo Energy & Environment, 2017.

Key developments in the department's modelling of CO_2 emissions

The following three key aspects of the department's CO_2 emissions modelling parameters have been updated to reflect the latest evidence:

- fuel burn rates for a range of flight distances and a range of different aircraft types using the EMEP/EEA air pollutant emission inventory guidebook - 2016 (previously referred to as EMEP/CORINAIR emissions inventory)
- revised adjustment to great circle flight distance to 5% for short-haul and 6% for long-haul to reflect the latest evidence in inherent inefficiencies in air traffic control, flight paths and airspace
- update to base year fuel consumption estimates for UK departing aircraft in line with the most recent NAEI bunker CO_2 return (2015) and published by BEIS

The Fleet Mix Model

3.20 The Fleet Mix Model (FMM), shown in Figure 3.2 is downstream of NAPAM in the aviation model structure and predicts the types of aircraft that will be used to meet future demand. The FMM does this by taking base year age distributions of ATMs by specific aircraft type operating at all the main UK airports and then forecasts the future changes to that composition, with assumptions about:

- the typical retirement age of each aircraft type
- the split of new aircraft entering the fleet each year

3.21 These forecast compositions are made across six seat classes and three carrier types which are output by NAPAM as shown in Table 7:

Seat class	Carrier type
C1 – 0-70 seats	Scheduled (Sch)
C2 – 71-150 seats	Chartered (Ch)
C3 – 151-250 seats	Low Cost Carriers (LCC)
C4 – 251-350 seats	
C5 – 351-500 seats	
C6 – 500+ seats	

Table 7 FMM segmentations

3.22 The FMM retires aircraft from the UK fleet as they reach a certain age, assumed to be 22 years for scheduled and low cost carriers (LCC) airlines and 25 years for charter aircraft, and replaces them with new aircraft. When an aircraft retires from the UK fleet it is assumed to be replaced by one of the three types present in the following year’s supply pool:

a. a new aircraft of the same type;

b. a new aircraft of an existing but different type; or

c. a new aircraft of a new type

3.23 The evolution of the composition of future UK fleets of ATMs is governed by assumptions in the supply pool. The supply pool is composed of existing and future aircraft types expected to come online and form part of the fleet of ATMs using UK airports and is also informed in the near term by current manufacturer order books. These supply pool types include:

- named types currently being manufactured
- named types expected to be in production within the next few years
- generic types (not associated with specific manufacturers or models) expected in two future waves in 2030 ('new G2') and 2040 ('new G3')

3.24 These assumptions reflect the variation in business models in the aviation industry with the different fleet replacement strategies used in different sectors of the market, i.e. scheduled, charter and low cost airlines.

3.25 The methodology involves calculating the number of ATMs for each sub model that have reached retirement age in any forecast year, advancing the age of the distribution of ATMs by one year, calculating the number of retirements and replacing with new aircraft types from the supply pool. [52] So, for example, the first forecast year's number of ATMs, in each segmentation and for each aircraft type, is calculated as: base year ATMs – retired ATMs + replacement ATMs. Fleet mix forecasts for subsequent years are then calculated by the same process, taking the previous forecast year as the base year. Lastly, fleet mix forecasts are presented as percentage splits to apply to aircraft by size bands output by the NAPAM passenger to airport and ATM allocation model (see Figure 3.2). This then feeds into subsequent modelling steps for the purpose of emissions and noise assessments.

3.26 The department has recently refreshed and rebased the FMM to a 2015 aircraft fleet base year. This exercise included:

- updating the base year age distribution using age data on all ATMs using UK airports in 2015
- analysing current airline order books and aircraft production status and manufacturing cycles to provide latest evidence to the supply pool
- reviewing aircraft replacement trends on what future aircraft types now replace existing types
- harmonising retirement age assumptions across all carrier types to ensure consistency

3.27 The methodology underpinning the FMM had been peer reviewed in 2010. The updated version of the FMM has now been independently peer reviewed for a second time. The review by Ricardo Energy & Environment[53] considered three main aspects of the modelling:

- the level of assurance that could be attached to changes made to inputs and parameter assumptions
- the appropriateness or fitness for purpose of the existing methodology
- further suggestions for overall improvement or future development

[52] This is first described in detail in Chapter 2 of *Future Aircraft Fuel Efficiencies – Final Report*, QinetiQ, 2010, https://pdfs.semanticscholar.org/b8e2/1ee0191ee64bf71e7e8e6b87b8c37a71b1cb.pdf

[53] *A Review of the DfT Aviation Fleet Mix Model*, Ricardo Energy & Environment, 2017

3.28 The outcome of the review was that the expert peer reviewer found the model to be fit for purpose with the following recommendations for immediate update:[54]

- amendment of production duration and out-of-production years for certain aircraft types based on the best available evidence at the time
- revisions to the entry into service for some new aircraft types revised in light of recent developments

3.29 These changes were incorporated into the FMM that is used in the production of these CO_2 forecasts. Their recommendations for future development will be considered in forthcoming versions of the model.

Modelling fuel burn and CO_2

Passenger ATMs and seat-kilometres

3.30 The key input to the fuel burn and subsequent CO_2 forecasts are NAPAM forecasts of annual ATMs for each airport, by route and by carrier type. These outputs are processed and allocated specific aircraft types by year in the FMM.

3.31 The forecast number of ATMs by specific aircraft types at each airport are converted into seat-kilometres at the same level of detail by applying projections of aircraft size (i.e. the number of seats per ATM), and the distance flown on each airport route. Distances are 'great circle' distances, a common metric for aviation purposes, representing the shortest air travel distance between two airports taking account of the curvature of the earth. The actual distance flown is longer than the great circle distance because of sub-optimal airspace routeing and other en route air traffic control inefficiencies and stacking for landing at airports during periods of congestion. An adjustment factor is therefore applied to uplift the distance flown by 5% for short-haul, and 6% for long-haul destinations.[55] This has been amended since the department's last forecasts in line with advice from the review by Ricardo Energy & Environment.

Freighter distances flown

3.32 Passenger aircraft ATMs account for most of the emissions from freight as 70% (by weight) of freight carried is in the bellyhold of passenger aircraft.[56] However, dedicated freight aircraft (freighters) do produce a material amount of carbon emissions. It is therefore necessary to make an assumption about the number of freighter ATMs separately. As set out in Chapter 2, it is assumed that the number of freighter ATMs does not change over the forecast period.

Modelling aircraft fuel burn

3.33 Current fuel burn rates by aircraft type are initially taken from the European Environment Agency's (EEA) air pollutant emissions inventory guidebook 2016.[57] Fuel burn is measured in kilograms of fuel per aircraft and is specific to bands of

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[54] For further details see *A Review of the DfT Aviation Fleet Mix Model,* Ricardo Energy & Environment, 2017

[55] Evidence from a study by Ricardo Energy & Environment (for the European Commission, DG MOVE) indicates that average extra distance flown (above Great Circle Distance) is between 4.5% and 5% for flights in Europe (https://ec.europa.eu/transport/sites/transport/files/2017-03-06-study-on-options-to-improve-atm-service-continuity-in-the-event-of-strikes.pdf). Another study (Reynolds, 2009) indicated that the extra distance flown on North Atlantic routes was 5%, while the extra distance on typical Europe – SE Asia routes was 7%.

[56] Source: DfT analysis of CAA statistics.

[57] https://www.eea.europa.eu//publications/emep-eea-guidebook-2016

flight distances and the different stages of the flight (e.g. the landing and take-off cycles and cruise stage).

3.34 The new inventory guide book represents an update to the department's 2013 forecasts which used the 2006 version of the emissions inventory ('Corinair') guidebook. The EEA inventory is an established and authoritative source of data on aircraft fuel burn rates, and has been significantly enhanced recently with many more aircraft types and anonymised actual operational data provided by airlines.[58] It is used for general reference and for use by parties such as the Convention on Long Range Transboundary Air Pollution (LRTAP) for reporting to the UNECE Secretariat in Geneva. And it is widely used by ICAO-CAEP in setting environmental policies and standards.[59]

3.35 Within the model, aircraft types' output are mapped to types for which data is provided in the EEA guidebook. Where data for the specific plane type is not available, it is mapped to a similar 'proxy' type and, where needed, an adjustment made to account for higher/lower fuel efficiency. As part of their review, Ricardo Energy & Environment provided advice on mapping aircraft types to those in the EEA guidebook. The review also advised on adapting guidebook fuel burn models for generic future aircraft types, mapping them to existing types but with an adjustment to account for anticipated performance improvements.

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

[59] https://www.icao.int/ENVIRONMENTAL-PROTECTION/Pages/CAEP.aspx

Fuel burn for future generic aircraft types

Data in the EMEP/EEA air pollutant emission inventory guidebook 2016 has been used to derive rates for fuel burn/distance (in kg/Nm) as a function of flight distance for most currently available aircraft types.

Fuel burn rates for future aircraft types, not contained in the guidebook, have been related to rates of existing aircraft types on the advice of Ricardo Energy & Environment as shown in the examples below.

Future aircraft type	Fuel burn
AIRBUS A319NEO*	A319 -15.0%
AIRBUS A330-900NEO	A333 -10.0%
BOEING 737 MAX 8*	B738 -15.0%
BOEING 777-9X*	B77W -13.0%
BOMBARDIER CS300	A319 -15.0%
EMBRAER E190-E2	E190 -15.0%
New G2 Post 2030 c1 1-70 seats*	ATR42 -24.5%
New G2 Post 2030 c2 71-150 seats*	B734 -24.5%
New G2 Post 2030 c3 151-250 seats*	B734 -24.5%
New G2 Post 2030 c4 251-350 seats*	B772 -27.5%
New G2 Post 2030 c5 351-500 seats*	A343B772 -27.5%
New G2 Post 2030 c6 500+ seats*	A380 -27.5%
New G3 Post 2030 c1 1-70 seats*	ATR42 -31.5%
New G3 Post 2030 c2 71-150 seats*	B734 -31.5%
New G3 Post 2030 c3 151-250 seats*	B734 -31.5%
New G3 Post 2030 c4 251-350 seats*	B772 -29.5%
New G3 Post 2030 c5 351-500 seats*	A343/B772 -29.5%
New G3 Post 2030 c6 500+ seats*	A380 -29.5%

* New future type developed from type in the guidebook with advice from Ricardo Energy & Environment

3.36 A key development in the 2016 version of the EEA guidebook from its 'Corinair' predecessor is the use of the EUROCONTROL Advanced Emission Model (AEM) to estimate the fuel burnt by each aircraft type over specific distance bands. The 2006 version used the older Piano model.[60] The 2016 version has a wider range of aircraft types which reduces the need for modelling using proxy aircraft. To match the guidebook distance fuel burn bands, the department's CO_2 model calculates the fuel burn of different aircraft types using a set of fifth-order polynomial curves for fuel burn/distance (in kg/Nm) as a function of flight distance (in Nm). The review from Ricardo Energy & Environment agreed that this approach produced a better model fit than alternative linear or other model specifications.

[60] Piano is a tool for the analysis of commercial aircraft. It is used in preliminary design, competitor evaluation, performance studies, environmental emissions assessments and other developmental tasks by airframe and engine manufacturers, aviation research establishments and governmental or decision-making institutions. http://www.piano.aero/

Fuel efficiency

3.37 Seat-kilometres per mass of fuel (i.e. seat-kilometres per tonne or kg of fuel) is the department's preferred metric for measuring aviation fuel efficiency. It was widely used by the IPCC and the research on which the IPCC study drew, although there is in practice a number of alternative fuel efficiency measures. [61] The value of the chosen metric is that it is essentially unaffected by the assumed or modelled load factors.

3.38 Gains in the fuel efficiency of air travel on the metric of seat-kilometres delivered per tonne of fuel can be split into two sources:[62]

- **Air traffic management and operational efficiencies**: better co-ordination and control of air transport movements, elimination of non-essential weight, optimisation of aircraft speed, limits to the use of auxiliary power etc, will result in less fuel being needed for each seat-kilometre flown.
- **Aircraft efficiency**: as new, more efficient aircraft replace older aircraft, the average efficiency of the fleet will rise. Improvements in new aircraft efficiency can be driven by better engine or airframe technology. These gains could take the form of new types of aircraft entering production (e.g. Boeing 787, Airbus A380 and A350) or incremental improvements to existing types of aircraft (e.g. new engine options on the Airbus A320 or Boeing 737 aircraft families). It is also possible for certain existing aircraft to become more efficient through retrofitting of the latest engine technology or the fitting of aerodynamic devices such as winglets and riblets.

Air traffic management and operational efficiencies

3.39 The route distances flown by class of aircraft output by NAPAM can be adjusted in response to assumptions about operational changes. The baseline input assumptions in the model on the potential gains from air traffic management are conservative. The forecasts are based on the assumption that future net gains in traffic management fuel efficiency from EUROCONTROL's Single European Sky ATM Research (SESAR) programme and other improvements are offset by an increase in traffic and load on the system. In effect these improvements are required to keep pace with rising demand while maintaining acceptable operational standards.

3.40 The baseline assumption is also that no improvement or gains in fuel efficiency result from changes in airline operational practices (e.g. optimised payloads, flying speeds and altitudes) to deliver fuel efficiency gains.

Aircraft efficiencies

3.41 The primary source of fuel efficiency gains is expected to come from the retirement of less efficient current aircraft types and their replacement by newer more fuel efficient types. As explained above, the FMM forecasts the distribution of the future fleet by aircraft type based on the retirement of old aircraft and the entry into the fleet of new aircraft. To project gains in the fleet's efficiency due to fleet turnover, it is therefore necessary to project the efficiency of the aircraft that will enter service in the years to 2050 and to feed that into the FMM. The box below presents some of the available evidence on fuel efficiency improvements seen over recent years and expectations over what might be expected in the future.

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[61] *Aviation and the Global Atmosphere*, Inter-governmental Panel on Climate Change, 1999

[62] Fuel efficiency is defined in department's modelling as seat-kilometre per tonne of fuel. It is therefore independent of load factors, which are accounted for elsewhere in the forecasting. A key issue is that a specific load factor can then be assumed, so a seat-km implies a certain tonne-km. This is helpful for making assumptions transparent when defining industry standards.

Trends in aircraft fuel efficiency

Jet aircraft in service today are well over 80% more fuel efficient per seat kilometre than the first jets in the 1960s. A range of estimates exist for the improvements in fuel efficiency in the aviation sector over recent years. Some studies have also set out their estimates of expected future improvements in efficiency.

To represent the range of evidence, the summaries below give a broad idea of the changes seen and forecast.

The IPCC (1999) reported that historical improvements in fuel efficiency have averaged at 1-2% per annum (measured as fuel burn per seat-kilometre) for new production aircraft. This has been achieved through new engine and airframe technology. A similar trend is assumed when projecting forward to 2050.

The IPCC drew on the research by Greene (1992) which looked at fuel efficiency (seat-kilometre per kg of fuel) to 2000 and extrapolated this forward to forecast annual fuel efficiency improvements over time.

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

IPCC, Aviation and the Global Atmosphere, 1999

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

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

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

Lee et al (2001) looked at the efficiency changes in the US only and suggested that annual improvements in energy intensity (fuel use per seat-kilometre and per passenger-kilometre) were relatively strong in the past but were set to slow.

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

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

The **ATAG** consortium of industry experts (2016) set a target of a 1.5% improvement in fuel efficiency per annum until 2020. Beyond that point, net carbon emissions from aviation are planned to be capped through carbon neutral growth. By 2050, ATAG aim to halve net aviation emissions compared to 2005 levels.[63]

The **IATA (2013) Technology Roadmap** predicts a 30% or more fuel efficiency improvement after 2020 that could be realised only if suitable aircraft development programmes are launched in the respective time frame. The greatest efficiency improvement of around 2% per annum until 2030 is forecast for the regional aircraft category. Aircraft between 100 and 400 seats are expected to improve by 1.2 to 1.5% pa. In the category above 400 seats, the expected improvement is expected to be relatively low and in the order to 1% pa after 2020.

3.42 The forecasts generally assume that there will be gradual improvements relative to conventional aircraft technologies. These improvements are expected to reduce the weight of the engines and airframe through the increased use of new materials, improve various airframe efficiency metrics such as the reduction of aero-dynamic drag and increase both the thermo-dynamic and propulsive efficiency of engines. The forecasts do not reflect more radical departures such as the blended wing body aircraft or open rotor engines.

3.43 Fuel efficiency in the model baseline is driven primarily by increased aircraft efficiency through the turnover of the fleet and the gradual introduction of new aircraft types over time. Air traffic management and operational efficiencies have neutral assumptions - i.e. they are assumed to keep pace with air traffic growth so provide no further efficiencies in the baseline.

3.44 Table 8 shows the range of annual average fuel efficiency improvements underpinning the updated forecasts across the three scenarios. It shows that under the central forecasts average fleet fuel efficiency improves by 10% between 2016 and 2030, equivalent to 0.6% per annum, with efficiency gains accelerating in the 2020s as the current fleet is largely replaced by the next generation.

	Low demand	**Central demand**	**High demand**
2016-2030 (average annual)	0.63%	0.62%	0.50%
2030-2040 (average annual)	1.29%	1.31%	1.40%
2040-2050 (average annual)	1.46%	1.45%	1.38%
2016-2030 (aggregate)	9.94%	9.68%	7.81%
2016-2040 (aggregate)	26.56%	26.58%	25.67%
2016-2050 (aggregate)	48.37%	48.31%	46.13%

Table 8 Fuel efficiency improvements to 2050

Alternative fuels

3.45 The use of biofuels does not in itself increase fuel efficiency (the amount of fuel burnt per distance flown), but it will increase CO_2 efficiency (the amount of CO_2 emissions per distance flown) and so is considered in the baseline emission forecasting. As with

[63] http://www.atag.org

the department's last central CO_2 forecasts, these forecasts assume that biofuels are gradually introduced in the 2020s and make up 1% in 2030 and 5% of all aviation fuel burnt by aircraft departing UK airports in 2050.[64] These assumptions reflect the advice of the independent experts working on the department's earlier MACC analysis in 2010-2011 following a review of the evidence on future biofuels prices. More recently, Ricardo Energy & Environment have also reviewed the biofuel assumptions as part of their review of the CO_2 modelling.[65] Although they made a recommendation to increase the biofuel penetration rate based on recent literature, it was felt this evidence was not sufficiently robust to warrant changing the uptake assumptions for these baseline forecasts.

Fuel burn to CO_2 emissions

3.46 Once the above method has forecast the amount of fuel that is burned on flights departing each airport on each route by aircraft type, this is converted into CO_2 emissions on the basis that 1kg of kerosene emits 3.15 kg of CO_2.[66] Where biofuel uptake is assumed, this average carbon intensity factor is reduced on the assumption that biofuels are accounted for in the transport sector as having zero emissions.[67] For example, in the central forecast in 2050 with 5% biofuel take up, it is assumed that across the entire fleet 1kg of fuel emits 3.07kg of CO_2.

3.47 It should be noted that the metric used for the forecasts is CO_2 not CO_2e. In practice when kerosene is burned, small amounts of other greenhouse gases (included in the Kyoto Protocol[68]) are also emitted including methane (CH_4) and nitrous oxide (N_2O). However the amounts are small - they equate to around 1% of the global warming potential of the CO_2 itself.[69] These gases should not be confused with the impacts from other emissions including contrails and nitrogen oxides (described in the textbox at paragraph 3.16) that fall outside the Kyoto protocol but that nonetheless are likely to have an impact on global warming.

Validation of base year forecasts against bunker fuel outturn

3.48 The new baseline forecasts using the updated FMM and CO_2 models need to be validated, and so a new reconciliation against base year CO_2 actuals has been undertaken.

3.49 Aviation emission forecasts are adjusted to match the Department for Business, Energy and Industrial Strategy (BEIS) estimate of 2015 outturn (i.e. published) aviation CO_2 emissions (using the UNFCCC reporting method),[70] as reported in the National Atmospheric Emissions Inventory (NAEI). The BEIS estimates of outturn CO_2 emissions from aviation are based on the amount of aviation fuel uplifted from bunkers at all UK airports. In the modelling, the adjustment also reflects any difference in definition, including the absence from the modelling of the minor types

[64] But in practice in the modelling itself biofuel uptake rates are halved to account for lifecycle emissions.
[65] *Carbon abatement in UK aviation*, Ricardo Energy & Environment, 2017.
[66] Each 1 kg of kerosene contains 858 g of carbon and each 1kg of carbon is equivalent to 44/12 or 3.67 kg of CO_2. 0.858 * (44/12) = 3.15
[67] In practice, different biofuel feedstocks have different levels of life-cycle emissions and biofuels use in aviation is expected to result in lower emissions, but not reduce emissions to zero. Following the advice given at the time of the MACC study we assume one lifecycle emissions are taken into account, emissions are reduced by 50%. For modelling purposes, the biofuel uptake rate is halved and therefore equals 2.5% in 2050. The approach taken here is consistent with the accounting of biofuel use in the UK's carbon budget and in the EU ETS, and with the latest guidance from the International Panel for Climate Change (IPCC).
[68] http://unfccc.int/kyoto_protocol/items/3145.php
[69] Global warming potential is the common metric used to compare the global warming impacts of different gases where all gases are measured in terms of their impact relative to CO2, typically over a 100 year period.
[70] The 'forecast' for 2015 is about 1.0MtCO_2 (3%) below the latest revised BEIS estimate for that year. This residual amount is added back into the forecasts. A similar procedure is required by BEIS when converting DUKES air fuel sales data to CO_2 bunker emissions data for domestic and international civil aviation. The adjustment is held constant throughout the model period.

of traffic such as business jets which are difficult to model, or flights from very small airports that are not included in the model.

3.50 The most recent NAEI bunker CO_2 return is for 2015 and published by BEIS.[71] The reconciliation of 2015 modelled estimates against 2015 actuals, and the resulting residual adjustment, is shown in Table 9.

	International	Domestic
Bunker CO_2 actual 2015	32.95	1.52
Model CO_2 2015[72]	31.89	1.24
Difference or 'residual'	1.06	0.28

Table 9 Reconciliation of modelled CO_2 (Mt) with 2015 bunker fuel actuals

3.51 An overall residual of adjustment of around 1MtCO_2 for international is intuitive given that the modelling does not include all types of flights including a significant number of business jets who contribute to fuel usage. A larger proportion of domestic CO_2 is also expected because there will be more un-modelled non-passenger flights and more flights from minor un-modelled airports in this category. The department's new CO_2 model therefore appears to perform very well against bunker outturn actuals. Because it represents an unknown, the residual is held constant throughout the forecasting period in the CO_2 model.

Summary of key CO_2 modelling input assumptions

- future ICAO CO_2 standards are assumed to have minimal effect as future fleet is assumed to be compliant
- retirement ages by airline type of: scheduled - 22 years; charter – 25 years; low cost carrier – 22 years
- no retro-fitting
- first generation future aircraft types (expected by 2020) typically have a 10-15% fuel burn improvement on existing aircraft types, the 2030 second generation having a 24.5-27.5% improvement and the 2040 third generation having a 29.5%-31.5% improvement
- no net air traffic management system gains as improvements from SESAR and other programmes are assumed to accommodate the growth in ATMs without further deterioration in levels of service
- no improvement from airline operational efficiency practices
- 1% biofuel use in 2030 rising to 5% by 2050 (with in practice input uptake rates halved to account for lifecycle emissions)
- base year residual CO_2 adjustment to bunker fuel returns held constant throughout the model period

[71] See table 8 of *BEIS 2015 UK greenhouse gas emissions: final figures - data tables.* https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015
[72] The 2016 modelled output factored down to 2015 by observed seat-km growth.

4. Past and present: changes in aviation since 2011

Introduction

4.1 This forecast uses a model base year of 2016, the most recent year for which a full annual set of statistical data is available. The department's previous forecasts published in January 2013[73] had been validated to reproduce aviation activity in 2011.[74]

4.2 This chapter is set out in three parts:

- the changes in the UK aviation passenger markets between the two forecasting base years of 2011 and 2016 using detailed statistical and survey data collected by the CAA and analysed by the department
- the capability of the new 2016 based aviation model to reproduce 'actual' aviation activity - the 'base year validation'
- a comparison of the department's recent forecasts against outturn total aviation demand

UK aviation 2011 and 2016

4.3 The box below compares the headline measures of activity at the 30 largest UK airports used elsewhere in the modelling.[75] All the analysis below also uses the department's aviation model definitions of charter and LCC airlines and DfT analysis of bespoke statistics provided to the department by the CAA.[76]

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

74 Technically the 2013 forecasts used an initial demand input of 2008 drawn from CAA surveys conducted 2005-2008. However, this was supplemented and updated with survey data from surveys in 2009-2011 in order that the model could be validated in detail satisfactorily against 2011 observed actuals.

75 2011 activity included passenger flights which have now ceased at Blackpool. The 2016 figures include Southend which was not operating significant passenger services in 2011. Of other airports in the model Plymouth closed in 2011 and Coventry ceased operations before 2011.

76 Charter is as defined in CAA published statistics. LCC airlines in the aviation model are easyJet, Jet2, Ryanair and Thomsonfly (CAA recorded scheduled short-haul services only).

The aviation market 2011 - 2016: key statistics

Since 2011 terminal passengers have grown by almost 50 million (23%) at the 30 modelled UK airports. Throughput in 2016 was at an historic high. Over the 5 years the biggest increases were at Gatwick (+10m), Manchester (+7m), Heathrow and Stansted (+6m) and Luton (+5m).

Passengers mppa	2011	2016	growth	per year
London	134	162	22%	4.0%
Outside London	84	105	25%	4.5%
National	218	267	23%	4.2%

Source: Analysis of DfT version of CAA statistics

The London / outside London totals relate to the location of the chosen airport, not necessarily the ground origin

Capacity in terms of the number of aircraft movements (ATMs) and seats delivered increased by less than the number of passengers because of higher load factors and larger aircraft.

		2011	2016	growth
Average aircraft size	London	177	186	5%
(seats)	National	147	157	6%
Passengers per ATM	London	135	147	9%
(aircraft loads)	National	111	124	12%
Load factor	London	76%	79%	
(passengers/seats)	National	75%	79%	

Source: Analysis of DfT version of CAA statistics

ATMs (000s)	2011	2016	growth	per year
London	991	1107	12%	2.2%
Outside London	971	1042	7%	1.4%
National	1962	2149	10%	1.8%

Seats (million)	2011	2016	growth	per year
London	176	206	17%	3.3%
Outside London	113	131	15%	2.9%
National	289	337	17%	3.1%

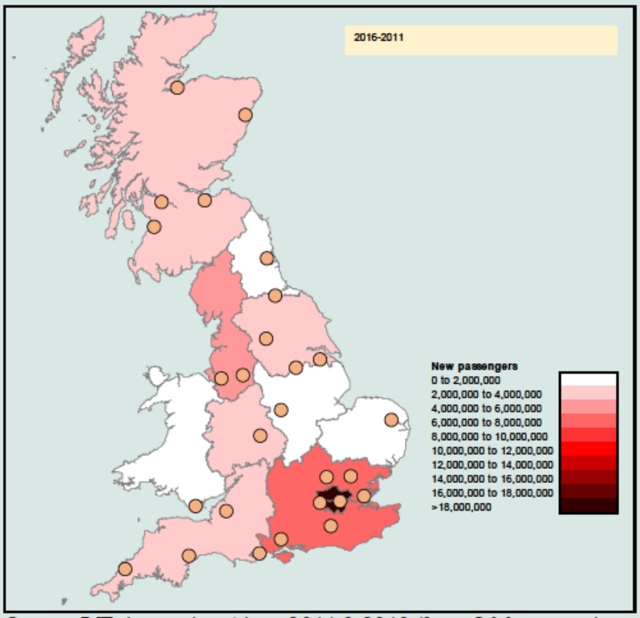
The London / outside London totals relate to the location of the chosen airport, not necessarily the ground origin

The number of short-haul flights has increased significantly. Both 'full service' scheduled and low cost (LCC) flights have grown strongly, in part through the marked drop in charter flights. Overall both domestic and long-haul passenger flights increased by 12% over the 5 year period, compared to a 29% growth in short-haul flights.

	Domestic			Short haul			Long haul		
mppa	2011	2016		2011	2016		2011	2016	
Scheduled	21.5	22.5	*4%*	59.5	83.0	*39%*	43.9	51.5	*17%*
LCC	12.7	16.0	*26%*	57.4	80.3	*40%*	0.3	0.0	*-88%*
Charter	0.8	0.7	*-19%*	17.7	11.0	*-38%*	3.7	2.1	*-44%*
Total	35.1	39.2	*12%*	134.6	174.3	*29%*	47.9	53.6	*12%*

Source: Analysis of DfT version of CAA statistics

In the department's model, domestic scheduled and LCCs are merged as a single category; domestic charter is not separately represented, but may be under 'others', and no long-haul LCC are modelled.
Domestic flights in this table include both internal domestic flights and those passengers travelling to connect onto an international flight.



Source DfT demand matrices 2011 & 2016 (from CAA surveys)

The pattern of ground origins of passengers has shifted significantly, with recent growth concentrated in London. Excluding those transferring at hubs, there were 45m (+25%) more terminal passengers from mainland UK in 2016. The highest growth rate (36%) was in London, the lowest (6%) was in the North East.

Of the 45m new passengers 58% were drawn from London and the South East.

There were 3m more international-international transfers at hubs and just over 1m more passengers originating in Northern Ireland to account for the full passenger increase of 49m.

The proportion of passengers travelling for leisure - both UK and foreign resident - has increased since 2011. Aside from international-international transfers, business passengers dropped from 22% to 19% of all passengers, while the overall proportion of leisure passengers grew from 69% to 72%.

mppa	2011		2016	
UK business	19.6	*9%*	18.8	*7%*
UK leisure	81.2	*37%*	112.4	*42%*
Charter (UK leisure)	20.6	*9%*	12.8	*5%*
Foreign business	13.6	*6%*	16.7	*6%*
Foreign leisure	35.6	*16%*	51.4	*19%*
Domestic business	14.3	*6%*	15.2	*6%*
Domestic leisure	13.5	*6%*	16.2	*6%*
Total business	*47.5*	*22%*	*50.7*	*19%*
Total leisure	*151.0*	*69%*	*192.9*	*72%*
International-international transfer	21.2	*10%*	24.3	*9%*

Source DfT demand matrices 2011 & 2016 (from CAA surveys)

London and regional airport use

- In both 2011 and 2016 the 5 London airports accounted for just over 60% of passengers at the modelled UK airports and just over half the air transport movements (ATMs).
- In 2011 Heathrow accounted for over half the London passengers (and nearly a third of national passengers and nearly a quarter of ATMs), but by 2016 these shares have dropped as capacity constraints have bitten and other airports have been able to grow faster in a competitive environment.
- Growth at almost all airports has picked up since around 2014 to exceed pre-recession numbers of passengers by 2016. Growth has been strong at alternative London airports during the five years with Luton increasing by 54%, London City by 52%, Stansted 35% and Gatwick 28%.

mppa	2011	2012	2013	2014	2015	2016
Gatwick	34	34	35	38	40	43
Heathrow	69	70	72	73	75	76
London City	3	3	3	4	4	5
Luton	10	10	10	10	12	15
Stansted	18	17	18	20	23	24
London total	134	134	139	146	154	162
Birmingham	9	9	9	10	10	12
Bristol	6	6	6	6	7	8
East Midlands	4	4	4	5	4	5
Edinburgh	9	9	10	10	11	12
Glasgow	7	7	7	8	9	9
Liverpool	5	4	4	4	4	5
Manchester	19	20	21	22	23	26
Newcastle	4	4	4	5	5	5
Larger regional airports	63	64	66	69	73	81
Other regional airports	21	21	22	22	23	24
Total outside London	84	85	88	91	96	105
UK Total	217	219	227	237	250	267

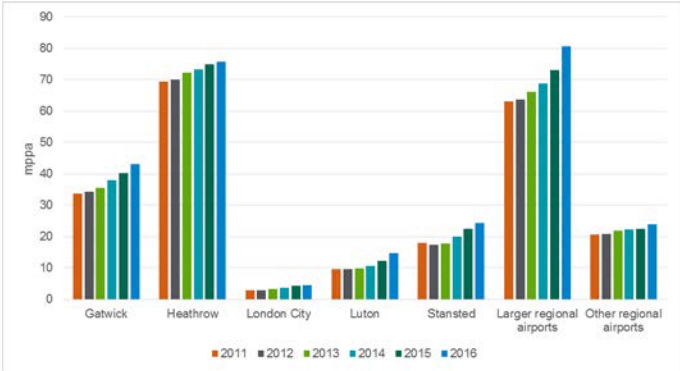


Table 10 Historic number of passengers at large airports

- Manchester is the largest non-London airport in terms of passengers and ATMs and has the strongest growth (36%) of the larger airports with it growing particularly strongly in the last year and its share of national passengers at the airports included in the department's model has increased from 8.7% to 9.6%.
- Glasgow (36%), Birmingham (35%), Bristol (32%) and Edinburgh (32%) also all grew strongly.
- Bigger airports have generally grown faster than the smaller airports. Where national traffic 2011-2016 grew by 23%, London airports by 22% and traffic at the larger airports outside London by 28%, passengers at the other smaller airports only grew by 16% with Manston, Plymouth and Blackpool closing to commercial passenger aviation during the period.

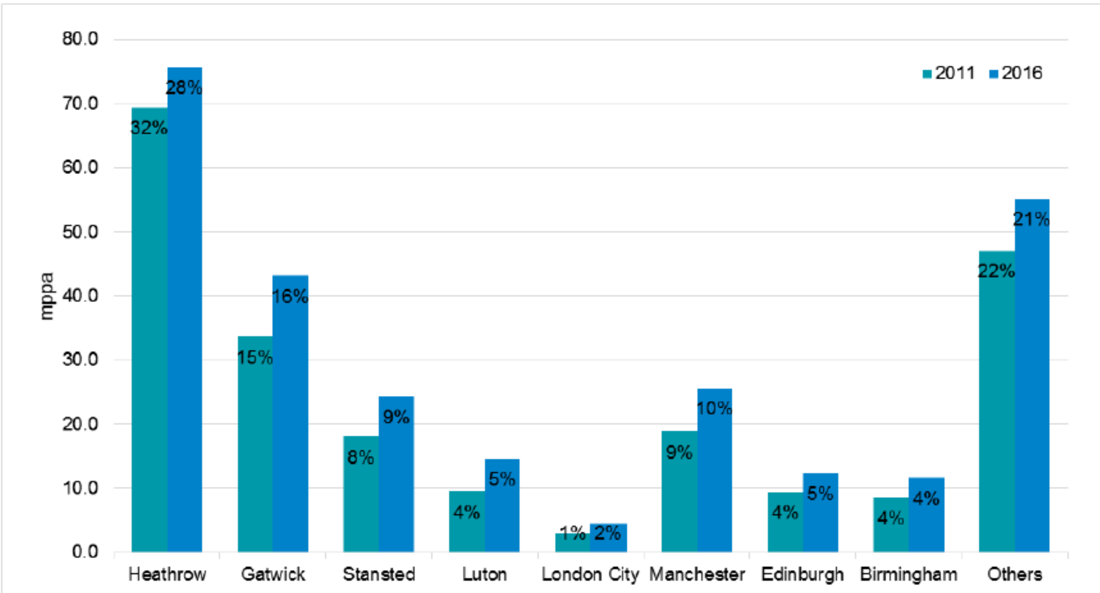


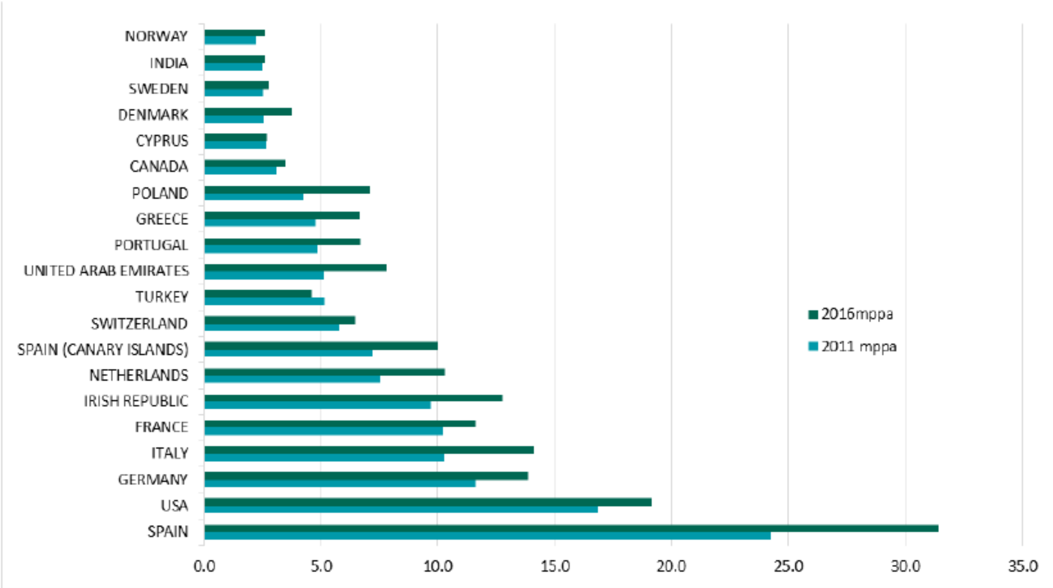
Figure 4.1 Share of national terminal passengers by airport, 2011 and 2016

Range of destinations served / connectivity

- The UK's busiest domestic route in 2011 was between Heathrow and Edinburgh, with close to 1.3 million passengers flying between these airports and with nearly half of them transferring to/from another flight at Heathrow. By 2016 this was still the busiest domestic route, but passenger numbers had dropped to under 1.1 million.

- The majority of international destinations served by UK airports remain within Europe. In 2011 72% of international passengers were on flights bound for Europe, by 2016 this proportion had grown to 75%.

20 most popular international destinations for UK passengers (mppa)



Increase in passengers (between 2011 and 2016) to the 20 most popular destinations (mppa)

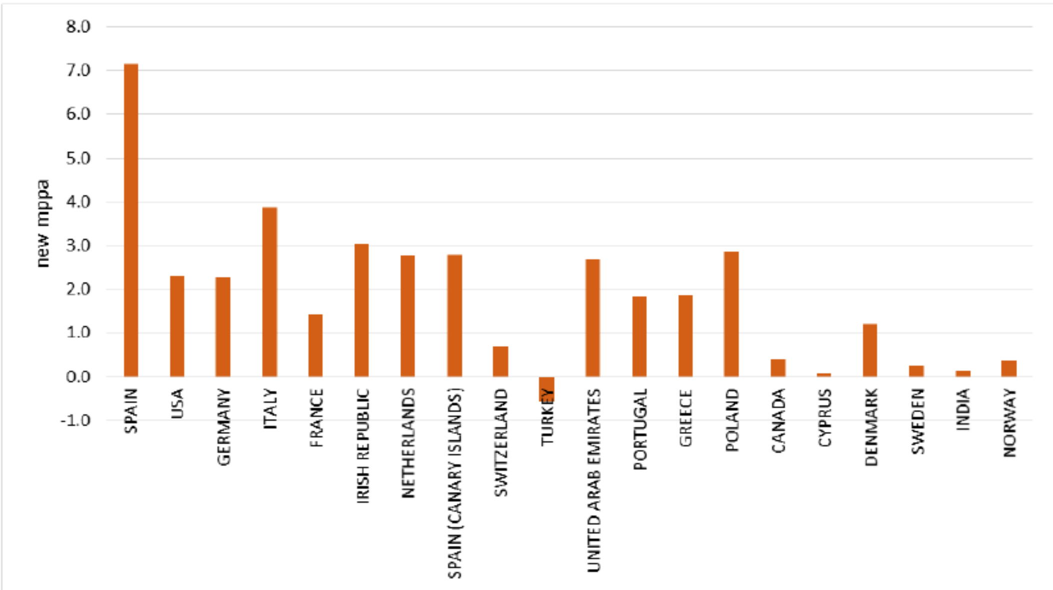


Figure 4.2 Most popular international destinations from UK airports

- The 20 most popular destination countries for UK passenger flights in the CAA statistics were the same in 2011 and 2016 with the most popular country for passengers flying to/from the UK being Spain (including the Canary Islands) which accounted for 17% of international passengers in 2011 rising slightly to 18% in 2016.
- In both years, the USA was the second most popular destination with 9% of all international passengers in 2011 and 8% in 2016. It was the most popular long-haul destination by some way. The UAE (Dubai) is the next most popular, but it is

now outside the top 20 destinations and had around 3% of UK passengers in both years. Overall, long-haul dropped from 29% to 27% in the period 2011-2016.

- The top 20 destination countries contributed 37m of the new passengers 2011-2016 of which Spain (including the Canary Islands) was by far the largest component, contributing close to 10m, followed by Italy (+4m), Ireland and Poland (both +3m).
- In 2011 there were 192 international destinations served with at least daily services and 44 domestic routes from at least one UK airport; by 2016 this had risen to 203 with 45 domestic routes. [77] There were 372 destinations served at least once a week in 2016 compared to 363 in 2011.
- The range of long-haul destinations has been growing nationally and at London airports. Nationally there are now 127 long-haul destinations served with at least one service a week compared to 122 in 2011. Nearly all these are served from London.

	All UK airports				**London airports**			
	Daily		Weekly		Daily		Weekly	
	2011	2016	2011	2016	2011	2016	2011	2016
Europe	128	132	241	245	140	129	233	234
Long-haul	64	71	122	127	67	70	120	126
Total International	192	203	363	372	207	199	353	360
Domestic Routes	44	45	60	56	14	16	17	17

Table 11 Daily and weekly destinations served, 2011 and 2016

- Among the airports, Heathrow serves the most destinations with at least a **daily** service in both 2011 (120 routes) and 2016 (131 routes). The number of routes with at least daily services was only slightly changed at Gatwick (-4 routes), Stansted (+3 routes), but there were larger increases at Manchester (+14 routes) and Luton (+9). Increases at other airports outside London were small.
- Gatwick serves the most destinations with at least a **weekly** service - Gatwick had 187 in 2011 rising to 190 in 2016, while the number of destinations served weekly from Heathrow rose from 163 to 175.
- Stansted is not far behind the largest London airports in both years with 142 at least weekly services in 2011 rising to 159 in 2016. These are predominantly short-haul services.
- Heathrow had the most daily long-haul destinations - 57 in 2011 rising to 63 in 2016.[78] Gatwick had 9 daily long-haul destinations in 2011 and 11 in 2016 and Manchester had 7 in 2011 rising to 8 in 2016. The number of at least weekly long-haul departures rose from 87 to 90 at Heathrow, from 44 to 50 at Gatwick and was held constant at 36 at Manchester.

[77] For this analysis, based on DfT's own version of CAA statistics, daily service is defined as more than 360 departures throughout a calendar year and weekly is defined at more than 51 departures throughout a calendar year.
[78] Long-haul is defined here as inter-continental flights.

Daily destinations served | **Weekly destinations served**

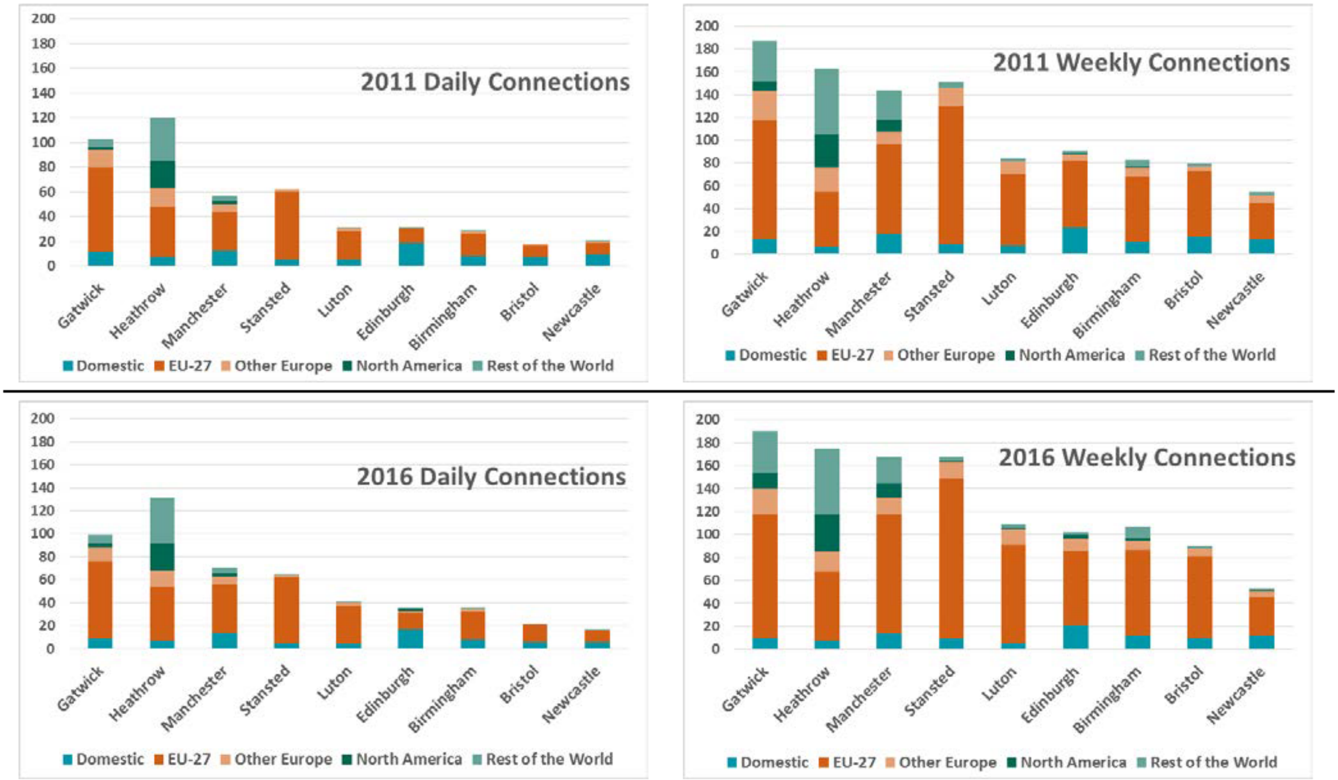


Figure 4.3 Destinations served by at least daily and weekly departures, 2011 and 2016

Airlines

- The top 10 airlines in terms of passengers at UK airports carried 69% of all passengers in 2011 and 72% in 2016.[79] Since 2011, nine of these airlines are unchanged. British Airways remains the carrier serving the most passengers, with easyJet carrying almost the same number and Ryanair a close third. These three airlines carried 46% of passengers in 2011 but now carry slightly more than half (51%).
- BMI and bmibaby in their previous forms have effectively disappeared and been replaced by central and eastern Europe based carrier Wizz. In 2011 nine of the airlines were UK-registered, with this total dropping to eight in 2016.[80]

[79] At all the airports in the department's aviation model.
[80] Ryanair and Wizz are not registered in the UK.

Airline	**2011**		**2016**	
	mppa	rank	mppa	rank
British Airways	37.8	1	48.5	1
easyJet	35.6	2	47.2	2
Ryanair	27.2	3	41.8	3
Flybe	10.8	4	10.8	5
Thomsonfly	10.9	5	13.3	4
Thomas Cook	8.0	6	6.6	7
Monarch	5.7	7	5.4	10
Virgin	5.4	8	5.5	9
BMI	4.9	9	0.3	*62*
Jet2	4.3	10	6.7	6
Wizz	2.8	*15*	6.4	8
Total	**150.7**		**192.3**	

Table 12 Ten most used passenger airlines at modelled UK airports, 2011 and 2016

- The top 5 airlines at Heathrow in terms of passengers carried in 2011 were British Airways, Virgin Atlantic, BMI, Lufthansa and Aer Lingus. In 2016 the top 5 airlines were British Airways (BA), Virgin Atlantic, American, Aer Lingus and United. Heathrow is dominated by BA with 40% of passengers in 2011 rising to 48% in 2016 (partly due to their purchase of BMI) and in 2016 it was joined in the top 5 by its IAG partner Aer Lingus and alliance partner American Airlines.

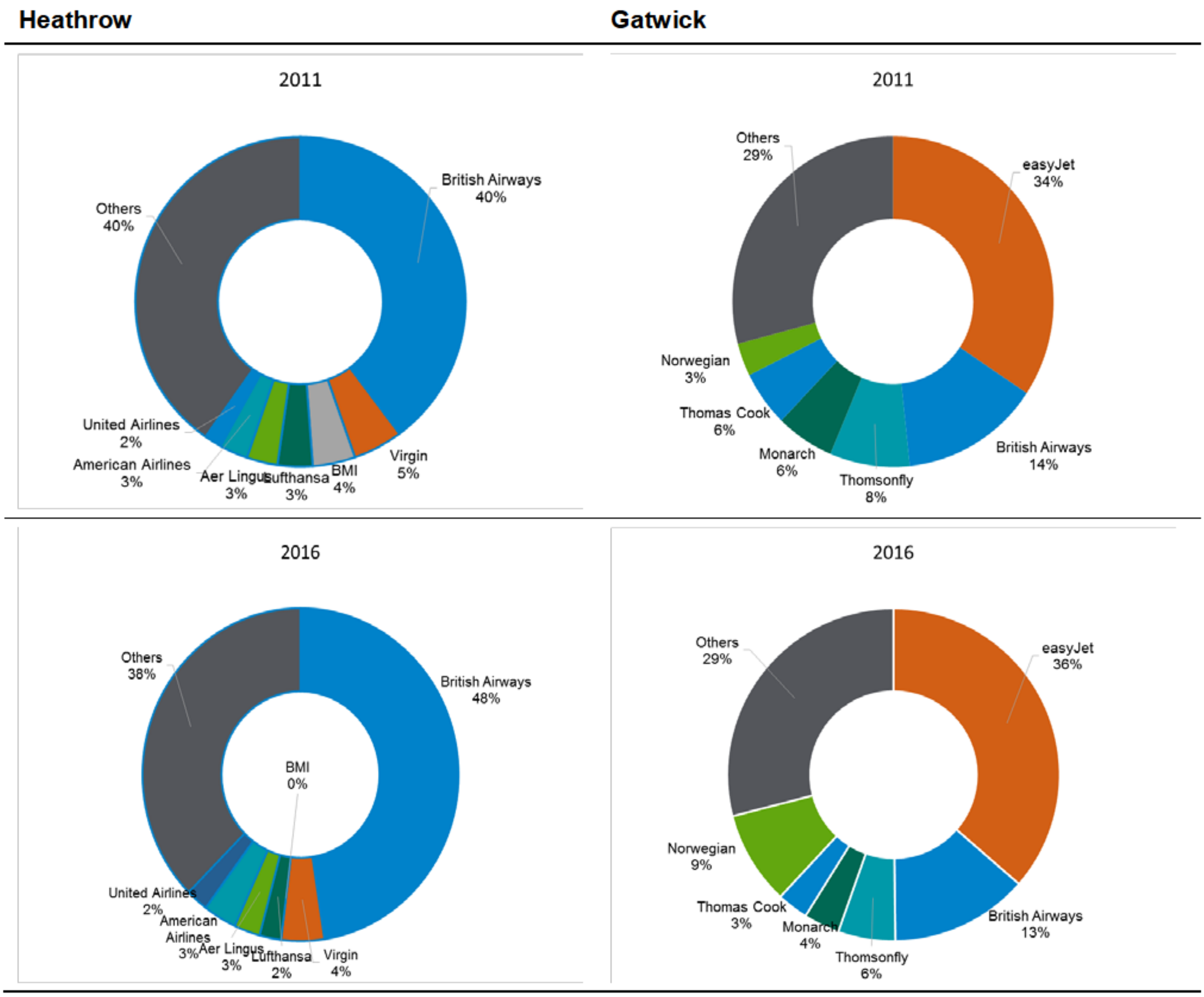


Figure 4.4 Main airlines by passengers carried at Heathrow and Gatwick, 2011 and 2016

- As shown in Figure 4.4, there is a very different pattern of airline use at Gatwick. The only change in the top 5 airlines at Gatwick from 2011 to 2016 was that Norwegian became the third most used airline (from 9th in 2011) replacing Thomas Cook. Apart from Norwegian, the most noticeable feature was the decline of the charter carriers (Thomas Cook, Thomsonfly and Monarch) and the consolidation of easyJet.
- At Manchester, Ryanair has replaced Thomsonfly as the top airline in terms of passengers carried, with easyJet replacing Thomas Cook as the second most used. But no airline dominates with Ryanair carrying just 15% of the passengers in 2016.
- Ryanair continues to dominate at Stansted, carrying 68% of the passengers in 2011 and 82% in 2016. At Luton, easyJet were the main carrier in both 2011 and 2016, but its share of passengers dropped from 45% to 40% while the second carrier, Wizz, increased its passenger share from 24% to 33% during the five years.

Freight

4.4 Freight, in terms of both tonnage and numbers of aircraft movements, has not kept pace with the growth in passenger numbers. In 2011 (70%) and 2016 (69%) most freight by tonnage is carried in the holds of passenger aircraft ('bellyhold'). Total freight carried at the UK airports rose from 2.3 million tonnes in 2011 to 2.4 million tonnes in 2016, with a growth of about 5% in the weight of cargo carried on both freighter and passenger aircraft.[81]

4.5 Figure 4.5 illustrates that the past five years see an extension of trends apparent in the previous decade with modest growth (by weight) of both types of freight. The decline in freighter ATM numbers but relatively constant levels of freight tonnage highlight that air freight has been increasingly carried on bigger freight aircraft.

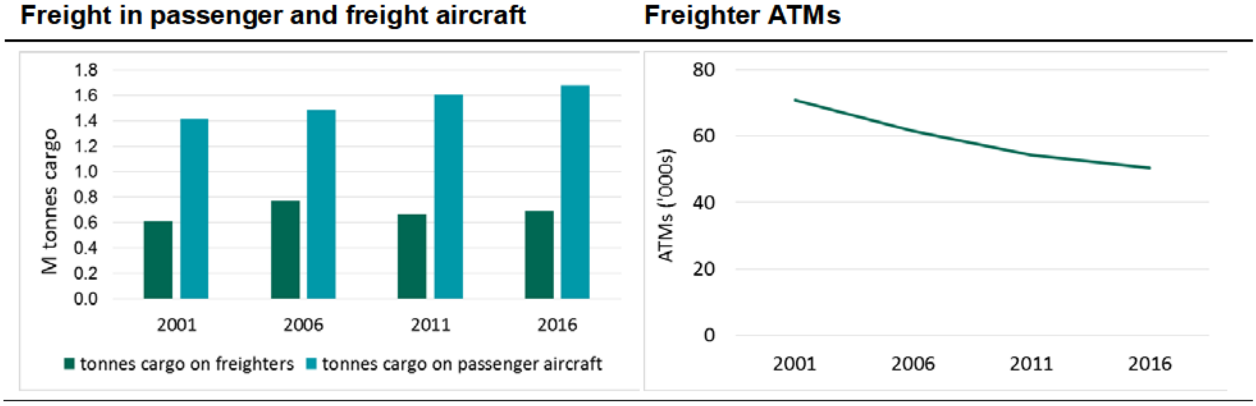


Figure 4.5 Historic freight carried at all modelled airports

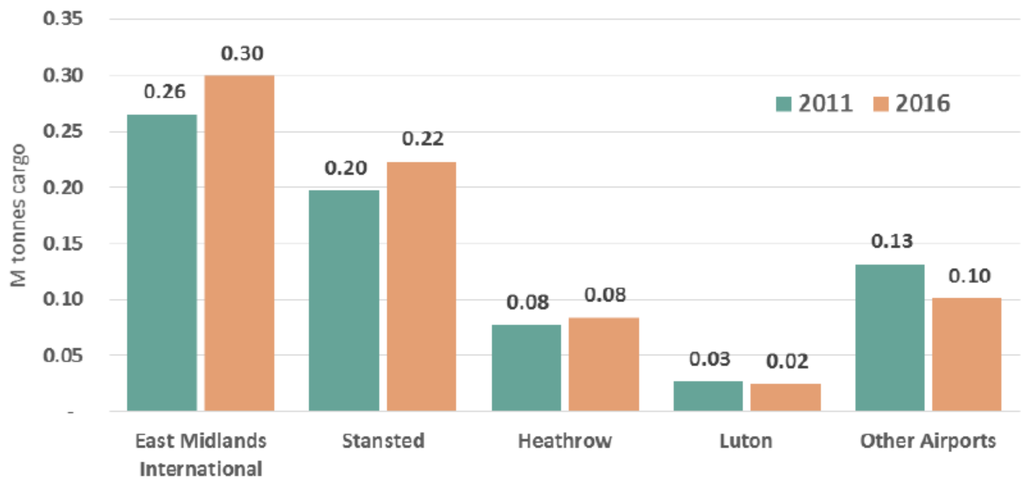
4.6 The top five airports for the tonnage of cargo carried in freight aircraft and for freight carried bellyhold in passenger aircraft have changed relatively little from 2011 to 2016. Cargo carried on freighter aircraft is dominated by East Midlands and Stansted which consolidated their positions together carrying 56% of cargo tonnage in 2011 and 63% in 2016.

4.7 Heathrow remains much the most significant airport in terms of freight tonnage carried on passenger aircraft with around 85% of the UK total in 2016. Much of this freight is carried on long-haul aircraft, and reflect Heathrow's strength in that market.

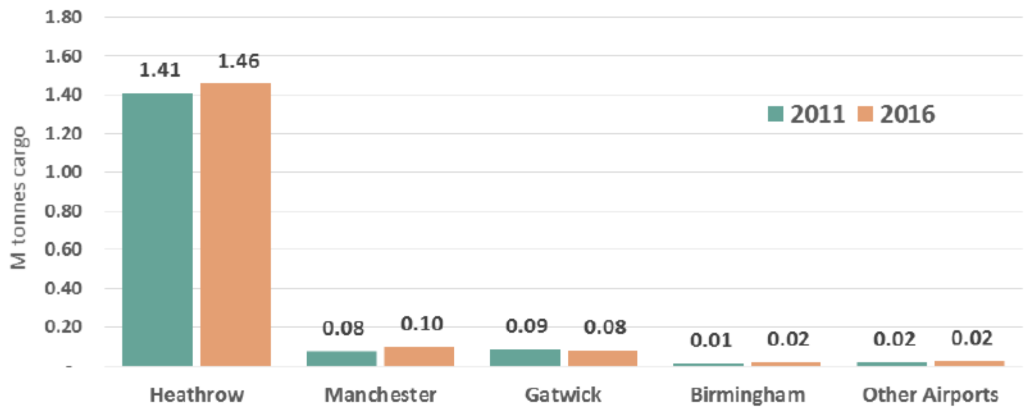
4.8 Figure 4.6 illustrates the top five airports for freight by tonnage for the two types of freight carriage. In both cases it is clear that freight continues to concentrate at a few airports where there are extensive freight handling facilities.

[81] Source: DfT analysis of CAA statistics. This includes an adjustment made to the total relating to Belfast International, following advice from CAA.

On freighter aircraft



On passenger aircraft ('bellyhold')



Belfast International freight data had data supply issues in 2016; so, for this airport the split between freight and bellyhold freight has been estimated using the overall total for 2016 and the previous year split.

Figure 4.6 Freight tonnage by airport, 2011 and 2016

Base year model validation

4.9 An important factor determining the confidence that can be placed in a calibrated model is its ability to replicate independent observed data of the type presented above in this chapter. The process of comparing modelled or 'predicted' output against independent 'actual' or observed data is known as 'validation'. In the passenger to airport allocation model, this assessment is undertaken at various levels of detail:

- overall airport throughput (passengers and aircraft)
- passengers and aircraft travelling between individual airports and destination areas (zones)
- loadings on aircraft
- numbers of specific routes operating at individual airports.

4.10 These assessments are an important part of the quality assurance of the forecast results.

4.11 The full set of validation exercises undertaken which are made at the individual route level for the 2016 base year are:

- international passengers on all routes with > 10,000 passengers per annum separately in the scheduled, LCC and charter market segments (almost 1,000 routes)
- modelled ATMs on all routes with > 10,000 passengers per annum separately in the scheduled, LCC and charter market segments (almost 1,000 routes)
- modelled aircraft loadings on all routes with > 10,000 passengers per annum separately in the scheduled, LCC and charter market segments (almost 1,000 routes)
- modelled passengers, ATMs and aircraft loading on domestic flights
- numbers of destinations served by routes with >5,000 passengers at all UK airports separately for scheduled, LCC and charter market segments
- surface ground origins of passengers at major CAA surveyed airports in 2015
- transfer passengers at UK hubs (Heathrow, Gatwick & Manchester) and 4 modelled overseas hubs
- all passengers at Amsterdam, Frankfurt, Paris and Dubai

4.12 Model validation is a data intensive exercise and is only possible here to provide sufficient summary of the results of this detail as evidence of the suitability of the model base for forecasting in this report.

4.13 The process involves obtaining full sets of passenger demand for all UK passengers from CAA interviews covering the period 2011-2016 and assembling matching statistics. The initial passenger demand and supply networks (the airports and the routes they offer) are input for 2016 which is also the most recent year for which the full CAA statistical returns data are available. This CAA data is used as the independent check data (the 'actual' heading in the tables below).

4.14 The 2016 model validation exercise assumes that both Heathrow and Gatwick have become ATM capacity constrained by 2016-2017.[82]

[82] Capacity constraints at one or other in the initial two years, the model then stabilises with constraints at both in subsequent years.

Airport level passenger and ATM validation

	2016 Passengers (mppa)				2016 ATMs (1000s)				2016 Aircraft loads (passengers)		
	Actuals	Modelled	Difference		**Actuals**	Modelled	Difference		**Actuals**	Modelled	Difference
Gatwick	**43.1**	43.4	0.3	1%	**278.9**	277.2	-1.7	-1%	**155**	157	2
Heathrow	**75.7**	76.0	0.3	0%	**480.6**	476.4	-4.2	-1%	**157**	159	2
London City	**4.5**	4.0	-0.5	-11%	**80.5**	73.7	-6.7	-8%	**56**	55	-2
Luton	**14.6**	14.5	-0.1	-1%	**103.0**	101.2	-1.7	-2%	**142**	143	1
Stansted	**24.3**	24.5	0.2	1%	**164.5**	172.8	8.4	5%	**148**	142	-6
London	**162.3**	162.5	0.1	0%	**1107.4**	1101.4	-6.1	-1%	**147**	148	1
Aberdeen	**2.9**	2.6	-0.4	-13%	**78.6**	72.7	-5.9	-7%	**37**	35	-2
Belfast International	**5.1**	5.1	-0.1	-1%	**38.1**	41.6	3.4	9%	**135**	122	-13
Belfast City	**2.7**	2.7	0.0	1%	**41.5**	42.7	1.2	3%	**64**	63	-1
Birmingham	**11.6**	12.3	0.6	5%	**105.2**	103.9	-1.3	-1%	**111**	118	7
Bournemouth	**0.7**	0.6	-0.1		**4.3**	3.4	-0.9	-21%	**155**	165	10
Bristol	**7.6**	7.6	0.0	0%	**61.1**	58.2	-2.9	-5%	**124**	131	6
Cardiff	**1.3**	1.4	0.0	3%	**16.2**	17.5	1.3	8%	**83**	79	-4
East Midlands	**4.7**	4.8	0.1	2%	**55.6**	57.6	2.0	4%	**84**	83	-1
Edinburgh	**12.3**	11.8	-0.5	-4%	**116.5**	109.1	-7.4	-6%	**106**	108	2
Exeter	**0.8**	0.8	0.0		**14.8**	12.0	-2.9	-19%	**57**	67	10
Glasgow	**9.3**	8.2	-1.2	-12%	**84.4**	76.3	-8.2	-10%	**110**	107	-3
Humberside	**0.2**	0.2	0.0		**9.2**	8.6	-0.6	-7%	**22**	25	3
Inverness	**0.8**	0.7	-0.1		**11.2**	11.5	0.3	2%	**70**	61	-9
Leeds-Bradford	**3.6**	3.4	-0.2	-6%	**31.7**	27.6	-4.1	-13%	**114**	123	9
Liverpool	**4.8**	4.8	0.1	1%	**38.3**	40.1	1.8	5%	**125**	121	-4
Manchester	**25.6**	26.8	1.2	5%	**185.0**	195.7	10.6	6%	**138**	137	-1
Newcastle	**4.8**	4.7	-0.1	-2%	**42.5**	40.8	-1.7	-4%	**113**	115	2
Newquay	**0.4**	0.4	0.0		**7.1**	7.8	0.7	9%	**52**	51	-1
Norwich	**0.5**	0.5	0.0		**28.7**	24.2	-4.5	-16%	**18**	21	4
Southend	**0.9**	0.7	-0.2		**8.3**	7.5	-0.8	-10%	**106**	96	-10
Southampton	**1.9**	2.0	0.1	5%	**37.9**	42.1	4.2	11%	**51**	49	-3
Durham Tees Valley	**0.1**	0.1	0.0		**3.7**	3.4	-0.3	-8%	**36**	44	8
Blackpool	**0.0**	0.0	0.0		**6.7**	.0	-6.7	-100%	**5**		-5
Doncaster Sheffield	**1.3**	1.2	-0.1	-7%	**10.2**	8.5	-1.6	-16%	**124**	137	13
Prestwick	**0.7**	0.8	0.1		**4.7**	5.0	0.3	7%	**143**	151	8
	104.8	104.2	-0.6	-1%	**1041.6**	1017.7	-23.8	-2%	**101**	102	2
Total	**267.1**	266.6	-0.4	0%	**2149.0**	2119.1	-29.9	-1%	**124**	126	2

Percentages only shown for airports > 1mppa

For consistency with other ATM tables, freighters are included, this means that passenger ATM loads will be understated at those airports with significant freighter movements - principally East Midlands and Stansted (over 60% of freight ATMs)

Blackpool has been closed in the model, but there have been some ad hoc commercial services operated in 2016 recorded in the CAA statistics (hence the 100% ATM error). But given the demolition of terminal facilities it is assumed that continuation of such activities will be at very low levels

Table 13 Validation of baseline modelled outputs against actuals, passengers, ATMs and aircraft loads, 2016

4.15 Table 13 reports the accuracy of the model in predicting passenger demand, ATMs and numbers of passengers on passenger aircraft at all modelled airports. It shows that the model is successful in predicting the number of passengers travelling through each UK airport with low percentage variations at the biggest airports.

4.16 The London area total fitted value is highly accurate. Demand is predicted to within +/-1% at the four largest London airports and for the London airports as a group. At all the larger airports outside the London area the model is accurate to within +/-10%. The national total for all 29 currently active airports in the model is also accurate. The largest differences are at Manchester (+1.2m) and Glasgow (-1.2m).

4.17 The ATM forecasts are in large part driven by the passenger to airport demand forecasts and are important because of the role of ATM numbers in forecasting runway shadow costs and CO_2 emissions. ATM forecasting is as demanding as passenger forecasting because it is the output of both the passenger allocation forecasts and then the ATM Demand Model.

4.18 At all the larger airports, including those in London, the model performs well in reproducing 2016 actuals - Heathrow and Gatwick are both within 1% of their 2016 actual throughputs. The larger percentage errors in ATM prediction generally occur at airports with less than 5mppa. Flights at these airports are almost all domestic and international short-haul, and usually on smaller aircraft, so error here has minimal impact on either the runway capacity or CO_2 emissions forecasting.

4.19 Aircraft passenger loads are a result of both the passenger allocation and ATM modelling. Therefore given the standard achieved in both, the model performs well at getting close to the actual reported loads at the most significant airports. As the box on recent trends in the previous section has illustrated (see page 59), rising aircraft loads have been an important explanation for the growth in airport usage in the past few years. The model is picking up this effect well.

4.20 More detailed analysis of the model's calibration and validation at all airports for passengers, ATMs and aircraft loads for different airline markets is set out in Table 47 to Table 50 of the data annexes.

Ground origins of passengers - validation checks

4.21 The pattern of ground origins/destinations of passengers at the major airports has been monitored during the validation process. The modelled UK regional distributions of passenger origins at the largest London airports and Manchester have been checked against the most suitable recent CAA passenger interview survey (2015) where it has been possible to robustly code UK originating passengers to the model's district zones.[83]

4.22 Although the fit is generally good, it should be noted that:

- The pattern of ground origins/destinations in the model is drawn from the ground origins of passengers for 6 years of survey data for the 6 years 2011-2016 and not just 2015.
- The model is less good at representing very long trips to the London airports (e.g. there are no Scottish ground originating passengers in the modelled distributions), but the numbers from such remote origins in the actuals are very small.

4.23 Table 14 compares modelled against actual percentage shares of all ground of traffic with modelled ground. Given the difference in absolute passenger numbers between the 2015 survey and the 2016 model, these percentage shares provide a more useful indicator of the goodness of the model fit than absolute numbers.

[83] At the time of model validation the 2016 passenger interview dataset was only available in quarterly instalments and had not been geo-coded to the level of earlier years so was not used in this validation exercise.

	Gatwick		Heathrow		Luton		Stansted		Manchester	
	CAA2015	model 2016	CAA2015	model 2016	CAA2015	model 2016	CAA2015	model 2016	CAA2015	model 2016
London	43%	49%	54%	53%	35%	40%	53%	51%	0%	0%
South East	43%	42%	27%	29%	40%	36%	23%	27%	0%	0%
Eastern	3%	2%	3%	3%	5%	6%	14%	13%	0%	0%
East Midlands	2%	1%	3%	3%	9%	9%	4%	4%	4%	5%
West Midlands	2%	1%	2%	3%	4%	5%	2%	1%	6%	8%
South West	5%	4%	7%	7%	2%	3%	2%	1%	0%	1%
North	0%	0%	0%	0%	0%	0%	0%	0%	2%	1%
Yorkshire & Humberside	1%	0%	1%	1%	2%	1%	1%	1%	20%	20%
North West	0%	0%	1%	0%	1%	0%	1%	0%	61%	58%
Scotland	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Wales	1%	1%	2%	2%	1%	1%	1%	0%	5%	5%

Table 14 Percentage share comparison of modelled ground origins of passengers and actuals

Destinations validation

4.24 In the model definition (see the box on page 32) the 21 largest European airports in terms of UK traffic are discretely modelled as separate zones. However, all the long-haul airports and the rest of the European airports are members of 27 'route group' zones. The NAPAM passenger to airport allocation model analyses the level of demand between a UK airport and a 'route group zone' to forecast how many members of the zone are served by a particular UK airport. The quality of this aspect of model performance is important in three key respects. It:

- determines the numbers of aircraft movements to a route group
- determines the modelled aircraft sizes to different zones and allows a mix of different aircraft sizes to the different destinations within the route group
- provides a more meaningful measure of connectivity at specific UK airports

4.25 The first two attributes impact on frequency and on the allocation of passengers to routes, the forecasting of numbers of aircraft movements and the validation reported above. However, it is the third aspect that is particularly relevant when using the model as an indicator of future UK connectivity. A base year model validation against actuals exercise has therefore been undertaken on this aspect of model performance to establish the suitability of the model for forecasting and quantifying future UK connectivity.

4.26 Table 15 reports the modelled destinations by airline type on routes with an annual passenger threshold of 5,000 per annum for 2016 with a comparison with actuals taken from department's detailed set of CAA 2016 statistics. Each of the model's 27 route group zones can have from 2-20 destinations associated with the zone in the modelling. Overall the new model reaches a high standard as demonstrated by the r^2 coefficient values, approaching 1.00, illustrating the level of variance between observed and model fitted values. Lower levels in the charter market are less significant in terms of the number of passengers involved - 13m out of 267m passengers in 2016.

	Scheduled		LCC		Charter	
	Actual	Modelled	Actual	Modelled	Actual	Modelled
Aberdeen	**12**	13	**0**	0	**8**	11
Belfast Intl	**3**	3	**28**	21	**17**	15
Belfast City	**6**	6	**0**	0	**0**	0
Birmingham	**86**	86	**29**	27	**50**	51
Bournemouth	**0**	0	**11**	9	**10**	9
Bristol	**33**	36	**73**	70	**36**	32
Cardiff	**12**	13	**1**	2	**21**	26
East Midlands	**23**	24	**49**	49	**28**	26
Edinburgh	**32**	32	**68**	65	**13**	21
Exeter	**9**	9	**0**	0	**13**	16
Gatwick	**159**	159	**106**	105	**81**	73
Glasgow	**37**	37	**46**	50	**31**	30
Heathrow	**180**	179	**0**	0	**0**	0
Humberside	**1**	1	**0**	0	**2**	0
Inverness	**2**	2	**0**	0	**0**	0
Leeds/Bradford	**14**	13	**50**	45	**8**	8
Liverpool	**13**	15	**47**	54	**1**	0
London City	**39**	36	**0**	0	**0**	0
Luton	**62**	57	**64**	63	**22**	24
Manchester	**114**	116	**97**	100	**71**	69
Newcastle	**32**	33	**43**	43	**6**	6
Newquay	**1**	1	**2**	0	**0**	0
Norwich	**3**	5	**0**	0	**10**	6
Southend	**4**	5	**14**	14	**0**	0
Southampton	**23**	23	**0**	0	**0**	1
Stansted	**27**	40	**150**	149	**24**	29
Teesside	**1**	1	**0**	0	**0**	0
Doncaster Sheffield	**19**	19	**0**	0	**18**	17
Prestwick	**0**	0	**16**	13	**0**	0
Total	**947**	964	**894**	879	**470**	470
r2		0.998		0.998		0.991

Only routes with more than 5,000 passengers per annum are included

Table 15 Validation of number of destinations by airport and airline type, 2016

Comparison of recent forecasts against outturn

4.27 The last three DfT aviation forecasts were published in 2009, 2011 and 2013. Figure 4.7 compares their forecasts with outturn.

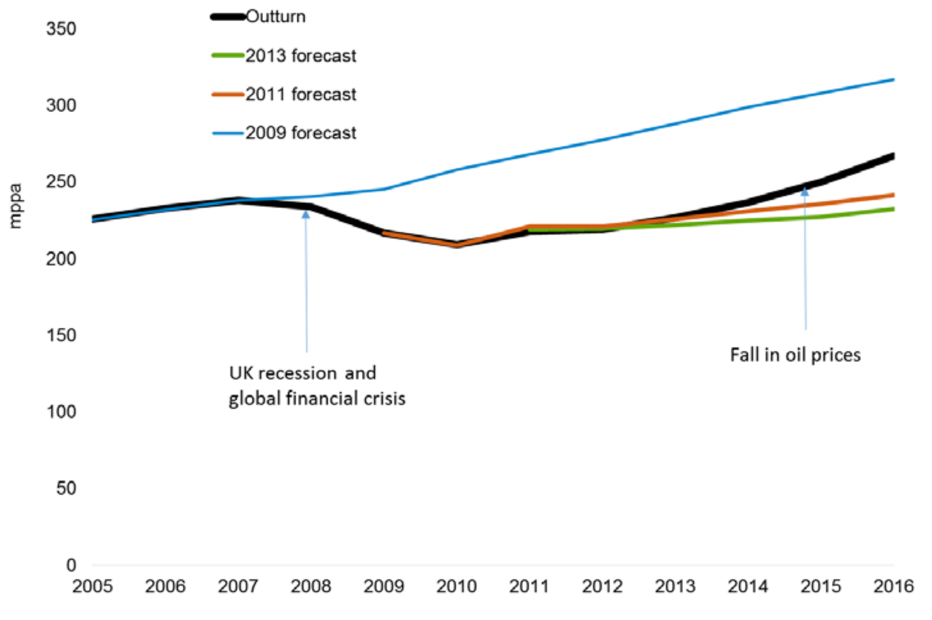


Figure 4.7 Comparison of 2009, 2011 and 2013 baseline central forecasts with outturn

4.28 The 2009 forecast was published early in the year and used economic inputs that pre-dated the recession, so it is unsurprising that its forecast was significantly too high.[84] The 2011 and 2013 forecasts both pre-dated the large fall in oil price which began towards the end of 2014.[85] This is likely to be the main explanation for the under-forecasting of the 2011 and 2013 reports, although some under-forecasting prior to the oil price fall is detectable.

4.29 There is no obvious pattern of systematically under or over-forecasting across these publications, but this exercise highlights the uncertainty around this type of forecasting, particularly in the short term. With respect to demand at a national level, there are three key sources of forecasting inaccuracy:

- the contemporary economic forecast inputs used at time as drivers; for example, those relating to economic activity and oil prices
- the responsiveness of demand in the econometric models to such inputs; for example, relating to market maturity
- industry and regulatory structure; for example, if the sector were to face a change of a similar scale to that which occurred with 'open skies' deregulation and the entry of low-cost carriers into the market

4.30 Although the department's modelling has always attempted to make the best and the most rigorous use of the available evidence base, uncertainty is large and there is no reason to believe such uncertainties will reduce in future years.

4.31 This analysis has considered demand at a national level. At individual airport level, uncertainties are even greater, as individual airport's demand patterns could be further affected significantly by changes in just a small number of airlines' or airports' business models and commercial agreements coming into effect.

[84] http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/aviation/atf/co2forecasts09/co2forecasts09.pdf. .
[85] https://www.gov.uk/government/publications/uk-aviation-forecasts-2013 and https://www.gov.uk/government/publications/uk-aviation-forecasts-2011.

5. Input assumptions

Introduction

5.1 This chapter describes how the drivers of demand are projected forwards to produce forecasts of passenger demand and gives more detail about the other key model inputs. It also demonstrates how the model is validated against baseline observed or 'actual' data in readiness for forecasting.

5.2 There is of course inherent uncertainty in projecting any of these variables. To reflect this the forecasts adopt a range of assumptions for many of the key inputs and present these using demand growth scenarios and sensitivity tests.

5.3 This chapter is split into the following sections:

- the main NAPDM inputs to model national unconstrained demand in the central case:
  - economic activity
  - fares
  - population
  - local growth at overseas hubs
  - market maturity assumptions
- definition of the low and high demand growth scenarios
- airline market sectors
- airport capacities
- surface access

5.4 Further detail is provided in Annex B. They are also included in the supplementary tables made available alongside this report.

NAPDM inputs to model underlying demand

5.5 Projections for each of the driving variables are fed into the relationships (introduced in Chapter 2) for each market segment to produce forecasts of aviation demand. It is helpful to group the passenger demand inputs into the two main drivers of aviation demand: economic activity and air fares.

5.6 Growth in incomes is driven by:

- UK GDP growth
- UK consumer spending growth
- foreign GDP growth

Changes in air fares are driven by:

- oil prices, exchanges rates and fuel efficiency
- carbon prices
- Air Passenger Duty (APD)
- airline 'other' costs

Inputs influencing income and economic activity

GDP and consumer expenditure

5.7 The short term (up to 2021) UK GDP and consumer expenditure forecasts are those from the Office of Budget Responsibility (OBR) published alongside the March 2017 budget.[86] For the longer term, the OBR January 2017 Fiscal Sustainability Report is used for GDP forecasts, with consumer expenditure forecast to grow at the same rate.[87]

5.8 Foreign GDP growth projections are split by the four broad NAPDM geographic regions as set out in Chapter 2. Projections for 2017 to 2022 are based on the IMF World Economic Outlook (WEO), April 2017.[88] Beyond 2022, the forecasts are based on the OECD's Economic Outlook.[89] In both cases the projections are then weighted by the proportion of traffic travelling between the UK and the relevant countries comprising the NAPDM forecasting region.

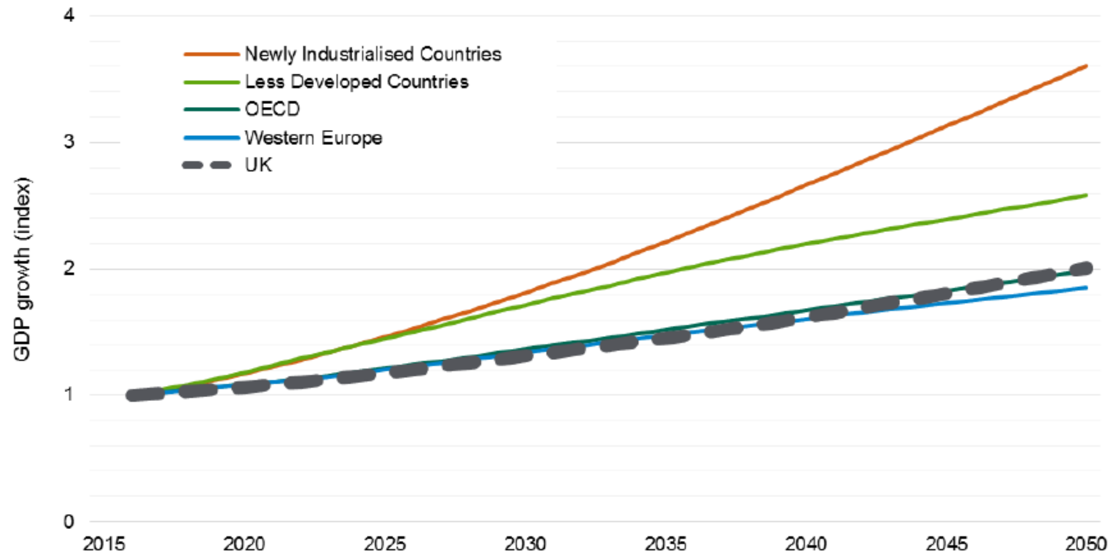


Figure 5.1 Index of real GDP growth forecast by NAPDM region, central case

Trade

5.9 The treatment of trade as a driver of aviation growth has not been changed from previous forecasts. As previous forecasts have shown, visible trade growth tends to be correlated with GDP growth. Analysis of historical data reveals that trade with

[86] *Economic and fiscal outlook – March 2017*, Office of Budget Responsibility, http://budgetresponsibility.org.uk/efo/economic-fiscal-outlook-march-2017

[87] *Fiscal Sustainability report – January 2017*, Office for Budget Responsibility, http://budgetresponsibility.org.uk/fsr/fiscal-sustainability-report-january-2017/

[88] *World Economic Outlook – April 2017*, International Monetary Fund, https://www.imf.org/external/pubs/ft/weo/2017/01/weodata/index.aspx

89 Economic Outlook No 93 Long term baseline Projections – May 2014, http://stats.oecd.org/

Western Europe and non-European OECD members is more strongly correlated with GDP in those foreign regions. Therefore the growth rate of trade with Western Europe and other OECD members grows at the same rate as the local GDP of those regions. However, trade with NICs and LDCs is found to be more strongly correlated with UK GDP, so the growth rate of trade with NICs and LDCs has been assumed to grow at the same rate as UK GDP.

Fare inputs

5.10 Fares are a key driver of passenger demand, with lower fares driving faster growth and vice versa. NAPDM includes a fares model which breaks out the components of fare into:

- fuel costs
- carbon costs
- Air Passenger Duty (APD)
- airline 'other' costs

5.11 As noted in Chapter 2, all fare inputs, except APD, are estimated on a per seat-kilometre basis with APD is added to derive a total fare. As the forecast components change over time, so does the forecast fare.

Fuel costs

5.12 As set out in Chapter 2, oil price forecasts are a key input into forecast fuel costs. Oil price forecasts are based on BEIS published projections, which forecast the price rising to $80 per barrel by 2030.[90] Historic data relating to the spot fuel price is based on the CIF jet fuel wholesale price series provided by BEIS.[91] The CIF (costs, insurance and freight) series does not include all costs associated with fuel use (e.g. fuel costs incurred within the airport are excluded); these additional costs – which may not vary with the fuel price – are captured within the 'other' costs category.

5.13 The dollar to sterling exchange rate assumption determines the price of oil when expressed in sterling and is based on the average rate over the full calendar year. The outturn figure for 2016 averaged $1.34 per barrel. The short term forecasts of the exchange rate is inferred from the OBR Economic and Fiscal Outlook (March 2017), resulting in an exchange rate of $1.25 in 2017, rising gradually to $1.31 in 2021.[92] This figure is then assumed to remain constant until the end of the modelling period.

5.14 This process results in the costs per seat-kilometre (in 2016) set out in Table 16. Such costs change over time as oil prices and fuel efficiency changes.

[90] https://www.gov.uk/government/publications/fossil-fuel-price-assumptions-2016
[91] CIF stands for cost, insurance, freight price.
[92] They are created by dividing the reported forecast of price of oil in $ per barrel by the price of oil in £ per barrel, provided in table 4.1 of *Economic and Fiscal Outlook*, OBR, March 2017, http://budgetresponsibility.org.uk/efo/economic-fiscal-outlook-march-2017

	Fuel cost (pence per seat-kilometre)
Domestic	**1.2**
Western Europe	**0.8**
OECD	**1.0**
Newly Industrialised Countries	**1.1**
Less Developed Countries	**0.9**

Table 16 Estimated fuel costs in 2016, pence per seat-kilometre by NAPDM region (2016 prices)

5.15 In the forecasts presented here, it is assumed that the airlines' small increased use of biofuels does not affect their overall fuel costs. Because of this the increase in penetration of biofuels has no effect on air fares or on demand; it does, however, affect CO_2 forecasts as set out in Chapter 3.

Carbon prices

5.16 Carbon prices are assumed to grow in line with BEIS's March 2017 appraisal values.[93] In 2016 they were £4 / tCO_2, and they rise to £77 in 2030 and £221 in 2050 (all in 2016 prices). These are converted into fare impacts using annual fuel efficiency outputs from the CO_2 model. They are assumed to be faced by all passengers using any airport within the model.

Fuel efficiency and trip length

5.17 As noted above fuel efficiency influences air fares. Modelling the turnover of the future aircraft fleet changes the fuel and carbon cost elements of air fares, as new generations become increasingly fuel efficient. Aircraft fuel consumption over time is forecast for each destination region using the outputs from the aviation Fleet Mix (FMM) and CO_2 models.

5.18 There have been significant improvements in recorded fuel efficiency in recent years and the FMM and CO_2 models project further improvements which are expected to vary with the different types of aircraft deployed to the main forecasting regions. Indices of these changes are shown in Figure 5.2. They show forecast improvements in fuel efficiency (measured by seat-kilometres divided by fuel consumption) in the range of 14% - 85%. The improvement in fuel efficiency for flights to NICs is particularly large because this destination tends to use the largest aircraft (especially A380s) which are all retired and replaced by the 2040s. More detail on the FMM and CO_2 models are available in Chapters 2 and 8.

[93] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Indices of fuel efficiency

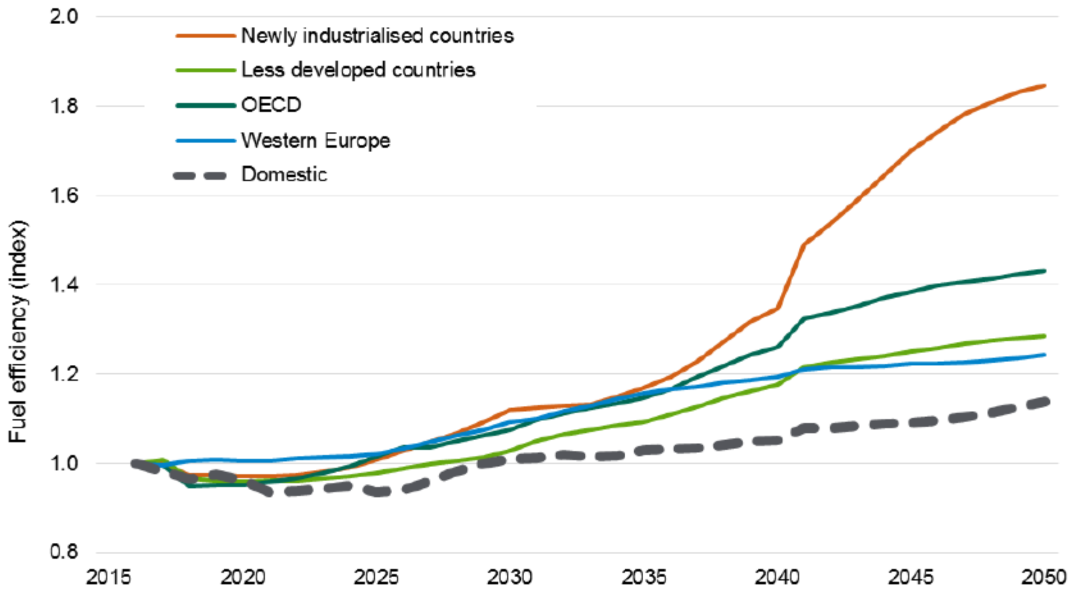


Figure 5.2 Indices of fuel efficiency by NAPDM forecasting region

5.19 Assumed average trip length makes very little difference to changes in fares over time and is therefore not a material driver of changes in demand. But it does affect the absolute levels of fares reported in Table 54 in the data annexes.

Air Passenger Duty (APD)

5.20 Rates are based on HMRC figures set out in April 2017.[94] The rate in each geographic region in the forecast model is aligned with APD geographic bands using CAA passenger survey data and is a weighted average across APD rates for reduced and standard classes. In addition, an adjustment has been made to reflect that those aged under 16 are now exempt. The rates are assumed to be held constant in real terms for the rest of the modelling period and are only applied when departing from a UK airport. Table 17 sets out the average rates used in the forecasts converted from the APD band areas to the NAPDM forecasting regions.

NAPDM region	APD rate, £
Domestic end-end	25
Western Europe	13
OECD	78
Newly Industrialised Countries	81
Less Developed Countries	66

APD is paid when departing a UK airport, and aviation trips entirely within the UK involve doing so twice. The domestic end-end rate is about double the Western Europe rate because of this.

Table 17 2016 weighted average two-way APD rates per passenger by NAPDM region, 2016 prices

[94] https://www.gov.uk/government/publications/rates-and-allowances-excise-duty-air-passenger-duty/rates-and-allowances-excise-duty-air-passenger-duty

Airline 'other' (non-fuel) costs

5.21 The other airline costs contributing to fare levels include all costs not attributed to the fuel, carbon and APD group of costs. These are mainly aeronautical charges, fleet, labour and sales and administration costs.

5.22 Such costs are calculated by comparing fare levels against the sum of the other quantified components of fares set out in this chapter – the difference between these two is assumed to be the 'other' costs. Non-fare revenue and airline profits are not included in this calculation – it is effectively assumed that these two elements cancel out.[95]

5.23 Fare data is taken from the 2015 International Passenger Survey (IPS) for international trips and the 2015 CAA passenger survey for domestic trips. These data sources relate only to fares paid by UK residents and so it is assumed that foreign residents pay the same fares as their UK counterparts. All calculations are undertaken per seat-kilometre. Table 18 shows the costs by NAPDM region and journey purpose:

	Business	Leisure
Domestic	7.8	4.1
Western Europe	10.1	3.2
OECD	9.2	2.3
Newly Industrialised Countries	6.4	1.4
Less Developed Countries	8.0	2.3

Table 18 2015 Non-fuel costs by journey purpose and region, pence per seat-km, 2016 prices

5.24 Estimated costs are higher for passengers travelling on business because they are less likely to travel economy class. As such they are more likely to be provided with larger seats and more expensive extras incorporated into the fare such as use of particular lounges etc. As a rule, longer haul flights see lower non-fuel costs per seat-kilometre, as some costs are fixed (and such costs are spread out over a greater distance), although the proportion of passengers flying economy class also plays a role.

5.25 CAA financial data reveal that these costs (per seat-kilometre) have fallen from 1998 to 2014 by on average, by 2.3% a year in real terms.[96] This is shown in Figure 5.3 which also includes a logarithmic fitted trend line.

[95] In practice, these elements are small enough not to affect the calculations significantly as, according to CAA financial data (https://www.caa.co.uk/Data-and-analysis/UK-aviation-market/Airlines/Datasets/UK-Airline-financial-tables/Airline-financial-tables-2014-2015), non-fuel costs are almost ten times non-fare revenue. Profits are much more volatile but have normally been smaller than non-fare revenue.

[96] This relates to the four largest UK airlines (measure by distance travelled): British Airways, easyJet, Flybe and Virgin Atlantic. Costs are deflated using the Consumer Price Index (CPI) measure of inflation.

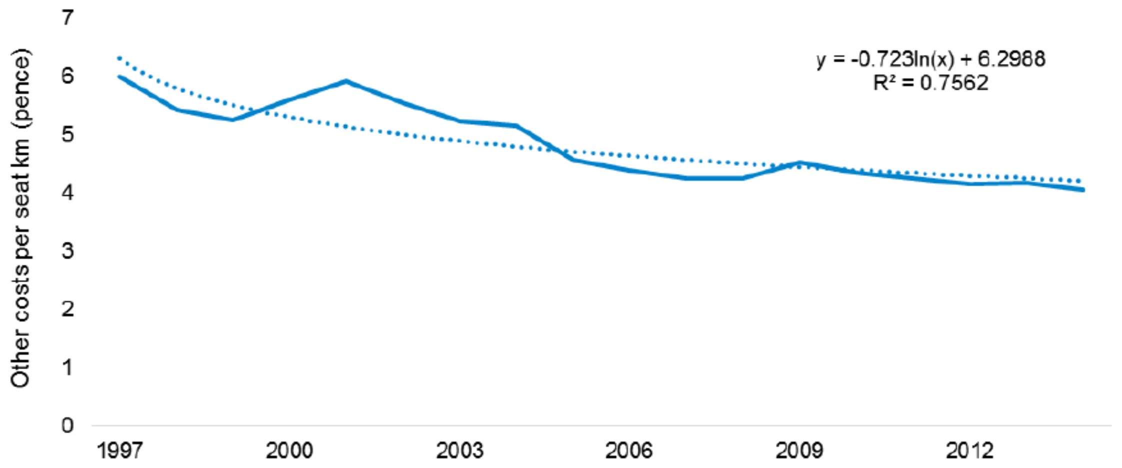


Figure 5.3 Historic non-fuel airline 'other' costs

5.26 It is assumed that such costs continue to fall into the future, although at a slower rate - this logarithmic function is applied for forecasting purposes. This results in the annual rate of decline falling from 0.9% in 2017 to 0.6% in 2030. From 2030 onwards, as with previous forecasts, it is assumed that such costs stop falling. In a slight departure from previous forecasts the same rate of growth is applied to both the short-haul and the long-haul markets. This is because the underlying data is at airline level and some airlines operate both short- and long-haul.

Load factors

5.27 Load factors are another input into the overall fare faced by passengers – the higher the load factor, the greater the number of passengers over which the costs are spread and the lower the fare. They are extracted from model outputs annually and vary by NAPDM market.

Overall change in modelled fares

5.28 Figure 5.4 provides an overview of the modelling of average total fares split by component.

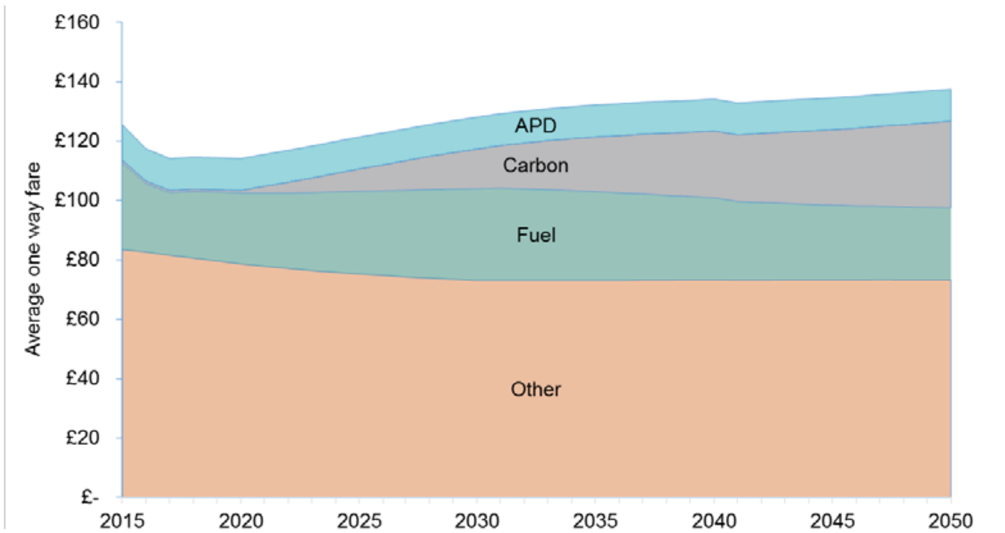


Figure 5.4 Projected composition of future air fares (all flights) weighted by terminal passengers, central demand

Population and distribution of demand across the UK

5.29 The OBR forecasts discussed in paragraph 5.7 incorporate forecasts of UK population into their UK GDP forecast; therefore population growth is not included as a separate driver of national demand. But the geographical distribution of population growth is expected to influence the distribution of demand growth as set out in Chapter 2.

5.30 The population data for UK regions has been updated with the department's latest National Trip End Model (NTEM) 7.2 release updated from NTEM 6.2. NTEM 7.2 shows a slightly higher share of population growth attributable to districts in the London and the South East, further contributing to a concentration of growth in that area, also referred to in Chapter 2.

5.31 The annual population growth rates by aggregated aviation model region is shown in Table 19.

Region	2016-2030	2016-2050
London	0.9%	0.7%
South East	0.7%	0.6%
Eastern	1.1%	0.8%
South West	0.6%	0.5%
Wales	0.3%	0.2%
West Midlands	0.5%	0.4%
East Midlands	0.6%	0.5%
Yorkshire & Humberside	0.4%	0.4%
North West	0.3%	0.3%
North	0.3%	0.3%
Scotland	0.4%	0.3%

Table 19 Population forecasts growth rate by region, per annum (CAGR)

Local demand growth at the overseas hubs

5.32 The inclusion of overseas hubs as capacity constrained modelled airports in NAPAM, as explained in Chapter 2, requires a forecast of 'local' (point-to-point) demand at these airports. This helps to improve the robustness of the demand forecasts for international-international transfers at these airports and ensures overseas capacity constraints at the key hubs are taken into account.

5.33 It is assumed that such local demand at overseas European hubs grows at the same rate as demand from foreign residents travelling to the UK (varying by NAPDM market). At Dubai, demand has in past years grown significantly more quickly than this approach would suggest and so in the short term a blended approach is used. Recent demand growth at Dubai (8% per annum over the past five years) is blended with forecast NAPDM foreign resident demand growth to the NIC region. This results in local demand growth of 7% in 2017, gradually falling to around 1.6% (leisure) and 3.5% (business) in 2021. Post 2021, foreign resident forecast growth to the NIC region is used.

Summary of main NAPDM econometric sources

5.34 Table 20 summarises the sources used to project the key drivers of demand.

Model input	Period	Source
UK GDP and consumption expenditure growth rates	2016 - 2021	OBR, March 2017
	2022 - 2050	OBR, January 2017
Foreign GDP growth rates	2016- 2022	IMF, April 2017
	2023 - 2050	OECD, May 2014
Carbon prices	2016 - 2050	BEIS, March 2017
Oil prices	2016 - 2040	BEIS, November 2016
	2041 - 2050	Held constant in real terms by assumption*
Dollar : sterling exchange rate	2016 - 2021	OBR, March 2017
	2016 - 2050	Held constant by assumption
Air passenger duty	2016 - 2018	HMRC, January 2017
	2019 - 2050	Held constant in real terms by assumption
Load factors	2016 - 2050	NAPAM, July 2017
Fuel efficiency	2016 - 2050	NAPAM, July 2017
Population by district	2016 - 2050	DfT NTEM 7.2
* There is no change in the source oil price forecast between 2030-2040		

Table 20 Summary of NAPDM input assumption sources

Definition of low and high scenarios

5.35 The definition of these scenarios follows similar macroeconomic input assumptions to those used by the Airports Commission in their final report in defining their global fragmentation (low) and global growth/low-cost is king (high) scenarios. The scenarios do not replicate the Airports Commission demand inputs exactly because the input macroeconomic central values have been updated[97] and the airport specific assumptions have not been applied.[98]

5.36 The defining low and high scenario forecast input assumptions are set out in Table 21.

[97] In the case of oil price forecasts the source has been changed from IEA to BEIS in all demand scenarios, including the central.
[98] The Airports Commission used the same global growth macroeconomic inputs to define the global growth and low-cost is king scenarios and the same carbon prices (consistent with a global emissions trading scheme) was common to all scenarios except global fragmentation.

Demand scenario	Description	Specifics
Low	Lower economic growth worldwide with restricted trade, coupled with higher oil prices and failure to agree a global carbon emissions trading scheme. These national demand inputs are based on the Airports Commission's global fragmentation scenario	Twentieth percentile of the OBR GDP forecast range up to 2021, and 0.5% per annum lower than the central forecast for all future years. GDP growth for all other countries 1% per annum lower than the central forecast for all years. A fall in the growth in trade in line with the change in GDP for all world zones International-international transfer traffic falls back to base year (2016) levels by 2040. BEIS high oil prices (rising to $120 by 2030). Carbon price applies only to the leg of the journey that relates to passengers departing UK airports.
High	Higher passenger demand from all world regions, lower operating costs and a global emissions trading scheme These national demand inputs are based on the Airports Commission's global growth and low-cost is king scenarios	GDP growth increased relative to the central forecast by 2% points per annum for NIC and LDC countries, and 0.5% elsewhere Trade increased in line with the change in GDP for all world zones An increase in international-international transfer passenger demand of 1% pa cumulatively over and above that forecast by NAPDM BEIS low oil prices (rising to $55 by 2030).

Table 21 Definition of the low - high demand scenario assumptions

Airline market splits

5.37 A key stage in the forecasting process is to identify if there are distinct markets within which passenger demand can be expected to differ. In line with previous forecasts, passengers and airline markets are split between scheduled, low cost carrier and charter flights and within these markets, passengers are also split by their journey purpose. This split does not affect forecast national underlying demand.

5.38 This split has been reviewed in the light of the new data. Given the recent falls in the share of the market attributable to charter traffic, it is now assumed that the charter share of the UK resident leisure market will decrease from around 10% in 2016 to about 5% in 2030. After 2030, the charter share is held constant.

5.39 In line with analysis of the most recent evidence, forecasts continue to assume that both the low cost carrier and scheduled airline market sectors retain constant shares of the non-charter market from 2016 onwards. This means that both sectors see an increase in overall share, as the charter market is forecast to decline. This assumption is driven by passenger survey data which show that, at a NAPDM market level, the share of the non-charter market has not changed between the scheduled and the low-cost carrier markets.[99]

Airport Capacities

Baseline capacities

5.40 Forecasting the impact of capacity constraints using NAPAM requires assumptions about both the terminal and runway capacities of each airport included in the model.

5.41 The overall principles adopted in these forecasts of defining annual airport capacities have been to:

- retain current planning ATM and terminal caps
- use information from airports' master plans.
- update theoretical capacities in line with observed (reflecting actual throughput) operational limits as appropriate at busy airports, where no formal cap restricts capacity
- continue to treat the two Northern Ireland airports as a special case because of the restricted airport choice for passengers in the model[100]

5.42 The baseline capacity scenario (alternatively known as the Do Minimum) assumes that no new runways are built in the UK, but that incremental improvements in line with developments already in the planning system or in published airport masterplans are implemented. These baseline assumptions include up to a 13% capacity gain (where possible) through operational and technological improvement in areas such as air traffic control and airspace management.

5.43 Where there is an expectation that some baseline capacity improvements beyond those in published sources will still be required, then these are deemed to be implemented (taking a cautious account of physical constraints) after 2030.[101] [102]

5.44 Table 22 shows the runway and terminal passenger capacities assumed for each airport in the airport capacity baseline. The terminal passenger capacity is the maximum number of passengers an airport's terminal and associated passenger handling infrastructure is assumed capable of serving a year. The table shows that in general most of the capacity added after 2016 is provided at regional airports.

5.45 In London, the changes made since previous forecasts are:

- The reduction of longer term ATM capacity from 120k to 111k and terminal capacity from 8mppa to 6.5mppa at London City. This is in line with the planning approval of July 2016. The terminal input capacity rises from 5m to 6.5m and is assumed to be implemented in 2022.
- An increase of Gatwick ATM capacity from 280k to 290k in 2016 to reflect the actual throughput in 2016 and the likelihood of further increase in 2017. The

[99] The DfT definition of low cost carrier continues to be restricted to easyJet, Jet2, Ryanair and Thomsonfly. This is significant as the scheduled sector in terms of this split is increased by airlines such as Wizz and Norwegian who are often considered LCCs.

[100] Because Northern Ireland is modelled as a closed system consisting of only the two Belfast airports, over-capacity at one of these airports can cause model runs to fail to converge, even though the performance of these two airports has only a minimal impact on mainland UK airports. Therefore Belfast City and Belfast International are given just enough capacity to avoid incurring shadow costs.

[101] An example is Gatwick, where an increase in the assumed capacity beyond the current 45mppa to 50mppa is likely to be required sooner but has been delayed until after 2030 pending a revised masterplan for a single runway airport which the airport have currently held back during the Government draft NPS and Aviation Strategy consultations.

[102] Manchester has published potential post-2030 expansions to terminal and runway capacities in its masterplan and so these have been adopted.

terminal capacity has been increased to 50mppa, but consistent with the principle set out in paragraph 5.43, this increase has been held back until after 2030 pending publication of a new Gatwick masterplan.

- Luton is given its planning cap capacity of 18mppa in 2017 to take account of terminal work completion.

5.46 Outside London, the most significant changes in capacity input assumptions relate to the reduction in Bristol's terminal capacity from 12mppa to 10mppa in line with the current planning cap and the Doncaster Sheffield planning cap being restored throughout the model period for the purpose of consistency with other mainland airports with planning caps - this last change has no impact on any of the forecasts.

5.47 Elsewhere there are a number of smaller changes following a recent review by the department of published airport plans. Many of these reflect airports' more cautious expectations that terminal capacity expansion will most likely delayed until nearer the time demand requires it. A number of increases in capacity after 2030 (where there is no planning restriction) reflect this approach, often where the airport has not stated an aspiration, but with reference to earlier higher growth DfT forecasts.

	Runway ATMs (000s)					Terminal passengers (mppa)				
	2016	2020	2030	2040	2050	2016	2020	2030	2040	2050
Gatwick	290	290	290	290	290	45	45	45	50	50
Heathrow	480	480	480	480	480	90	90	90	90	90
London City	111	111	111	111	111	5	5	7	7	7
Luton	130	160	160	160	160	18	18	18	18	18
Stansted	259	259	259	259	259	35	35	35	35	35
London	1270	1300	1300	1300	1300	193	193	195	200	200
Birmingham	206	206	206	206	206	27	27	37	37	37
Bristol	150	150	226	226	226	10	10	10	10	10
East Midlands	264	264	264	264	264	6	6	10	10	10
Edinburgh	150	150	225	225	225	13	15	20	20	35
Glasgow	226	226	226	226	226	10	10	20	20	20
Liverpool	213	213	213	213	213	7	7	15	15	15
Manchester	324	324	400	500	500	30	30	38	55	55
Newcastle	213	213	226	226	226	9	9	9	9	9
Larger regional	1746	1746	1985	2085	2085	112	114	159	176	191
Aberdeen	175	175	225	225	225	6	6	6	6	6
Blackpool	0	0	0	0	0	0	0	0	0	0
Bournemouth	150	150	150	150	150	3	3	5	5	5
Cardiff	105	105	150	150	150	3	3	8	8	8
Coventry	0	0	0	0	0	0	0	0	0	0
Doncaster Sheffield	57	57	57	57	57	2	2	2	2	2
Exeter	150	150	150	150	150	2	2	4	4	4
Humberside	150	150	150	150	150	1	1	3	3	3
Inverness	150	150	150	150	150	1	1	3	3	3
Leeds-Bradford	150	150	150	150	150	5	5	8	8	8
Newquay	75	75	75	75	75	0	0	1	1	1
Norwich	175	175	175	175	175	2	2	3	3	3
Prestwick	150	150	225	225	225	3	3	3	3	3
Southampton	150	150	150	150	150	3	3	3	7	7
Southend	30	45	53	53	53	5	5	5	5	5
Durham Tees Valley	150	150	150	150	150	1	1	1	1	1
Sub-total	1817	1833	2011	2011	2011	36	36	53	57	57
All regional	3563	3579	3995	4095	4095	148	150	212	233	248
Total	4833	4879	5295	5395	5395	341	343	406	432	447

Table 22 Runway and terminal capacity inputs, mainland UK modelled airports, baseline

5.48 Blackpool and Coventry airports have, for modelling purposes, been treated as closed to passenger traffic, as shown in Table 22. The airport capacities include allowance for freight aircraft and flights to non-UK airports, including oilfield helicopters, which are all included in the ATM modelling.[103]

5.49 In the department's last forecasts the competing overseas hubs in the model were not included as capacity constrained. The current overseas hubs capacity shown in Table 23 are the same as those adopted by the Airports Commission, including that only runway capacity is limited.

	Runway ATMs (000s)					Terminal passengers (mppa)				
	2016	2020	2030	2040	2050	2016	2020	2030	2040	2050
Paris	690	690	690	690	690	Unlimited				
Amsterdam	510	510	630	750	750					
Frankfurt	700	700	700	700	700					
Dubai	560	560	1360	1760	1760					
Total	2460	2460	3380	3900	3900					

Table 23 Baseline runway and terminal capacity inputs at modelled overseas hubs

Airport development options (draft NPS)

5.50 Capacities for the expansion options are the same as those used by the Airports Commission. This is to ensure consistency for the further assessments being undertaken in conjunction with the preparation of the draft Airports National Policy Statement on new runway capacity and infrastructure in the South East (the NPS). The assumed final and incremental extra capacity provided is shown in Table 24:

Option	Abbreviated form	ATM capacity increment	Year implemented	Total ATM capacity
Gatwick Second Runway[104]	LGW 2R	270,000	2025	560,000
Heathrow Extended Northern Runway	LHR ENR	220,000	2026	700,000
Heathrow Northwest Runway	LHR NWR	260,000	2026	740,000

Table 24 Capacity expansion options, ATM capacity inputs

5.51 In common with the Airports Commission assessment, the modelling assumes that runway capacity is the constraint and subject of the proposals. So in each expansion option it is assumed that sufficient terminal capacity is provided so as not to prevent full use of the expanded runway capacity.

[103] An exception to this principle is Stansted. Here the capacity allows for freighters, but the planning cap capacity of 264,000 is reduced to allow for a significant volume of non-commercial jet flights which occur at this airport.

[104] Because the baseline capacity was increased from 280,000 to 290,000 in these forecasts, the capacity increment is now assumed to be 270,000 and not 280,000. This is to maintain the same overall capacity (560,000) following expansion as assumed by the Airports Commission.

Surface access inputs

5.52 The estimated time and money costs of accessing airports by road or rail help to determine passenger airport choice. These forecasts include updates relating to values of time (reflecting changes in WebTAG[105]), rail fares and road costs.

5.53 As well as including a set of surface access networks, NAAM2, as explained in Chapter 2, incorporates potential future changes in rail and road networks ensuring that a representation of large schemes like HS2 is included. For modelling purposes, the scheme assumptions made by the Airports Commission in their demand modelling have been retained, including those associated with the shortlisted capacity options.[106] The department recognises that in some cases such plans have progressed since the Commissions' analysis, and that going forward the plans will continue to evolve; as such, there is significant uncertainty relating to these assumptions.

[105] https://www.gov.uk/government/publications/webtag-tag-data-book-july-2017
[106] These are set out in *Strategic Fit: updated forecasts*, Airports Commission, July 2015, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/439687/strategic-fit-updated-forecasts.pdf. See, in particular, Appendix 2.

6. Unconstrained forecasts

Introduction

6.1 This chapter sets out underlying UK passenger demand in the absence of airport capacity constraints. These forecasts are therefore a hypothetical case independent of any airport development options.

6.2 Unconstrained passengers represent the underlying demand to use UK airports in any year. They include passengers who in the future may be priced out of travelling by capacity constraints as well as those who cannot use their preferred airport. They will also include a number of travellers who do not start or end their journeys in the UK. Such 'international-international interliners' pass through the UK interchanging at a hub airport, such as Heathrow, but could potentially use a competing overseas hub, such as Amsterdam, because of capacity constraints at the UK alternative.

6.3 The unconstrained forecasts are essentially a modelling diagnostic tool. They are very useful in recognising underlying patterns of demand growth and for checking that the linkages between key modelling components, the NAPDM and NAPAM, are functioning correctly. They are also useful to aid understanding of the geographical location of underlying demand and, when combined with capacity information, where in the country capacity constraints are forecast to exist. But they are highly theoretical in that they include input assumptions that could not exist. Because of this, airport specific unconstrained forecasts are not provided and these are not used directly by the department in economic appraisal.

Passenger forecasts

6.4 The forecasts reported here are derived from the National Air Passenger Allocation Model (NAPAM) using the methodologies described in Chapter 2 and the inputs described in Chapter 5. The unconstrained demand presented below is taken from NAPAM passenger allocations so that the units are terminal passengers rather than trips. This is for compatibility with the reporting of constrained passenger allocations elsewhere.

6.5 Terminal passengers[107] per annum (mppa) at the national level for the demand growth scenarios are summarised in Figure 6.1.[108] The definition of the three demand scenarios is given in Chapter 5 of this document. The range is formed in a different way to previous DfT forecasts; they represent three scenarios with the central forecast using the economic variable inputs described in Table 20.

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[107] See paragraphs 2.5-2.9 for definition and discussion of the unit of 'terminal passenger'.

[108] These are modelled unconstrained passengers after allocation by the National Air Passenger Allocation Model. These will differ from the unconstrained terminal passenger forecasts produced by the input National Air Passenger Demand Model because the National Air Passenger Allocation Model allocates passengers to indirect routes such as via UK hubs where a single one way journey may be counted as three terminal passengers.

	Low	Central	High
2016	**267**	**267**	**267**
2020	285	300	315
2025	305	325	345
2030	335	355	380
2035	360	385	415
2040	395	420	455
2045	435	460	495
2050	470	495	535

Rounded to nearest 5 mppa

2016 are CAA recorded actuals for UK modelled airports

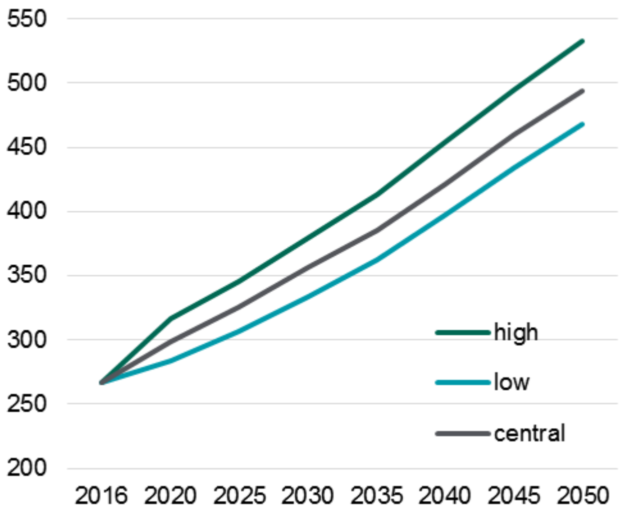


Figure 6.1 National passenger forecast, unconstrained capacity, mppa

6.6 Figure 6.1 shows growth in 5 yearly intervals from the model base year of 2016. The forecast is for underlying demand to increase by 84% from 2016 to 2050 with the forecast ranging between 75% (low) and 99% (high).

6.7 In the central and high demand cases, annual growth rates are higher at the beginning of the modelled period. The impact of lower carbon prices in the low scenario, which partially offsets the impact on demand of slower GDP growth, makes the range narrow. This effects grow stronger later in the forecasting period as carbon prices increase.

	low	central	high
2016 -2020	1.5%	2.8%	4.3%
2020 -2030	1.6%	1.8%	1.8%
2030 -2040	1.8%	1.7%	1.8%
2040 -2050	1.7%	1.6%	1.6%

Table 25 Compound annual growth rate, unconstrained capacity

Air passenger destinations.

6.8 In Table 26 UK passengers destinations are presented in the four international regions used in the NAPDM.[109] The table is compiled from NAPAM allocation model output so that transfer passenger components of the forecast can be separately identified.[110]

[109] A correspondence list between the international NAPDM regions and the 48 international zones used in the allocation model is given on page 32.

[110] But note that international-international transfers between the department's 2013 and 2017 forecasts are treated differently. Unlike the 2013 forecast, the new forecasts include overseas hubs in the airport allocation model and potentially some passengers who are using those hubs who wish to use UK hubs.

	2016		2030		2050	
NAPDM Regions	mppa	share	mppa	share	mppa	share
WE	165.3	62%	204.0	57%	291.4	59%
OECD	17.9	7%	22.6	6%	31.2	6%
NIC	21.3	8%	27.0	8%	44.0	9%
LDC	1.8	1%	2.2	1%	3.4	1%
International total	206.3	77%	255.9	72%	369.9	75%
Domestic EE	29.0	11%	35.6	10%	48.1	10%
Dom-intl transfer	5.2	2%	19.7	6%	21.0	4%
Others	2.3	1%	2.3	1%	2.3	0%
Domestic Total	36.5	14%	57.7	16%	71.4	14%
II	23.9	9%	42.6	12%	52.7	11%
Total	266.6	100%	356.1	100%	494.0	100%

2016 figures are model outputs from the (constrained) validation forecast
Domestic EE - domestic passengers not leaving the UK
'Others' - normally passengers going from a UK airport in the model to a UK airport not in the model (e.g. oil rig traffic at Aberdeen)
II - international-international transfers at a UK hub airport
NAPDM regions are defined in Chapter 2

Table 26 Breakdown of demand by destination region, central demand, unconstrained capacity, mppa

6.9 Long-haul demand (defined as the NAPDM regions OECD, NIC and LDC) is forecast to be 16% of underlying demand in 2050, approximately the same proportion as today, but a near doubling of the absolute numbers forecast. The international proportion (including long-haul) also includes the international-international transfers, so the proportion of international passengers forecast in total is 86%, approximately the same share as today. OECD long-haul (principally North America) will in time form a slightly smaller proportion as this market is nearer maturity.

6.10 The 2016 total throughput of UK terminal passengers at 267mppa, from which the forecasts are projected, was significantly higher than the 2013 forecasts estimate for that year, due in large part to the sharp fall in oil prices since the last forecast. Nonetheless, primarily because of lower UK and worldwide GDP forecasts, the 2050 forecast of terminal passengers at 494mppa is now only 2.5% higher than the forecast for that year produced in 2013.

6.11 In the low demand scenario international short-haul forms a larger proportion of total traffic and grows by 74% from 2016-2050 compared with 70% growth for long-haul excluding transfers. In the high demand scenario forecast international traffic growth is driven by higher long-haul traffic growth. Long-haul grows by 127% from 2016-2050 compared to the 84% growth in international short-haul. Excluding transfers, the proportion of long-haul traffic in underlying demand rises to 18% in high growth and the proportion of short-haul drops.

6.12 International-international transfers also tend to grow faster with higher long-haul growth as the majority of such journeys have at least one long-haul leg. The cumulative growth over the modelled period in the unconstrained set of demand scenario forecasts are summarised in Table 27.

	low	central	high
Short-haul	74%	76%	85%
Long-haul	70%	92%	127%
All international	73%	79%	93%
All domestic	79%	96%	109%
Il transfers	89%	121%	143%
All	76%	85%	100%

Table 27 Demand growth by type of trip, unconstrained capacity, 2016-2050

6.13 Full details of how the traffic by destination varies across the demand growth scenario forecasts can be found in Table 55 in the data annexes.

Air passenger UK ground origins

6.14 With the exception of international-international transfers, the department's aviation model represents the two-way journeys by air passengers from their starting or finishing point in the UK (the ground origin) to a foreign destination and back, or, in the case of internal domestic journeys, to another UK ground origin or destination and back. When forecasting, the ground origins of both UK and foreign resident passengers are varied in line with population projections in the department's National Trip End Model (NTEM 7.2), although each is ultimately controlled to the national forecast for each destination region and journey purpose market. Chapter 2 sets out this process.

	mppa			Growth from 2016		Market share		
	2016	2030	2050	2030	2050	2016	2030	2050
London	67.7	87.7	127.2	30%	88%	25%	25%	26%
South East	46.5	58.3	83.8	26%	80%	17%	16%	17%
Eastern	7.0	9.0	13.3	29%	90%	3%	3%	3%
East Midlands	10.4	12.5	18.2	21%	75%	4%	4%	4%
West Midlands	12.8	15.2	21.9	19%	71%	5%	4%	4%
South West	14.3	17.3	25.1	21%	76%	5%	5%	5%
North	4.8	5.8	8.1	19%	68%	2%	2%	2%
Yorkshire & Humberside	11.1	13.2	19.1	19%	72%	4%	4%	4%
North West	19.6	23.0	32.9	17%	68%	7%	6%	7%
Scotland	21.7	25.9	35.1	19%	62%	8%	7%	7%
Wales	6.0	6.8	9.3	13%	55%	2%	2%	2%
Northern Ireland (international)	2.1	2.5	3.8	19%	77%	1%	1%	1%
Northern Ireland (domestic)	11.3	14.1	20.1	25%	78%	4%	4%	4%
Domestic-international hub transfer	5.2	19.7	21.0			2%	6%	4%
International-international hub transfer	23.9	42.6	52.7			9%	12%	11%
Other UK airports ("others")	2.3	2.3	2.3			1%	1%	0%
Total	266.6	356.1	494.0	34%	85%	100%	100%	100%

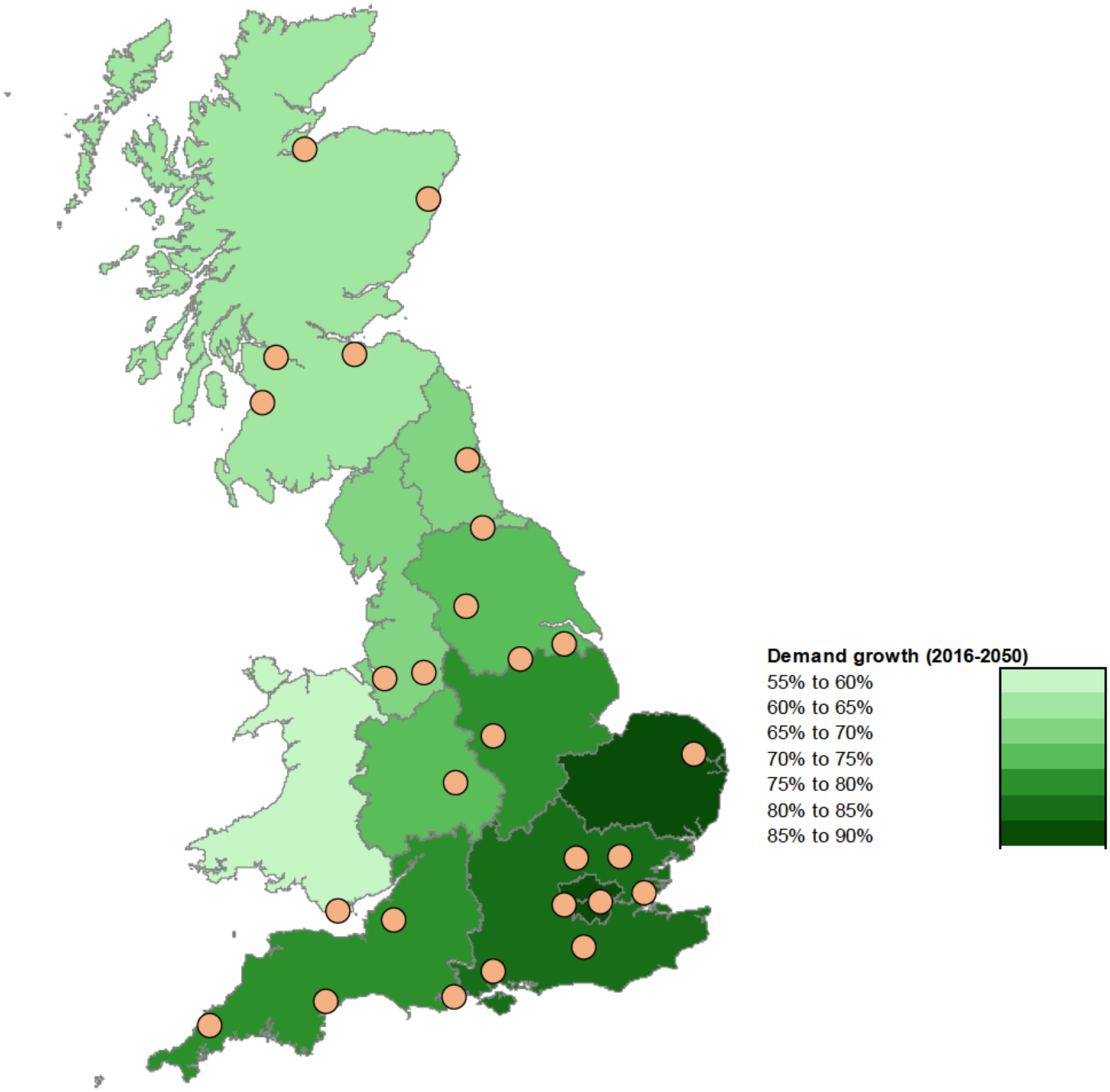
2016 figures are model outputs from the (constrained) validation forecast

'Others' - normally passengers going from a UK airport in the model to a UK airport not in the model (e.g. oil rig traffic at Aberdeen)

Table 28 Regional ground origins of passenger journeys, central demand, unconstrained capacity

6.15 Table 28 shows that over 40% of total terminal passengers start or end their air journeys in London and the South East. Once all transfers at UK hubs are excluded, then London and the South East currently accounts for 51% of the starting or ending point of all mainland UK journeys. This share is forecast to rise to 54% by 2050. Transfers at hub airports cannot be allocated to a region, and domestic international transfers are counted at the region where their journey ultimately starts or finishes.

6.16 Figure 6.2 shows the growth forecasts by region. The highest growth (90%) is projected for the eastern region, but this generates only 3% of UK passengers. London, with 30% of mainland UK ground origins, has the second highest growth (88%). London's dominance reflects its higher than national average growth since the department last produced forecasts, and the increased attractiveness of the capital to overseas visitors.



Circles denote modelled mainland UK airports

Figure 6.2 Growth in air journeys by region of ground origin 2016-2050, central demand, unconstrained capacity

Air passengers by residency and journey purpose

6.17 The department's aviation model splits passengers by their residency, UK or foreign, and their journey purpose, business or leisure. Business can be more narrowly defined as 'employer's business' as commuting by air is insignificant in terms of air passenger volumes.[111] Leisure includes a wide spectrum of purposes of which 'visiting friends and relatives' (VFR) has grown considerably and continues to grow alongside the more traditional holiday and city break markets.[112]

6.18 The international-international transfer category is not split by journey purpose in NAPAM and is kept separate in this analysis for clarity, but it might be noted that the majority of such passengers are on leisure trips and all are assumed to be foreign residents.[113]

6.19 Charter is defined as a separate category in the forecasts for compatibility with CAA statistical reporting. Charter is primarily package holiday traffic on flights not operating to a regular published schedule. For the purposes of further analysis, it is reasonable to treat charter passengers as part of the UK leisure market, as around 97% of charter passengers fall into this category.[114]

6.20 Domestic business and domestic leisure passengers are assumed to be UK residents.[115] This category is for internal UK flights where both the origin and destination are in the UK. Passengers making domestic-international transfers on domestic flights are included in the UK based international categories (UK or foreign residence, business or leisure).

[111] The CAA have produced a study of current business air passenger available at http://publicapps.caa.co.uk/docs/33/CAP796.pdf

[112] More detailed breakdowns of passenger journey purposes is collected in the CAA passenger surveys - see, for example, http://www.caa.co.uk/Data-and-analysis/UK-aviation-market/Consumer-research/Departing-passenger-survey/Departing-passenger-survey

[113] Between 2011-2016 the CAA passenger interview surveys show that 76% of international-international transfers were on leisure journeys.

[114] Based on observation in CAA surveys 2011-2016.

[115] CAA surveys 2011-2016 suggest around 94% of such flights are made by UK residents.

mppa	2016		2030		2050	
UK business	18.7	*7%*	25.9	*7%*	38.0	*8%*
UK leisure	112.0	*42%*	156.1	*44%*	224.1	*45%*
Charter (UK leisure)	12.8	*5%*	7.6	*2%*	11.2	*2%*
Foreign business	16.7	*6%*	22.2	*6%*	31.3	*6%*
Foreign leisure	51.2	*19%*	63.8	*18%*	86.3	*17%*
Domestic business	15.1	*6%*	18.5	*5%*	23.6	*5%*
Domestic leisure	16.2	*6%*	19.4	*5%*	26.8	*5%*
International-international transfer	23.9	*9%*	42.6	*12%*	52.7	*11%*
Total	266.6		356.1		494.0	
Business	50.6	*19%*	66.6	*19%*	92.9	*19%*
Leisure	192.2	*72%*	246.9	*69%*	348.4	*71%*
International-international transfer	23.9	*9%*	42.6	*12%*	52.7	*11%*
Total	266.6		356.1		494.0	
UK resident	174.8	*66%*	227.5	*64%*	323.8	*66%*
Foreign resident	91.8	*34%*	128.6	*36%*	170.2	*34%*
Total	266.6		356.1		494.0	
UK resident	174.8	*72%*	227.5	*73%*	323.8	*73%*
Foreign resident (no II transfers)	68.0	*28%*	86.0	*27%*	117.5	*27%*
Total	242.8		313.6		441.3	

2016 figures are model outputs from the (constrained) validation forecast
Domestic 'others' split equally between domestic business and leisure

Table 29 Demand by purpose, central demand, unconstrained capacity

6.21 The full set of growth scenario forecasts of underlying demand for 2030, 2040 and 2050 split by both purpose and destination region (and compatible in format with earlier department forecasts) is shown in Table 58 in the data annexes. Summaries of international demand broken down by short-haul and long-haul and of the composition of domestic traffic are also included in the tables in the data annexes.

7. Capacity constrained forecasts

Introduction

7.1 The previous chapter looked at the underlying passenger demand to use the UK airport system and competing overseas hub airports in the absence of capacity constraints. This chapter looks at the demand once airport constraints come into play. Constrained forecasts are produced by first inputting the underlying demand forecasts produced by the National Air Passenger Demand Model (NAPDM) into the National Air Passenger Allocation Model (NAPAM). Then aircraft (ATM) demand is calculated. Finally, both passenger and ATM demand are constrained to available terminal and runway capacity.

7.2 This chapter presents the forecasts constrained by runway and terminal capacities for the low-central-high set of scenario forecasts. The forecasts are presented for a baseline of no new runways, and for the three capacity expansion options the Government is consulting on in the draft Airports National Policy Statement.[116]

7.3 In addition to the material in this document, separate data files are available relating to fully disaggregated passenger and ATM outputs for 2030, 2040 and 2050.

Passenger forecasts

7.4 Forecast terminal passengers at the modelled UK airports are shown in Figure 7.1.

	Low	Central	High
2016	**267**	**267**	**267**
2020	265	275	290
2025	280	295	310
2030	295	315	330
2035	320	335	355
2040	345	360	380
2045	375	385	410
2050	395	410	435

Rounded to nearest 5 mppa

2016 are CAA recorded actuals for modelled airports

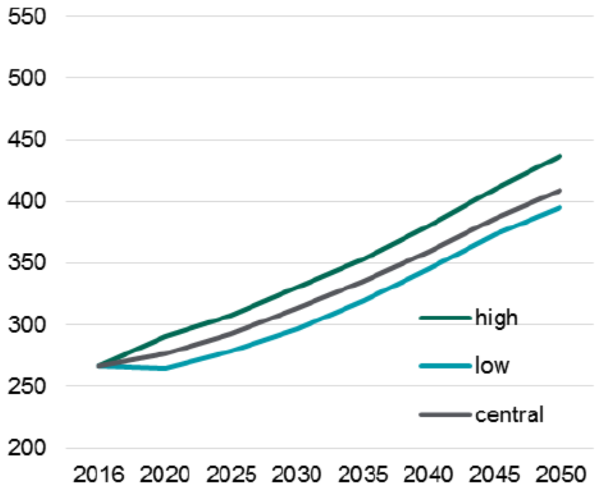


Figure 7.1 National passenger forecast, baseline capacity, mppa

[116] Department for Transport, *Draft Airports National Policy Statement: new runway capacity and infrastructure at airports in the South East of England*, February 2017.

7.5 The figure shows that, after allowing for runway and terminal passenger constraints, passengers at UK airports are forecast to grow to 315mppa in the central case in 2030 with a range of 295mppa to 330mppa. By 2050 the number of passengers are forecast to rise to 410mppa in the central case with a range of 395mppa to 435mppa. More detailed and unrounded constrained forecasts are available in Annex D.

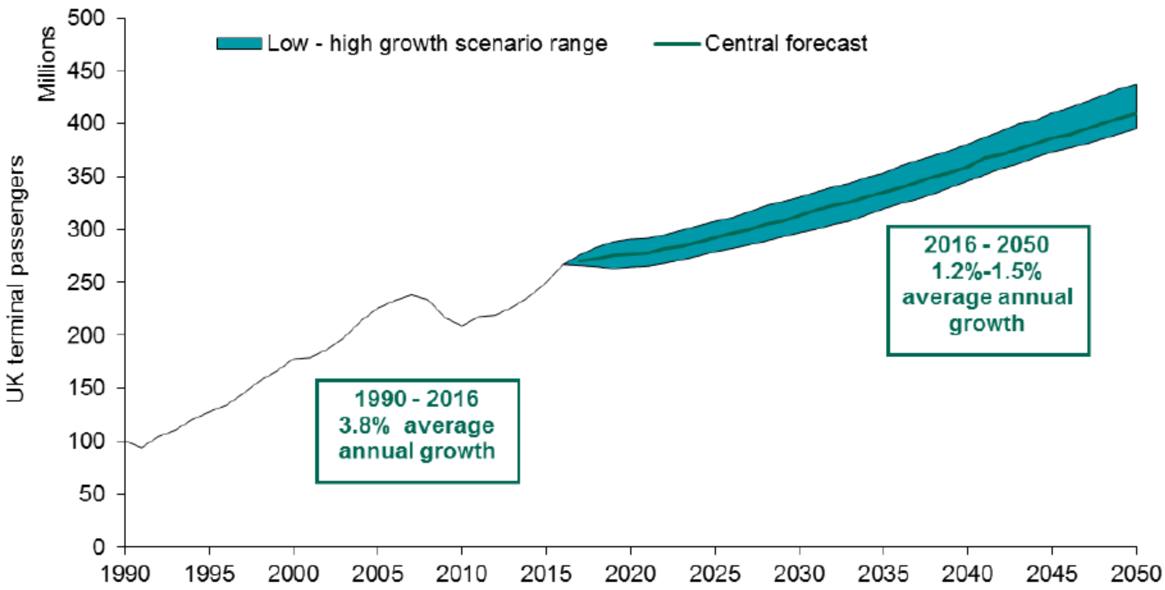


Figure 7.2 Historic and forecast national passenger demand, baseline capacity

7.6 The scenarios reveal a marked slowing of the rate of annual growth. Market maturity, lower economic growth inputs and higher carbon prices combine with capacity constraints to lower the set of central constrained forecasts well below the 445mppa reported in the department's 2013 forecasts.

7.7 A comparison of the unconstrained national forecasts in Figure 6.1 with the constrained forecasts in Figure 7.1 shows that capacity constraints restrict national forecasts and this impacts increases over time. More passengers to and from the UK are deterred from travel, or in the case of international-international transfers switch to competing overseas hubs.

7.8 Table 30 shows the difference between constrained and unconstrained passenger numbers throughout the model period. In the central forecasts airport capacity constraints lower demand by about 45mppa in 2030, rising to about 85mppa by 2050. At the low end of the forecast range, capacity constraints lower constrained demand by about 35mppa in 2030 and 75mppa in 2050. At the high end of the range the number of passengers either not travelling or transferring away from UK hub airports reaches about 95mppa by 2050.

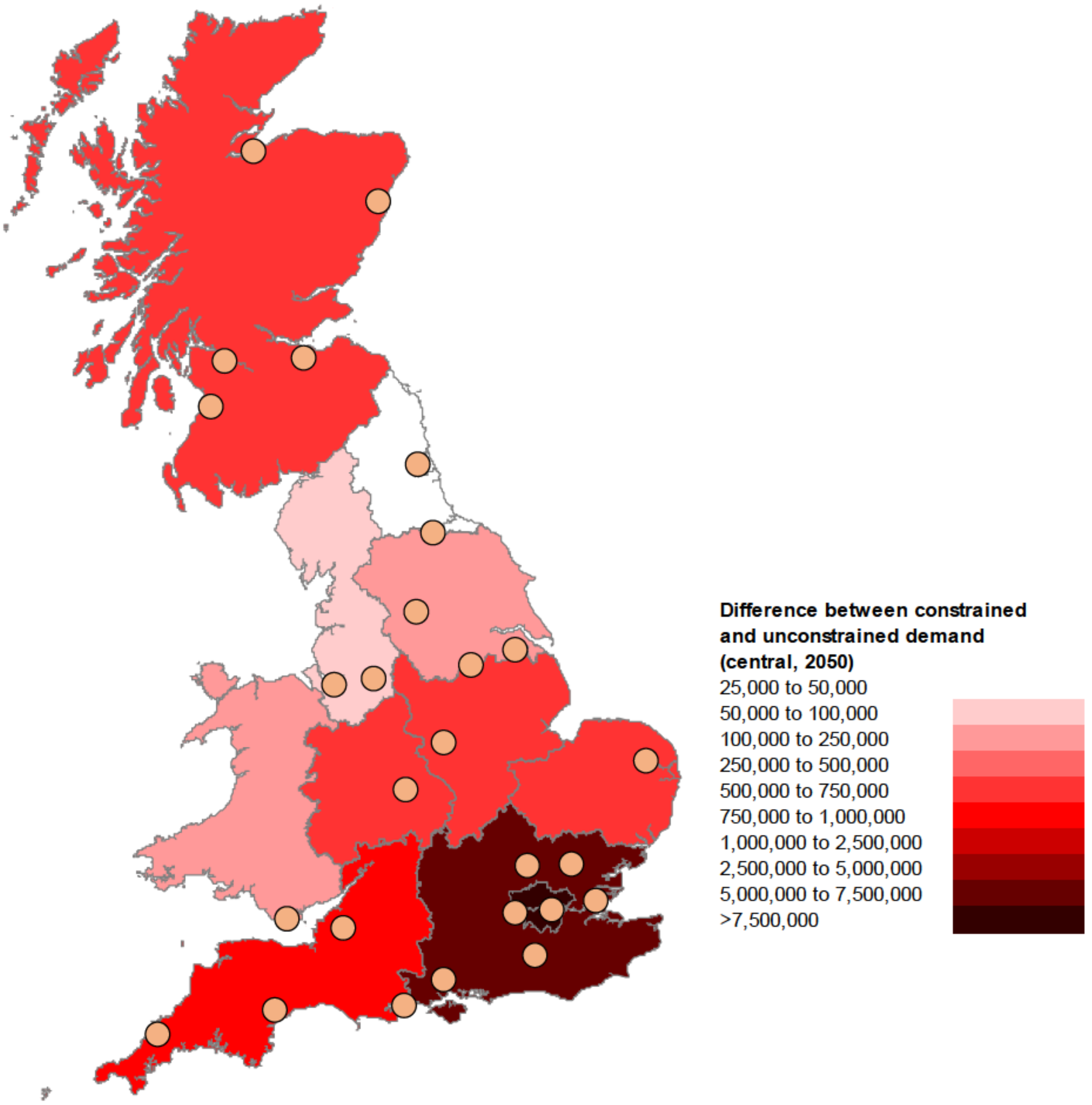
	Low	Central	High
2020	20	20	25
2025	30	35	40
2030	35	45	50
2035	45	50	60
2040	50	60	75
2045	60	75	85
2050	75	85	95

All figures are rounded to the nearest 5mppa

Table 30 Difference between constrained and unconstrained passenger national demand, mppa

7.9 The majority of the passengers lost to the UK terminal passenger total in the baseline are transfers at UK hub airports as such transfers effectively need to use scarce runway slots twice - and so pay 'shadow costs' (the premium for using a constrained airport) twice - to complete a one-way journey. As congestion mounts and shadow costs rise, such passengers are more likely to become displaced. In some cases domestic-international transfers will instead use direct flights after travelling by surface modes to an alternative airport, with some new routes being stimulated at less congested airports. Most of the international-international transfers will switch to competing overseas hubs (see the box on page 37).

7.10 The regional locations of those passengers deterred from travelling to or from mainland UK are mapped in Figure 7.3. Outside of London and the South East the higher levels of lost travel are in Scotland and can be largely attributed to the high demand for interchanges at the congested London airports and the loss of several domestic flights to London.



Circles denote modelled UK airports

Figure 7.3 Difference between unconstrained and constrained passenger demand by region, central demand, 2050, passengers

7.11 Table 31 repeats the analysis in Chapter 6 (in Table 29) for the case when demand is constrained by baseline capacity and it makes the comparison with the unconstrained case.

7.12 Business passengers remain a low proportion of total travellers, but their numbers are little changed from the unconstrained case, continuing to travel mainly because of their willingness to pay higher fares. By 2050 a large number of foreign residents are lost from the constrained forecast, but these are essentially international-international transfers increasingly using overseas hubs. The bottom line of the table shows that, if this element is removed from the analysis, the foreign resident share of the total market remains broadly constant.

			2050				
	2016		unconstrained		constrained		difference
UK business	19	*7%*	38	*8%*	37	*9%*	1
UK leisure	112	*42%*	224	*45%*	199	*49%*	25
Charter (UK leisure)	13	*5%*	11	*2%*	11	*3%*	1
Foreign business	17	*6%*	31	*6%*	31	*8%*	1
Foreign leisure	51	*19%*	86	*17%*	78	*19%*	8
Domestic business	15	*6%*	24	*5%*	23	*6%*	0
Domestic leisure	16	*6%*	27	*5%*	26	*6%*	1
International-international transfer	24	*9%*	53	*11%*	5	*1%*	48
Total	267		494		410		84
Business	51	*19%*	93	*19%*	91	*22%*	2
Leisure	192	*72%*	348	*71%*	314	*77%*	35
International-international transfer	24	*9%*	53	*11%*	5	*1%*	48
Total	267		494		410		84
UK resident	175	*66%*	324	*66%*	296	*72%*	28
Foreign resident	92	*34%*	170	*34%*	114	*28%*	56
Total	267		494		410		84
UK resident	175	*72%*	324	*73%*	296	*73%*	28
Foreign resident (no II transfers)	68	*28%*	118	*27%*	109	*27%*	9
Total	243		441		405		37

2016 figures are model outputs from the (constrained) validation forecast
Domestic 'others' split equally between domestic business and leisure

Table 31 Passenger demand by journey purpose, central demand

7.13 More detailed breakdowns of these data are also included in Annex D.

Airport level constrained forecasts

7.14 The primary purpose of the passenger forecasts is to inform strategic aviation policy in the longer term. Less emphasis is placed on the role of these forecasts in informing highly detailed predictions of passengers and ATMs at each individual airport in the shorter term. Where there is a particular interest in the short term, there is close competition amongst similar airline types at neighbouring airports and where hard to model commercial factors are important, uncertainties are higher. Consideration may be given to the use of alternative forecasts (for example, sensitivity tests), particularly if they are more recent.

7.15 For both continuity with previous publications and transparency of the forecasting methodology, airport level forecasts continue to be included in this document. But it is recognised that the uncertainty reflected by the demand growth scenarios at the national level is compounded at the level of the individual airport. Where airports individually produce their own forecasts for their own uses, these may differ. Such forecasts may be produced for different purposes as well as being informed by specific commercial and local information. This information may be particularly relevant in the short-term.

7.16 Airport level forecasts are produced by the National Air Passenger Allocation Model (NAPAM). This model forecasts how passengers will be distributed to airports in a system-wide manner after taking account of both runway and terminal passenger constraints. NAPAM also forecasts how many aircraft (ATMs) will be needed to service demand and use the runway on each route at each airport.

7.17 When airports fill, the model allocates passengers to the next most suitable airport. The choice of airport will depend on journey purpose, where the passenger is starting or ending the journey, the level of congestion and the availability of a suitable service (route). This process occurs if either the runway or the terminal exceeds its capacity. In some locations, both can exceed capacity as demand rises over time. In this situation the model assumes that the runway is the harder constraint and terminal capacity can be 'flexed' beyond its capacity within limits. Some throughputs reported in the tables may therefore be slightly higher than their input capacities and it means that there may be no significant difference between low, central and high scenarios for an individual airport once it is full.[117]

Baseline airport forecasts

7.18 Table 32 shows the scenario forecasts under baseline capacity. As the airports become full, the forecast demand range narrows and the annual rates of growth reduce. By around 2040 this effect is evident even in the low growth scenario.

7.19 The range of the demand growth scenarios remains wider outside London. However airports which share some overlaps of catchment areas with the London airports (e.g. Birmingham and Bristol) experience 'spill' of passengers from London seeking alternatives to London airport and in time such airports also near or reach capacity. A full version of this table is in Table 63 in the data annexes.

	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	43	45	45	49	50	50	54	52	52	55
Heathrow	76	87	86	86	89	90	90	91	93	97
London City	4	7	6	7	7	6	6	7	6	7
Luton	15	18	18	18	18	18	18	18	18	18
Stansted	25	24	31	35	35	35	35	35	35	35
London	162	180	187	195	199	199	204	203	205	212
annual growth rate		0.7%	1.0%	1.3%	1.0%	0.6%	0.5%	0.2%	0.3%	0.4%
Birmingham	12	16	18	20	23	27	30	31	33	36
Bristol	8	8	10	10	10	10	10	10	10	10
East Midlands	5	6	6	7	8	9	10	10	10	10
Edinburgh	12	12	13	13	14	15	16	17	18	19
Glasgow	8	11	12	13	12	13	14	14	15	16
Liverpool	5	4	4	5	5	5	6	9	8	12
Manchester	27	29	31	33	37	39	41	46	50	55
Newcastle	5	4	5	5	5	5	5	6	6	6
Larger regional airport total	81	92	98	105	114	123	133	144	151	165
Other regional	23	25	28	31	32	37	43	49	53	61
Total outside London	104	117	126	136	146	160	177	193	204	226
annual growth rate		0.8%	1.4%	1.9%	2.3%	2.4%	2.7%	2.8%	2.4%	2.5%
Total	**267**	**297**	**313**	**331**	**346**	**360**	**381**	**395**	**410**	**437**
annual growth rate		0.8%	1.2%	1.5%	1.5%	1.4%	1.4%	1.3%	1.3%	1.4%

2016 is modelled

Table 32 Passenger demand by airport, baseline capacity, mppa.

[117] A difference of 1 or 2 mppa at large airports such as Heathrow or Gatwick ought not be regarded as materially different once the airport is full (i.e. subject to shadow costs).

7.20 On an annual basis Heathrow and Gatwick runways are full or very close to full in the base year. Heathrow now operates very near to its planning cap of 480,000 ATMs a year. Gatwick handled 43mppa in 2016 and is expected to handle more than that in 2017. But Gatwick, although it has no planning cap, is showing symptoms associated with over-capacity with runway slots at a premium in peak hours and the peak summer season.[118] Both Heathrow and Gatwick can continue to grow passenger numbers at a slower rate through operating with larger aircraft and higher load factors, and in uncapped Gatwick's case potentially through more low-season demand.

	2016	2030	2040	2050
Heathrow	100%	100%	100%	100%
Gatwick	100%	100%	100%	100%
Stansted	70%	88%	100%	100%
Luton	81%	100%	100%	100%
London City	80%	100%	100%	100%
London	93%	98%	100%	100%
Manchester	89%	81%	70%	91%
Birmingham	50%	66%	95%	100%
Bristol	76%	95%	100%	100%
East Midlands	79%	63%	87%	100%
Southampton	82%	99%	100%	100%

2016 is modelled

The proportions shown relate to the higher of the terminal capacity or runway capacity used

The London total proportions relate to a weighted average by number of passengers

Runway capacity is assumed to increase at Manchester; so lower utilisation figures reflect an increase in capacity rather than a decrease in demand

Table 33 Proportion of capacity used by airport, central demand, baseline capacity

7.21 Airports such as Birmingham, Bristol and Southampton are noticeably affected by spill from London during the 2030s, with the effects of spill spreading to East Midlands and Southend in the 2040s. This effect is geographically nuanced. It is not simply a matter of 'London' demand moving to (say) Birmingham. Increasing numbers of passengers who live in areas where catchments overlap (e.g. on the M4 corridor between the M25 and Bristol, or on the M40/HS2 corridor between the M25/Old Oak Common and Birmingham) consider alternatives, and airlines using airports outside London see sufficient new demand to increase frequencies and start new routes. Note that in Table 33 the proportion of capacity used at Manchester drops because of increased capacity provided after 2020.[119]

7.22 The analysis of capacity take up at the London airports and the spill to surrounding airports for the low-high set of scenario forecasts can be found in Table 64 in the data annexes. These tables show that even in the low demand growth scenario all London airports are full by 2040. Under the high demand growth scenario, all the

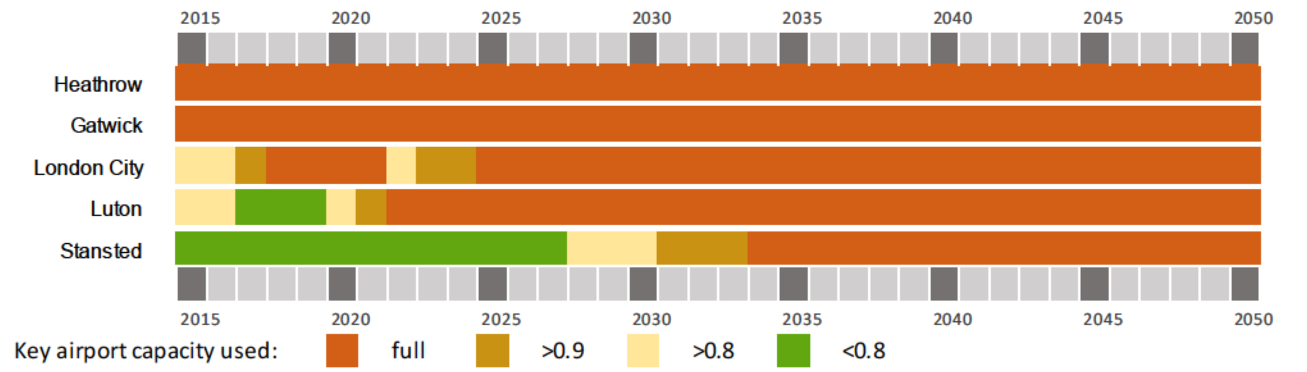
[118] The CAA have recently investigated the growing operational difficulties at Gatwick and published the results of their researches. See http://publicapps.caa.co.uk/docs/33/CAP1516%20Gatwick%20delay%20causation%20study%20-%20Final%20report%20v06_ISSUED.pdf , CAA, May 2017.

[119] A drop in the utilisation proportion also occurs at Southend. This should be treated with caution because the forecast of Southend is more uncertain than others in the model in the absence of a CAA survey being undertaken since opening.

London airports are full by 2030 and the further five airports listed in Table 33 are also all full by 2050.

7.23 The timeline shown in Figure 7.4 gives more detail of London airports filling.

Central growth scenario, no new runways, London airports, timeline of capacity usage



The proportions shown relate to the higher of the terminal capacity or runway capacity used
Luton's capacity increases in 2017
London City's capacity increases in 2022

Figure 7.4 Timeline of London airports' capacity filling, central demand, baseline capacity

7.24 The timeline shows that Luton is expected to reach its 18mppa planning cap soon after 2020, so the relief from congestion after extra capacity is provided around 2017 is short-lived. London City begins to operate close to capacity before the modelling assumes that it implements its planning consent to increase capacity to from 5mppa to 6.5mppa in 2022, providing some relief, but it fills again during the 2020s. Stansted becomes full during the 2030s.

7.25 This timeline analysis of the London airports is provided for the low and high scenario forecasts in Figure D.1 in the data annexes.

Capacity expansion forecasts

7.26 In October 2016 the Government accepted the conclusions of the Airports Commission, confirmed the need for new runway capacity in the South East and announced that its preferred scheme for adding the capacity was a Northwest Runway at Heathrow ('LHR NWR'). A draft Airports National Policy Statement was published in February 2017 and, from February to May 2017, the department consulted on this statement which included assessments of all options for additional capacity in the South East of England shortlisted by the Airports Commission.[120] The department is still considering the responses to the consultation and updating and further consulting on some elements. It is therefore still appropriate to include new forecasts for all the shortlisted capacity options.

7.27 Chapter 5, in particular Table 25, sets out the three capacity options considered. These are:

1 Gatwick Second Runway (LGW 2R)

[120] *Draft National Policy Statement: new runway capacity and infrastructure at airports in the South East of England*, DfT, February 2017.

2 Heathrow Extended Northern Runway (LHR ENR)

3 Heathrow Northwest Runway (LHR NWR)

7.28 The modelling assumes that runway capacity is the primary constraint. Therefore, for each option it is assumed that sufficient terminal capacity is provided so as not to prevent full use of the expanded runway capacity. These are the same final capacity settings as assumed by the Airports Commission.

7.29 Table 34 shows the central forecasts of millions of terminal passengers (mppa) for the baseline and three capacity expansion options. A set of forecasts for the low and high scenarios is included in Table 65 in the data annexes.

7.30 The range of the forecasts in the demand growth scenarios remain wider outside London and at the national level. However airports more accessible to the London area and which share some overlaps of catchment areas with the London airports (e.g. Birmingham and Bristol) experience 'spill' of passengers from London seeking alternatives to London and in time such airports also near or reach capacity even with the expansion in London.

	2030				2040				2050			
	Baseline	LGW 2R	LHR ENR	LHR NWR	Baseline	LGW 2R	LHR ENR	LHR NWR	Baseline	LGW 2R	LHR ENR	LHR NWR
Gatwick	45	58	45	45	50	74	49	50	52	99	51	52
Heathrow	86	85	125	132	90	89	128	135	93	90	128	136
London City	6	7	5	4	6	7	7	7	6	7	7	7
Luton	18	18	18	18	18	18	18	18	18	18	18	18
Stansted	31	25	23	22	35	32	33	32	35	35	35	35
London total	187	192	216	222	199	220	235	241	205	249	239	248
Birmingham	18	18	16	15	27	24	22	21	33	30	32	31
Bristol	10	9	9	9	10	10	10	10	10	10	10	10
East Midlands	6	6	7	7	9	8	8	8	10	10	10	10
Edinburgh	13	13	13	13	15	16	16	16	18	18	19	19
Glasgow	12	12	12	12	13	13	12	12	15	15	14	14
Liverpool	4	4	5	5	5	5	5	5	8	9	8	8
Manchester	31	31	30	29	39	38	38	37	50	44	46	45
Newcastle	5	5	5	5	5	5	5	5	6	6	6	6
Larger regional airport total	98	97	95	94	123	118	117	116	151	142	145	143
Other regional	28	27	27	27	37	32	31	31	53	42	45	44
Total outside London	126	124	122	121	160	150	147	146	204	183	190	187
Total	313	317	337	343	360	370	382	387	410	432	429	435

Table 34 Passenger demand by airport, central demand, mppa

Air Transport Movements

7.31 As described in Chapter 2 (paragraphs 2.52-2.54), air transport movements (ATMs) are generated from the forecast passenger demand for each modelled route using established relationships between seats provided, load factor, airline type, type of aircraft operated and passenger demand. The ATMs output by the model (by size) are used both in the modelling of runway constraints and in the forecasting of CO_2 emissions.

7.32 Figure 7.5 shows the future demand growth range of UK ATMs and the historic growth in UK aircraft movements from 1990. The growth range of ATM forecasts is narrower than for passengers. This is because (a) the modelling adjusts aircraft size to fit demand, so that as passenger numbers grow some of that demand will be met by bigger, rather than more, aircraft and (b) demand is constrained by capacity, limiting the number of aircraft that can be accommodated. Table 35 shows the forecasts for all the capacity options.

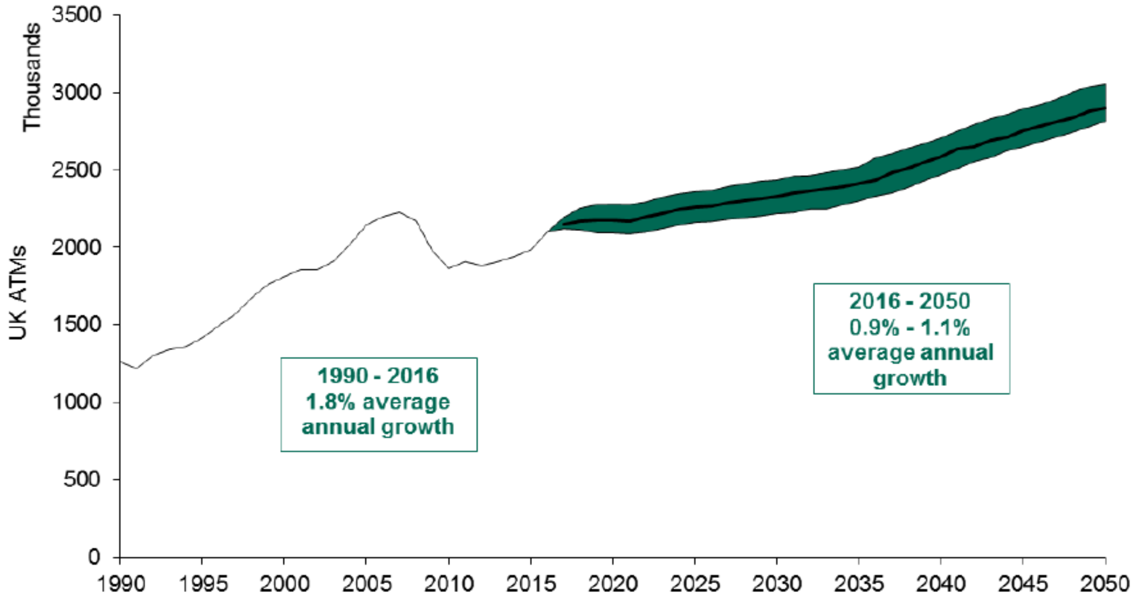


Figure 7.5 UK ATMs, historic data and forecasts

	2030				2040				2050			
	Baseline	LGW 2R	LHR ENR	LHR NWR	Baseline	LGW 2R	LHR ENR	LHR NWR	Baseline	LGW 2R	LHR ENR	LHR NWR
Gatwick	282	350	278	276	292	435	292	295	297	567	290	297
Heathrow	485	482	713	753	489	489	711	752	492	479	706	757
London City	98	99	80	73	96	98	101	102	94	100	105	103
Luton	119	118	116	115	115	114	114	113	115	113	113	112
Stansted	198	162	148	145	212	190	191	184	212	207	203	204
London total	1182	1211	1335	1363	1205	1326	1409	1446	1211	1467	1417	1472
Birmingham	135	131	120	118	195	168	158	150	206	205	208	205
Bristol	67	64	61	60	69	70	69	69	78	73	73	72
East Midlands	79	78	80	80	99	87	93	95	120	113	114	113
Edinburgh	116	119	123	122	130	135	144	147	143	148	162	160
Glasgow	94	93	90	91	96	90	87	86	103	100	95	97
Liverpool	34	34	36	36	37	37	38	39	56	58	54	55
Manchester	211	210	204	200	247	244	243	242	310	273	289	282
Newcastle	40	41	41	41	43	42	44	43	49	48	49	48
Larger regional airport total	777	771	755	747	915	873	876	871	1066	1018	1043	1032
Other regional	371	359	351	350	465	400	384	380	624	493	530	508
Total outside London	1148	1130	1106	1097	1380	1273	1260	1251	1690	1511	1573	1540
Total	2330	2341	2441	2459	2584	2599	2669	2697	2901	2978	2990	3013

Note that to allow the model to converge when constrained, ATMs at airports can exceed input capacity by up to 2.5%

Table 35 ATMs by airport, central demand, thousands

7.33 There are more ATM tables in Annex E:

- Table 66 gives the demand growth scenario ATM forecasts for 2030, 2040 and 2050 for all the modelled airports in the baseline
- Table 67 gives the demand growth scenario forecasts for each of the capacity expansion options for 2030, 2040 and 2050 for the London airports and the larger mainland UK regional airports
- Table 68 gives the demand growth scenario ATM forecasts 2016-2050 at the national level disaggregated by operator type (scheduled, low cost etc)

8. CO_2 emissions forecasts

Introduction

8.1 Chapter 3 describes the methodology and key input assumptions used for forecasting UK aviation CO_2 emissions updating the department's Fleet Mix and CO_2 models. This chapter reports the CO_2 emissions for the four capacity options under the low-high set of demand scenarios over the full model period. It considers only those emissions associated with passenger and freighter aircraft movements while on the ground and in the air. The emissions reported do not include passengers travelling to the airport or the operation of the airport itself.

8.2 No variations on aircraft fleet or carbon emissions assumptions (e.g. biofuels, operational practices, fleet retirements, fleet turnover and performance of new aircraft types) are modelled. The impact and potential to alter emissions forecasts with such variables are being separately assessed in a parallel study on carbon abatement in UK aviation.[121] The forecasts presented here will provide the baseline for the MACC work in developing strategy options for mitigating future CO_2 emissions.

National CO_2 forecasts in the future capacity options

8.3 As with the constrained ATM forecasts, from which these emissions forecasts are developed, the four capacity cases considered are:

1 Baseline (i.e. no new runways)

2 LGW Second Runway (LGW 2R)

3 LHR Extended Northern Runway (LHR ENR)

4 LHR Northwest Runway (LHR NWR)

8.4 Table 36 and Figure 8.1 show that under the central demand forecast in the baseline CO_2 emissions are forecast to be 37.0Mt by 2050. Adding a new runway adds from 2.2MtCO_2 to 2.9MtCO_2 by 2050 under the central growth scenario. With the high growth scenario the additional emissions from the baseline do not exceed 2.2MtCO_2 as in this scenario most of the additional demand accommodated is on shorter haul flights.

8.5 Future UK departing aircraft emissions will be closely related to the ATM and seat-kilometres being flown. The future size and load factors of aircraft will be a key determinant of the number of aircraft needed to meet future demand. Outputs of aircraft-kilometres, seat-kilometres and passenger-kilometres broken down into domestic, short-haul and long-haul ranges for the new forecasts are given in Table 71 to Table 74 of the data annexes.

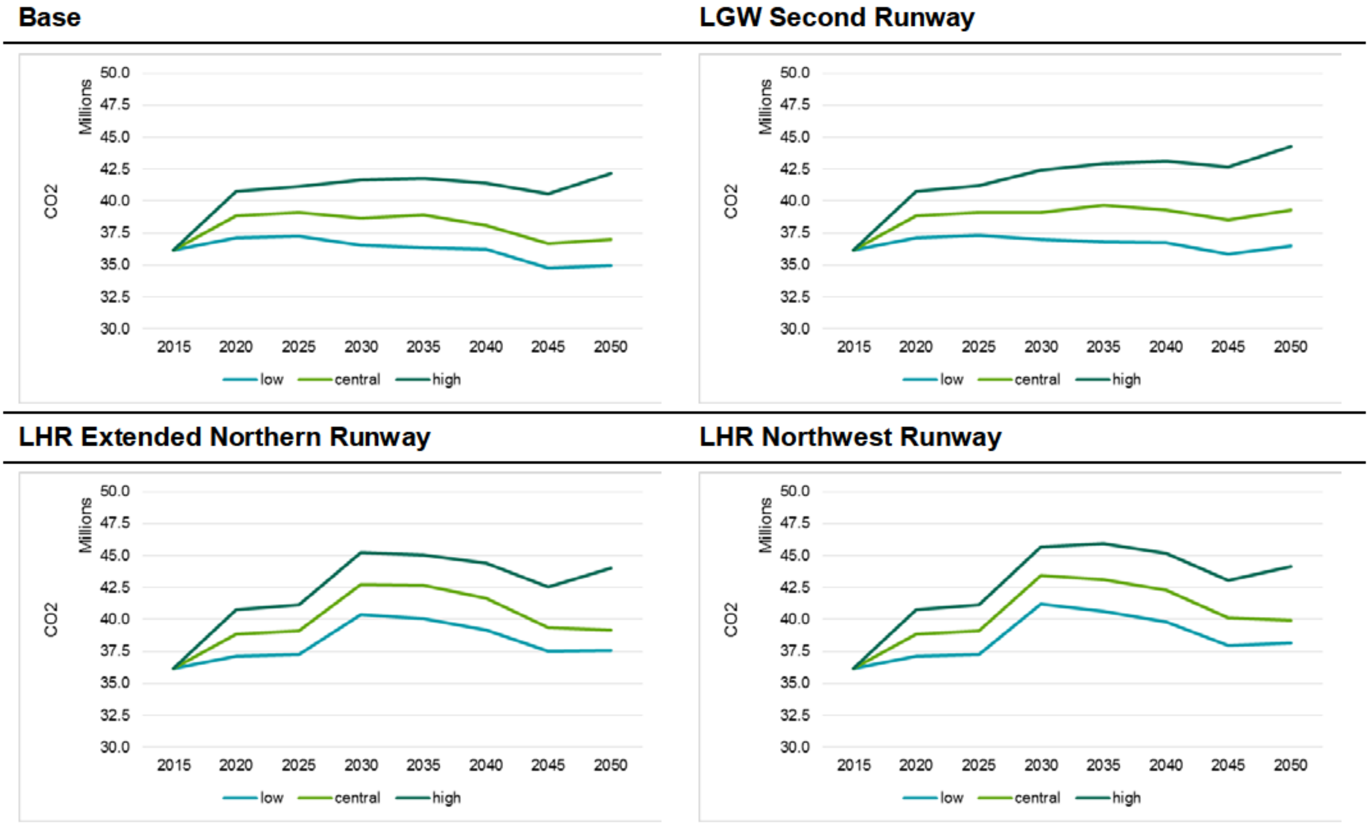
[121] *Carbon abatement in UK aviation*, 2017, Ricardo Energy & Environment.

Baseline	low	central	high	LGW Second Runway	low	central	high
2015	36.2	36.2	36.2	2015	36.2	36.2	36.2
2020	37.2	38.9	40.7	2020	37.2	38.9	40.7
2030	36.6	38.6	41.6	2030	37.0	39.1	42.4
2040	36.3	38.1	41.4	2040	36.7	39.3	43.1
2050	35.0	37.0	42.1	2050	36.5	39.3	44.3

LHR Extended Northern Runway	low	central	high	LHR Northwest Runway	low	central	high
2015	36.2	36.2	36.2	2015	36.2	36.2	36.2
2020	37.2	38.9	40.7	2020	37.2	38.9	40.7
2030	40.4	42.8	45.2	2030	41.2	43.5	45.7
2040	39.2	41.7	44.4	2040	39.8	42.3	45.1
2050	37.6	39.2	44.0	2050	38.1	39.9	44.1

$MtCO_2$, departing flights

Table 36 Total UK international and domestic departing aircraft CO_2 forecasts, $MtCO_2$



National $MtCO_2$ emissions, departing flights

Figure 8.1 Total UK international and domestic departing aircraft CO2 forecasts, $MtCO_2$

8.6 For assessing future climate change obligations it is usually necessary to consider international and domestic emissions separately. International emissions are shared between the departing and arriving country while domestic emissions are solely attributable to the UK. Table 37 isolates the domestic component of the emissions forecasts given in Table 36.

Baseline				LGW Second Runway			
	low	central	high		low	central	high
2015	1.51	1.51	1.51	2015	1.51	1.51	1.51
2020	1.53	1.56	1.62	2020	1.53	1.56	1.62
2030	1.49	1.58	1.64	2030	1.48	1.63	1.70
2040	1.51	1.61	1.69	2040	1.54	1.68	1.78
2050	1.57	1.67	1.77	2050	1.60	1.75	1.81
LHR Extended Northern Runway				**LHR Northwest Runway**			
	low	central	high		low	central	high
2015	1.51	1.51	1.51	2015	1.51	1.51	1.51
2020	1.53	1.56	1.62	2020	1.53	1.56	1.62
2030	1.69	1.77	1.85	2030	1.79	1.84	1.88
2040	1.62	1.70	1.76	2040	1.66	1.73	1.78
2050	1.62	1.75	1.82	2050	1.63	1.76	1.83
$MtCO_2$, departing domestic flights							

Table 37 Total domestic departing aircraft CO2 forecasts, MtCO2

Airport CO_2 emissions forecasts

8.7 Chapter 3 describes how CO_2 emissions are calculated route by route from the NAPAM airport level ATM outputs given at the end of the previous chapter. From this, CO_2 emissions forecasts can be presented at the airport as well as the national level.

8.8 Table 38 shows the contribution of the London airports to the national total of departing aircraft CO_2 emissions. Note that these model outputs only include emissions from departing passenger aircraft - this is the largest source of emissions associated with aviation.[122] However, the model outputs excludes:

- surface access journeys to airports
- airport ground operations
- construction activity

8.9 In the capacity constrained baseline the proportion of emissions attributable to London airports declines from 72% to 58% over the forecast period. This occurs as air traffic spills out to use regional airports and these airports develop more services.[123]

8.10 A full set of growth scenario forecasts for all the modelled airports are set out in Table 68 in the data annexes.

[122] The CO_2 forecasts in this report relate specifically to aircraft both on the ground and in the air. However, in appraising potential policy measures affecting capacity/level of activity at specific airports, elsewhere the department also considers the potential for significant impacts on CO_2 emissions from airport surface access, construction and operations. See *Updated Appraisal Report*, DfT, 2017 for more details.

[123] Note that some elements of the national carbon forecast cannot be robustly attributed to airports in the modelling. These are-emissions from ground auxiliary power units (APUs), freighters or the residual adjustment used to correct to bunker fuel outturn in the base year.

	MtCO2									
	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	4.5	3.0	3.6	4.7	2.9	3.3	4.5	2.7	3.0	3.9
Heathrow	19.5	19.6	20.0	20.7	17.8	18.2	19.0	15.0	15.9	18.0
London City	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3
Luton	1.0	1.1	1.0	1.0	1.0	0.9	0.8	0.8	0.8	0.7
Stansted	1.3	1.2	1.6	1.8	1.5	1.5	1.5	1.4	1.5	1.4
London	26.5	25.1	26.4	28.5	23.4	24.2	26.2	20.1	21.4	24.3
All regional	8.0	8.6	9.4	10.2	10.0	11.1	12.4	12.1	12.8	15.1
Ground (APUs)	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
Freighters	1.0	1.1	1.1	1.1	1.0	1.0	1.0	0.8	0.8	0.8
Residual	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total	37.3	36.6	38.6	41.6	36.3	38.1	41.4	35.0	37.0	42.1
	Share of national departing CO2									
Gatwick	12%	8%	9%	11%	8%	9%	11%	8%	8%	9%
Heathrow	52%	54%	52%	50%	49%	48%	46%	43%	43%	43%
London City	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Luton	3%	3%	3%	2%	3%	2%	2%	2%	2%	2%
Stansted	4%	3%	4%	4%	4%	4%	4%	4%	4%	3%
London	71%	69%	68%	69%	65%	64%	63%	58%	58%	58%
All regional	22%	23%	24%	25%	28%	29%	30%	34%	35%	36%
Ground (APUs)	1%	1%	1%	1%	1%	1%	1%	2%	2%	1%
Freighters	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%
Residual	4%	4%	3%	3%	4%	4%	3%	4%	4%	3%

Departing commercial passenger flights only
Ground APUs, freighters and the residual correction to baseline bunker fuel outturn cannot robustly be allocated around the airports
All figures are modelled

Table 38 CO_2 emissions from departing aircraft at London airports and nationally, baseline capacity

8.11 Table 39 reproduces the London airport CO_2 emissions analysis above for the central demand case for all the capacity expansion options. It should be emphasised that national totals are the most appropriate metric for assessing emissions because additional aircraft using the new capacity will reduce flights at other airports which had been accommodating some of the overspill traffic. These totals for the low, central and high demand growth scenario forecasts are summarised in Table 36 and Figure 8.1. Table 39 gives more information on how increased emissions at the expanded airport are partially offset by reduced emissions at other airports to give the national level forecast.

8.12 The full set of demand scenario CO_2 emissions forecasts for all the capacity options are set out in Table 70 in the data annexes.

	MtCO2											
	2030				2040				2050			
	Base	LGW 2R	LHR ENR	LHR NWR	Base	LGW 2R	LHR ENR	LHR NWR	Base	LGW 2R	LHR ENR	LHR NWR
Gatwick	3.6	4.9	3.0	2.9	3.3	5.4	2.8	2.8	3.0	6.8	2.7	2.7
Heathrow	20.0	19.6	26.3	27.3	18.2	18.2	23.4	24.3	15.9	15.7	19.3	20.3
London City	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Luton	1.0	1.1	1.1	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8
Stansted	1.6	1.3	1.1	1.1	1.5	1.4	1.4	1.4	1.5	1.6	1.4	1.5
London	26.4	27.1	31.6	32.5	24.2	26.3	28.8	29.7	21.4	25.1	24.6	25.5
All regional	9.4	9.1	8.2	8.0	11.1	10.2	10.0	9.8	12.8	11.3	11.8	11.6
Ground (APUs)	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Freighters	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	0.8	0.8	0.8	0.8
Residual	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total UK	38.6	39.1	42.8	43.5	38.1	39.3	41.7	42.3	37.0	39.3	39.2	39.9

	Share of national departing CO2											
Gatwick	9%	13%	7%	7%	9%	14%	7%	7%	8%	17%	7%	7%
Heathrow	52%	50%	61%	63%	48%	46%	56%	57%	43%	40%	49%	51%
London City	1%	1%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%
Luton	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Stansted	4%	3%	3%	3%	4%	4%	3%	3%	4%	4%	4%	4%
London	68%	69%	74%	75%	64%	67%	69%	70%	58%	64%	63%	64%
All regional	24%	23%	19%	18%	29%	26%	24%	23%	35%	29%	30%	29%
Ground (APUs)	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%	2%
Freighters	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Residual	3%	3%	3%	3%	4%	3%	3%	3%	4%	3%	3%	3%

Departing commercial passenger flights only

Ground APUs, freighters and the residual correction to baseline bunker fuel outturn cannot robustly be allocated around the airports

Table 39 CO_2 emissions from departing aircraft at the London airports and nationally, central demand case

9. Sensitivity tests

Introduction

9.1 As with any forecasting exercise, there is significant uncertainty over the path input assumptions will follow. Therefore sensitivities such assumptions have been considered for the following key variables:

- economic growth
- oil prices
- carbon prices
- market maturity assumptions

9.2 The purpose of the sensitivities is to provide transparency on the relative importance of the drivers of demand in the model. They illustrate the impact on the forecasts of varying the assumptions of these factors within reasonable bounds. The nature of each sensitivity test depends on the uncertainty surrounding the projected variable. The demand growth scenario range differs from these separate sensitivity tests in that the scenarios vary more than one input variable at once.

9.3 All these sensitivity test forecasts are built off a baseline of no new runways and the central demand case.

Economic growth

9.4 There is significant uncertainty about the future rates of economic growth, not least in the light of low productivity growth experienced in the UK over recent years. These sensitivities reflect uncertainties in relation to the direct economic growth drivers, in the UK and internationally. The following inputs are varied:

- UK GDP
- UK consumer expenditure
- GDP and trade projections of the four foreign demand forecasting world areas: Western Europe, other OECD, newly industrialising countries (NICs) and less developed countries (LDCs)

9.5 All the above are increased or decreased by 0.5 percentage points per annum to generate a range.

9.6 The different UK GDP growth assumptions, together with the resulting passenger forecast range, are summarised in Table 40. A comparison of these economic growth tests with the main low and high demand scenarios over the full forecast period is shown in Figure 9.1.

	GDP % change pa			Passengers mppa			Demand change from central	
	Low	Central	High	Low	Central	High	Low	High
2025	1.7%	2.2%	2.7%	279	293	305	-5%	4%
2030	1.6%	2.1%	2.6%	293	313	333	-6%	6%
2035	1.6%	2.1%	2.6%	307	336	363	-8%	8%
2040	1.8%	2.3%	2.8%	324	360	396	-10%	10%
2045	1.7%	2.2%	2.7%	343	386	434	-11%	12%
2050	1.6%	2.1%	2.6%	356	410	455	-13%	11%

Table 40 UK GDP assumptions and outputs of sensitivity tests, baseline capacity

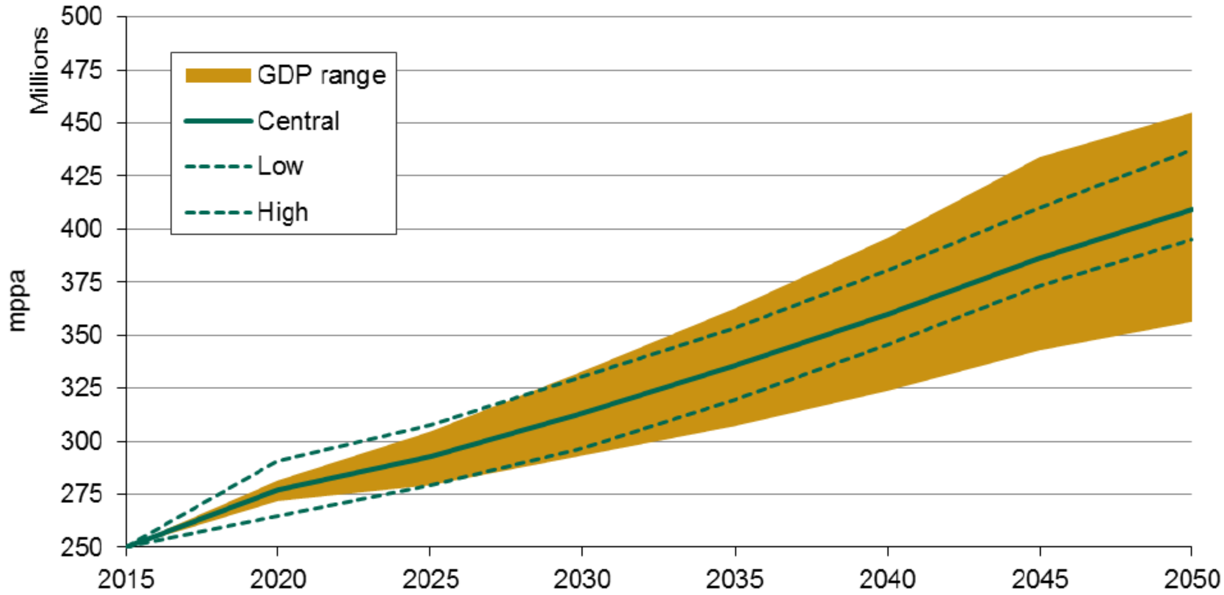


Figure 9.1 Passenger demand under economic growth sensitivity tests, baseline capacity

9.7 After the late 2020s the GDP sensitivity test range is wider than the demand scenario range. This is for two reasons. First, the scenarios vary growth in GDP but not consumer expenditure growth, which is a key driver of demand. Second, the low demand case assumes carbon prices are applied only to the departing leg of international flights, partially offsetting the reduction in demand caused by lower economic growth, narrowing the scenario range. Growth in the high economic growth sensitivity is slower at the end of the modelled period; because congestion levels in the system reduce the growth in demand that can be accommodated.

Carbon prices

9.8 The high and low carbon price assumptions published in BEIS's valuation of energy use and greenhouse gas are used to produce the high and low carbon price sensitivity tests up to 2050. In addition, a zero carbon price assumption has also been tested.

9.9 The assumptions and impacts on air passenger demand of these tests are summarised in Table 41, and a comparison against the demand scenario range is shown in Figure 9.2.

	Carbon price (£ / tCO2)			Passengers mppa				Demand change from central		
	Low	Central	High	Low	Central	High	Zero£	Low	High	Zero£
2025	£19	£41	£63	297	293	288	300	1%	-2%	3%
2030	£39	£77	£116	321	313	305	328	2%	-3%	5%
2035	£57	£113	£170	346	336	325	357	3%	-3%	6%
2040	£75	£149	£224	373	360	347	390	4%	-3%	8%
2045	£93	£185	£278	403	386	372	424	4%	-4%	10%
2050	£111	£221	£332	432	410	392	453	5%	-4%	11%

All financial figures are in 2016 prices

Table 41 Carbon price assumptions and outputs of sensitivity tests, baseline capacity

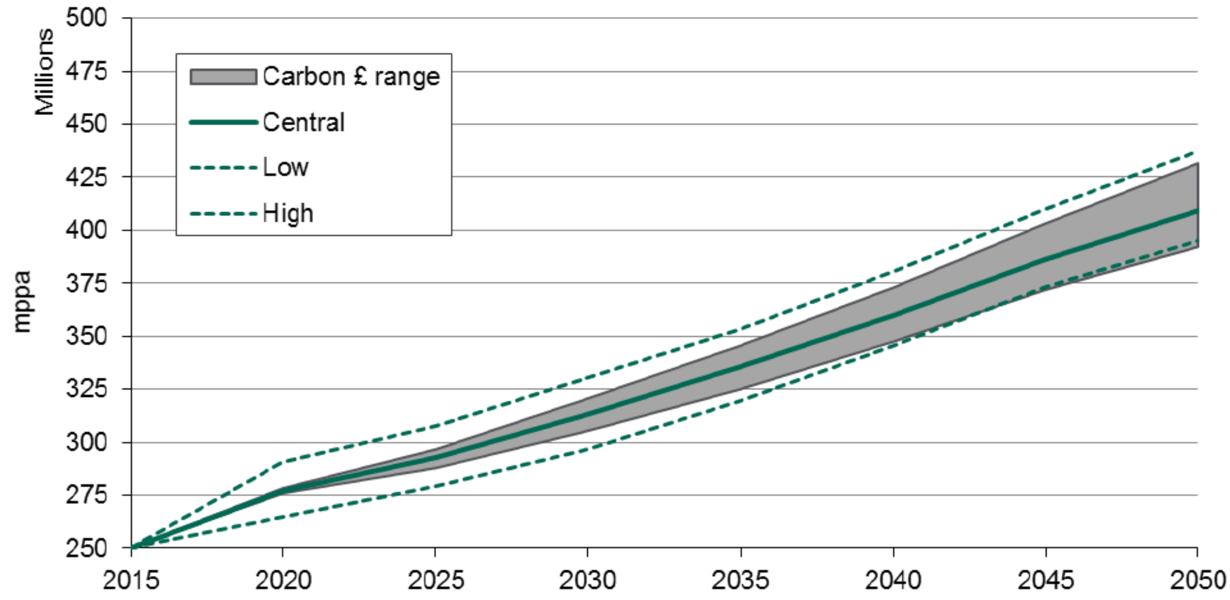


Figure 9.2 Passenger demand under carbon price sensitivity tests, baseline

9.10 The sensitivity range lies within the limits of the main forecast low-high demand scenario range for the majority of the forecast period.

Oil prices

9.11 The high and low oil price per barrel projections published by BEIS are used to produce the oil price sensitivity tests.[124] The assumptions and impacts on air passenger demand are summarised in Table 42, and a comparison with the demand scenario range is shown in Figure 9.3.

	Oil price ($ / barrel)			Passengers mppa			Demand change from central	
	Low	Central	High	Low	Central	High	Low	High
2025	$43	$67	$98	304	293	280	4%	-4%
2030	$55	$80	$120	326	313	297	4%	-5%
2035	$55	$80	$120	346	336	319	3%	-5%
2040	$55	$80	$120	371	360	345	3%	-4%
2045	$55	$80	$120	396	386	373	3%	-3%
2050	$55	$80	$120	419	410	396	2%	-3%

All financial figures are in 2016 prices

Table 42 Oil price assumptions and outputs of sensitivity tests, baseline capacity

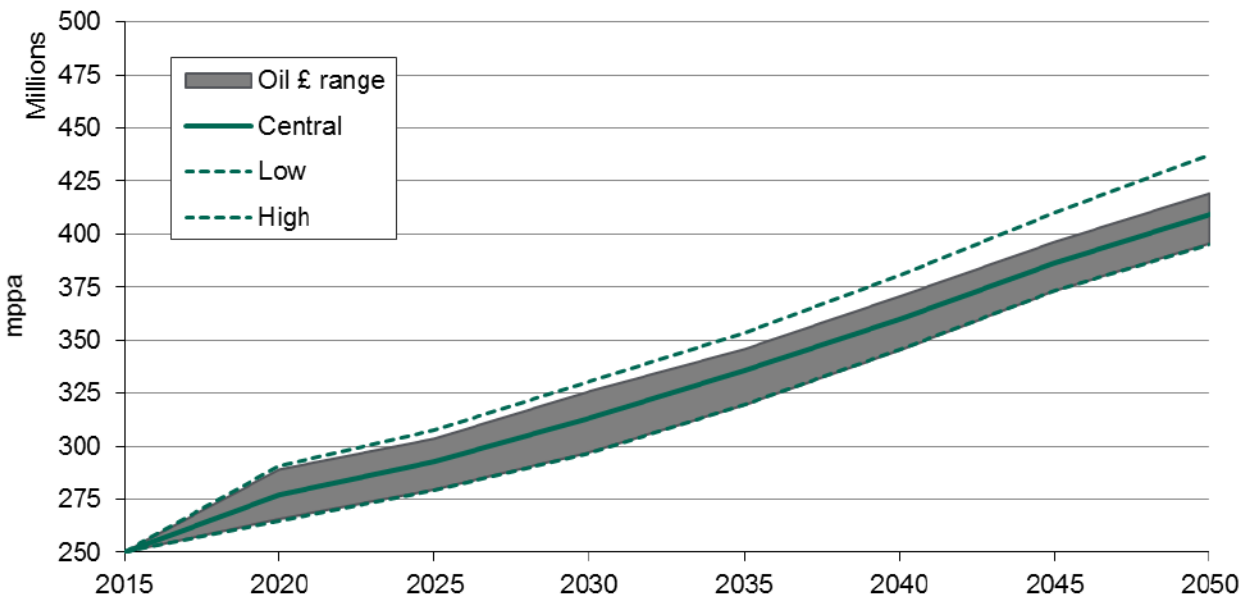


Figure 9.3 Passenger demand under oil price sensitivity test, baseline capacity

9.12 The oil price sensitivity range lies within the main forecast low - high demand scenario range.

[124] The BEIS projections show figures up to 2040. As with the central case, oil prices are assumed to be constant in real terms beyond 2040.

Fuel prices

9.13 This test combines changes to two variables to provide a demand range for use in the carbon abatement study.[125] Assumptions relating to oil and carbon prices are varied and combined to generate two fuel price sensitivities. The values are based on the oil and carbon price sensitivities described above.

9.14 The assumptions and impacts on air passenger demand are summarised in Table 43, and a comparison with the demand scenario range is shown in Figure 9.4.

	Oil price ($ / barrel)			Carbon price (£ / tCO2)			Passengers mppa			Demand change from central	
	Low	Central	High	Low	Central	High	Low	Central	High	Low	High
2025	$43	$67	$98	£19	£41	£63	309	293	277	6%	-5%
2030	$55	$80	$120	£39	£77	£116	333	313	291	6%	-7%
2035	$55	$80	$120	£57	£113	£170	359	336	311	7%	-7%
2040	$55	$80	$120	£75	£149	£224	385	360	334	7%	-7%
2045	$55	$80	$120	£93	£185	£278	416	386	359	8%	-7%
2050	$55	$80	$120	£111	£221	£332	441	410	379	8%	-7%

All financial figures are in 2016 prices

Table 43 Fuel price assumptions and outputs of sensitivity tests, baseline capacity

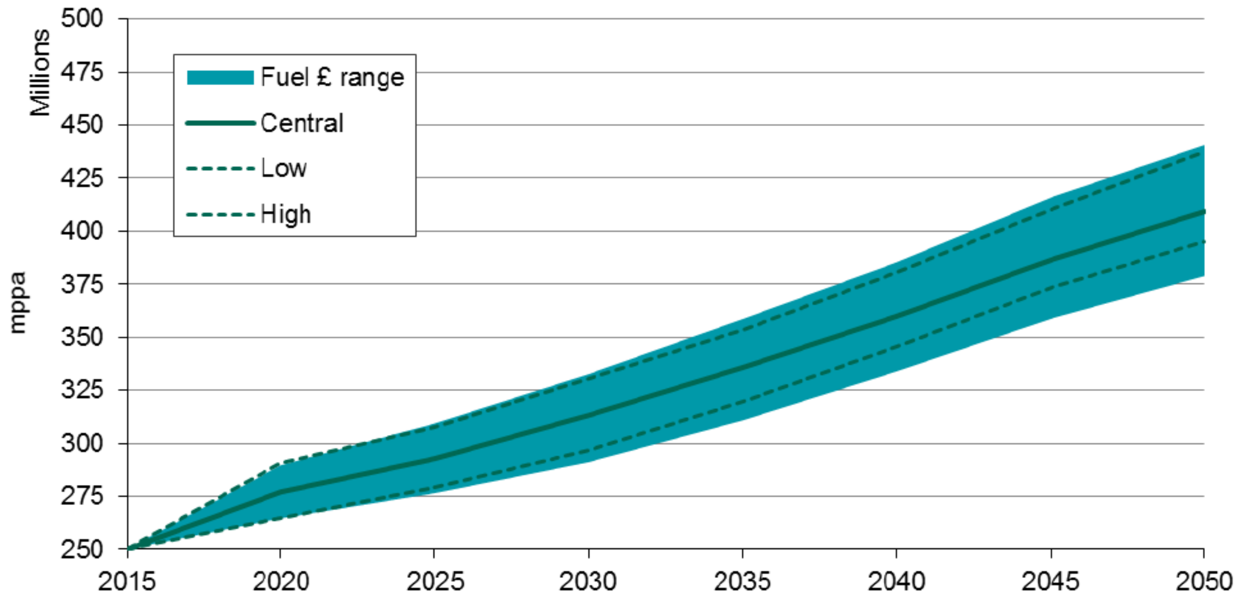


Figure 9.4 Passenger demand under fuel price sensitivity tests, baseline capacity

9.15 By combining both oil and carbon prices, the output passenger throughput lies outside the main forecast scenario demand range. This is because the main demand scenarios do not combine both drivers of fuel prices in this way.

[125] *Carbon abatement in UK aviation*, 2017, Ricardo Energy & Environment.

Market maturity

9.16 As described in Chapter 2, the term market maturity relates to the extent to which future demand is assumed to be sensitive to growing income (that is, the income elasticity of demand). Two tests are considered:

- high market maturity assumptions, resulting in low demand growth
- low market maturity assumptions, resulting in high demand growth

9.17 The tests encompass two sets of related changes. First, the starting income elasticity[126] is modified to reflect the possibility that elasticities have been under or over forecast using assumptions set out in previous analysis published by the department.[127] These assumptions increase incomes elasticities for the NIC and LDC markets in the low maturity case, and decrease income elasticities for the domestic, WE and OECD markets in the high maturity case. Second, and in addition, the rate at which income elasticities decline over time changes. In the low maturity test, elasticities fall to unity over a 70 year period (or remain the same if they started below unity), and in the high market maturity test, elasticities fall to 0.2 over 70 years.[128]

9.18 The impacts of these changes on income elasticities are set out in Table 44.

[126] This refers to the historic elasticities that were estimated to apply in 2008.
[127] *Reflecting changes in the relationship between UK air travel and its key drivers in the National Passenger Demand Model*, DfT, 2011, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4513/key-drivers-npdm.pdf.
[128] Again this approach draws on the DfT 2011 publication.

		Low market maturity		Central		High market maturity	
	Maturity starts	YED in 2016	YED in 2050	YED in 2016	YED in 2050	YED in 2016	YED in 2050
UK bus WE	2015	1.27	1.14	1.27	0.94	0.99	0.60
UK bus OECD	2015	0.97	0.97	0.97	0.79	0.96	0.59
UK bus NIC	2025	1.30	1.19	1.01	0.86	1.01	0.72
UK bus LDC	2025	1.30	1.19	1.01	0.86	1.01	0.72
UK lei WE	2015	1.33	1.17	1.32	0.97	0.99	0.60
UK lei OECD	2015	1.34	1.17	1.33	0.97	0.99	0.60
UK lei NIC	2015	1.58	1.29	1.57	1.09	1.28	0.75
UK lei LDC	2015	1.84	1.43	1.83	1.23	1.28	0.75
Foreign bus WE	2015	1.11	1.06	1.11	0.86	0.99	0.60
Foreign bus OECD	2015	0.55	0.55	0.55	0.55	0.55	0.38
Foreign bus NIC	2025	1.30	1.19	0.76	0.70	0.76	0.56
Foreign bus LDC	2025	1.30	1.19	0.69	0.66	0.69	0.51
Foreign lei WE	2015	1.20	1.10	1.20	0.90	0.99	0.60
Foreign lei OECD	2015	0.55	0.55	0.55	0.55	0.54	0.37
Foreign lei NIC	2025	1.30	1.19	0.51	0.51	0.51	0.40
Foreign lei LDC	2025	1.30	1.19	0.46	0.46	0.46	0.37
Domestic bus	2010	0.99	0.99	0.96	0.77	0.92	0.54
Domestic lei	2010	1.91	1.43	1.42	0.99	0.93	0.54
International-international transfers	2015	0.47	0.47	0.47	0.47	0.46	0.33

YED refers to income elasticity of demand
The definitions of the various markets are set out in Chapter 2

Table 44 Market maturity sensitivity test - input income elasticities (YED)

9.19 The impacts on air passenger demand are summarised in Table 45, and a comparison with the demand scenario range is shown in Figure 9.5:

	Passengers mppa			Demand change from central	
	Low	Central	High	Low	High
2025	293	293	286	0%	-2%
2030	319	313	298	2%	-5%
2035	346	336	311	3%	-7%
2040	377	360	327	5%	-9%
2045	415	386	342	8%	-11%
2050	445	410	354	9%	-14%

Table 45 Market maturity outputs of sensitivity tests, baseline capacity

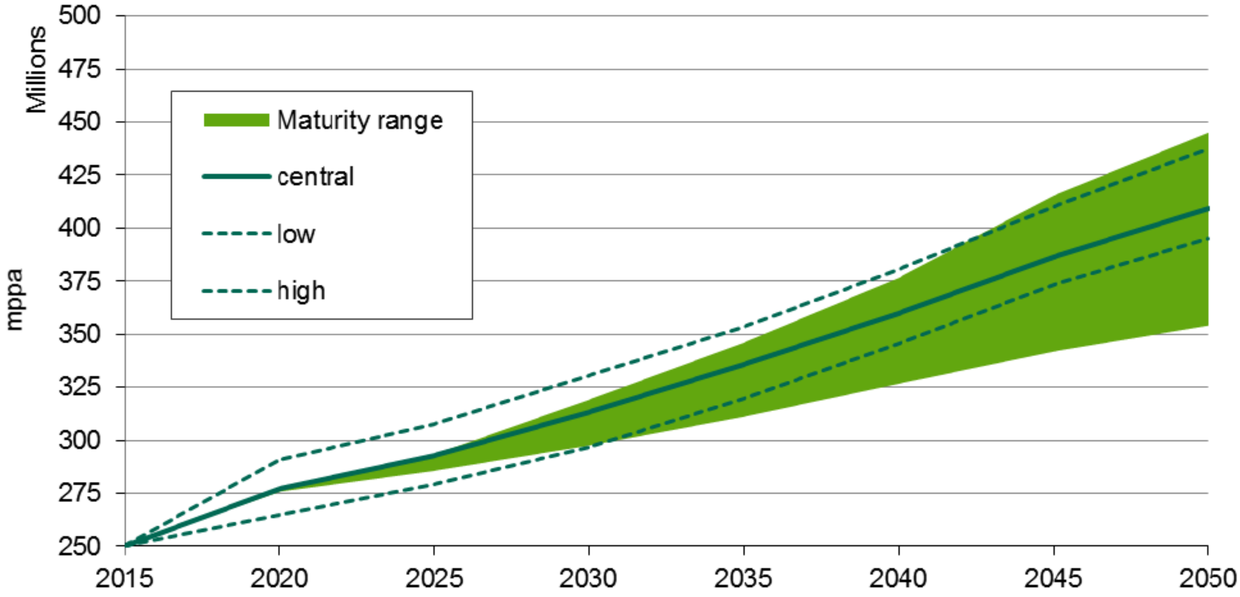


Figure 9.5 Passenger demand under market maturity sensitivity tests, baseline capacity

9.20 The sensitivity range lies within the bounds of the demand scenario range until around 2030. After this point the impacts of declining income elasticities become more significant, widening the sensitivity range. In particular, the low end of the sensitivity range lies well below the bottom of the scenario range. This is because the income elasticities for the largest markets are materially lower than in the central case, and elasticities are not varied in the scenario range. In the high end of the sensitivity range, capacity constraints partially limits the extent to which demand can be above the scenario range.

Summary of all test results

9.21 Table 46 summarises the results of each individual test described in this section and reports the change from the central demand case.

	2030		2040		2050	
mppa	passengers	change from central	passengers	change from central	passengers	change from central
central	**313**	**0**	**360**	**0**	**410**	**0**
low GDP	293	-20	324	-36	356	-53
high oil$	297	-16	345	-15	396	-14
high carbon£	305	-8	347	-12	392	-17
high oil+C£	291	-22	334	-26	379	-31
high maturity	298	-16	327	-33	354	-55
high GDP	333	20	396	36	455	45
low oil$	326	12	371	11	419	10
low carbon£	321	7	373	13	432	22
low oil+C£	333	19	385	25	441	31
low maturity	319	6	377	17	445	36
0 carbon£	328	15	390	30	453	44

Table 46 Results of all sensitivity tests, baseline capacity, mppa

Annex A: Additional validation information

A.1 The tables below show a comparison of the validation of the modelled base year against actual CAA statistical data for passengers, ATMs and passenger loads, broken down by the scheduled, low cost carrier and charter airline types used in the modelling.

Intl Scheduled	**2016**	**Passengers mppa**			**2016**	**ATMs 000s**			**2016**	**Loads (passengers / ATM)**	
mppa	Actuals	Modelled	Difference		Actuals	Modelled	Difference		Actuals	Modelled	Difference
Gatwick	**20.0**	20.4	0.4	2%	**126.4**	125.8	-0.6	0%	**159**	162	4
Heathrow	**70.9**	71.9	1.0	1%	**440.1**	440.3	0.2	0%	**161**	163	2
London City	**3.5**	3.2	-0.3	-8%	**61.3**	59.2	-2.1	-3%	**57**	54	-3
Luton	**6.4**	6.7	0.2	4%	**42.6**	45.0	2.4	6%	**151**	149	-3
Stansted	**1.2**	2.0	0.8	65%	**9.2**	17.0	7.8	84%	**131**	118	-14
London	**102.1**	104.2	2.2	2%	**679.5**	687.3	7.7	1%	**150**	152	1
Aberdeen	**0.8**	0.9	0.0	2%	**14.3**	14.3	-0.1	-1%	**58**	60	2
Belfast International	**0.1**	0.2	0.0		**.9**	.6	-0.4		**150**	276	126
Belfast City	**0.3**	0.5	0.3	107%	**2.5**	2.0	-0.4		**103**	257	155
Birmingham	**7.1**	7.8	0.6	9%	**65.4**	66.1	0.7	1%	**109**	118	9
Bournemouth	**0.0**	0.0	0.0		**.2**	.1	-0.2		**38**	49	10
Bristol	**1.1**	1.2	0.1	8%	**17.1**	14.5	-2.6	-15%	**63**	80	17
Cardiff	**0.6**	0.5	0.0	-7%	**7.8**	8.1	0.3	4%	**74**	67	-8
East Midlands	**0.5**	0.6	0.1	15%	**5.6**	8.3	2.7		**97**	74	-22
Edinburgh	**2.6**	2.6	-0.1	-2%	**23.8**	20.5	-3.3	-14%	**110**	125	15
Exeter	**0.3**	0.3	0.0	-10%	**5.6**	3.4	-2.3		**49**	74	25
Glasgow	**2.2**	2.2	0.0	2%	**15.4**	11.9	-3.5	-22%	**141**	185	44
Humberside	**0.1**	0.2	0.0		**2.3**	2.4	0.1		**54**	64	10
Inverness	**0.1**	0.1	0.0		**1.3**	1.3	0.0		**51**	57	5
Leeds-Bradford	**0.6**	0.7	0.1	22%	**6.3**	5.9	-0.4		**87**	115	28
Liverpool	**0.4**	0.5	0.1	21%	**4.8**	6.9	2.1		**91**	77	-14
Manchester	**11.9**	12.9	1.1	9%	**84.9**	91.8	6.9	8%	**140**	141	1
Newcastle	**1.4**	1.6	0.2	14%	**13.3**	12.8	-0.5	-4%	**105**	125	20
Newquay	**0.0**	0.2	0.2		**.5**	.6	0.1		**53**	340	286
Norwich	**0.2**	0.2	0.0		**3.5**	3.3	-0.2		**50**	60	11
Southend	**0.1**	0.1	0.0		**2.5**	2.6	0.1		**38**	29	-8
Southampton	**1.1**	1.2	0.1	9%	**22.4**	25.1	2.8	12%	**49**	47	-2
Durham Tees Valley	**0.1**	0.1	0.0		**2.0**	2.5	0.5		**53**	53	-1
Blackpool	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Doncaster Sheffield	**0.8**	0.8	0.0	-6%	**7.4**	6.3	-1.1		**110**	121	11
Prestwick	**0.0**	0.0	0.0		**.6**	.0	-0.6		**0**	0	0
Non-London total	**32.4**	35.2	2.8	9%	**310.3**	**311.2**	0.9	0%	**104**	113	9
Total	**134.4**	139.4	5.0	4%	**989.8**	**998.4**	8.6	1%	**136**	140	4

Passenger percentages shown only for airports with more than 200,000 passengers
ATM percentages shown only for airports with more than 7,500 ATMs

Table 47 Validation of ('full service') international scheduled services

Intl LCC	2016	Passengers mppa			2016	ATMs 000s			2016	Loads (passengers / ATM)	
mppa	Actuals	Modelled	Difference		Actuals	Modelled	Difference		Actuals	Modelled	Difference
Gatwick	**16.9**	17.0	0.1	0%	**113.4**	113.3	-0.1	0%	**149**	150	1
Heathrow	**0.0**	0.0	0.0		**.0**	.0	0.0		**304**	0	-304
London City	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Luton	**6.7**	6.4	-0.3	-5%	**45.7**	43.7	-2.0	-4%	**147**	147	0
Stansted	**20.6**	20.1	-0.5	-3%	**124.9**	125.1	0.3	0%	**165**	161	-5
London	**44.3**	43.5	-0.8	-2%	**284.0**	282.1	-1.9	-1%	**156**	154	-2
Aberdeen	**0.0**	0.0	0.0		**.0**	.0	0.0		**111**	0	-111
Belfast International	**1.1**	1.1	0.0	-2%	**7.9**	7.9	0.0	1%	**143**	140	-3
Belfast City	**0.0**	0.0	0.0		**.0**	.0	0.0		**146**	0	-146
Birmingham	**2.0**	2.2	0.2	12%	**12.0**	13.6	1.6	13%	**166**	165	-1
Bournemouth	**0.5**	0.4	-0.1	-18%	**2.8**	2.3	-0.5		**166**	168	2
Bristol	**4.6**	4.8	0.1	3%	**29.5**	31.1	1.6	5%	**157**	154	-3
Cardiff	**0.0**	0.0	0.0		**.1**	.2	0.0		**152**	147	-5
East Midlands	**3.2**	3.1	0.0	0%	**19.1**	19.0	-0.1	-1%	**165**	166	0
Edinburgh	**4.3**	4.6	0.3	8%	**27.2**	28.7	1.6	6%	**158**	161	3
Exeter	**0.0**	0.0	0.0		**.0**	.0	0.0		**2**	0	-2
Glasgow	**2.1**	2.0	-0.1	-3%	**13.0**	12.6	-0.5	-3%	**161**	161	0
Humberside	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Inverness	**0.0**	0.0	0.0		**.0**	.0	0.0		**68**	0	-68
Leeds-Bradford	**2.5**	2.3	-0.2	-8%	**15.8**	14.6	-1.2	-8%	**161**	161	0
Liverpool	**3.4**	3.4	0.0	0%	**22.6**	22.4	-0.1	-1%	**152**	154	1
Manchester	**8.6**	9.2	0.6	7%	**52.8**	55.9	3.1	6%	**164**	165	1
Newcastle	**2.1**	2.3	0.1	5%	**13.7**	14.3	0.6	4%	**156**	158	2
Newquay	**0.0**	0.0	0.0		**.2**	.0	-0.2		**153**	0	-153
Norwich	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Southend	**0.8**	0.6	-0.1	-18%	**5.7**	4.9	-0.9		**136**	131	-4
Southampton	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Durham Tees Valley	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Blackpool	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Doncaster Sheffield	**0.0**	0.0	0.0		**.0**	.0	0.0		**151**	0	-151
Prestwick	**0.7**	0.8	0.1	14%	**3.9**	4.4	0.5		**172**	171	0
Non-London total	**36.1**	37.0	0.9	3%	**226.5**	**231.8**	5.3	2%	**159**	160	0
Total	**80.4**	80.5	0.2	0%	**510.5**	**513.9**	3.5	1%	**157**	157	-1

Passenger percentages only shown for airports with more than 200,000 passengers
ATM percentages only shown for airports with more than 7,500 ATMs

Table 48 Validation of international low cost carrier (LCC) services

Intl Charter	2016	Passengers mppa			2016	ATMs 000s			2016	Loads (passengers / ATM)	
mppa	Actuals	Modelled	Difference		Actuals	Modelled	Difference		Actuals	Modelled	Difference
Gatwick	**3.3**	3.1	-0.2	-5%	**16.7**	15.8	-0.9	-5%	**197**	198	1
Heathrow	**0.1**	0.0	-0.1		**.8**	.0	-0.8		**166**	0	-166
London City	**0.0**	0.0	0.0		**.0**	.0	0.0		**76**	0	-76
Luton	**0.4**	0.4	0.0	-2%	**4.7**	3.3	-1.4		**96**	135	39
Stansted	**0.4**	0.5	0.1	13%	**2.6**	3.0	0.4		**166**	166	0
London	**4.3**	4.1	-0.2	-5%	**24.8**	22.1	-2.7		**174**	185	11
Aberdeen	**0.1**	0.1	0.0		**.8**	1.0	0.2		**129**	146	17
Belfast International	**0.3**	0.3	0.0	-3%	**1.8**	1.8	0.0		**182**	177	-5
Belfast City	**0.0**	0.0	0.0		**.1**	.1	0.1		**118**	85	-32
Birmingham	**1.3**	1.1	-0.2	-13%	**6.8**	5.8	-1.0		**191**	193	2
Bournemouth	**0.2**	0.2	0.0		**1.1**	1.0	-0.1		**172**	172	0
Bristol	**0.7**	0.5	-0.2	-25%	**4.2**	3.3	-0.9		**158**	151	-7
Cardiff	**0.5**	0.6	0.1	21%	**3.1**	3.5	0.4		**172**	182	10
East Midlands	**0.6**	0.7	0.1	11%	**3.3**	3.6	0.3		**179**	180	1
Edinburgh	**0.2**	0.3	0.1	24%	**1.7**	2.1	0.4		**146**	143	-2
Exeter	**0.2**	0.3	0.0	18%	**1.3**	1.6	0.2		**172**	174	2
Glasgow	**0.8**	0.8	0.0	-3%	**4.3**	4.1	-0.2		**187**	190	2
Humberside	**0.0**	0.0	0.0		**.2**	.1	-0.2		**105**	129	24
Inverness	**0.0**	0.0	0.0		**.0**	.0	0.0		**84**	0	-84
Leeds-Bradford	**0.1**	0.1	0.0		**.8**	.7	-0.1		**163**	167	4
Liverpool	**0.0**	0.0	0.0		**.2**	.0	-0.2		**139**	0	-139
Manchester	**2.9**	3.0	0.1	3%	**14.0**	14.5	0.6	4%	**208**	207	-2
Newcastle	**0.1**	0.1	0.0		**.7**	.7	-0.1		**196**	176	-20
Newquay	**0.0**	0.0	0.0		**.0**	.0	0.0		**87**	0	-87
Norwich	**0.1**	0.1	0.0		**.9**	.7	-0.2		**111**	166	56
Southend	**0.0**	0.0	0.0		**.0**	.0	0.0		**73**	0	-73
Southampton	**0.0**	0.0	0.0		**.1**	.3	0.2		**107**	80	-27
Durham Tees Valley	**0.0**	0.0	0.0		**.0**	.0	0.0		**107**	187	79
Blackpool	**0.0**	0.0	0.0		**.0**	.0	0.0		**0**	0	0
Doncaster Sheffield	**0.4**	0.4	0.0	-7%	**2.5**	2.2	-0.4		**170**	186	16
Prestwick	**0.0**	0.0	0.0		**.0**	.0	0.0		**51**	0	-51
Non-London total	**8.8**	8.7	0.0	-1%	**48.0**	**47.2**	-0.8		**183**	185	2
Total	**13.1**	12.8	-0.3	-2%	**72.8**	**69.3**	-3.5		**180**	185	5

Passenger percentages only shown for airports with more than 200,000 passengers
ATM percentages only shown for airports with more than 7,500 ATMs

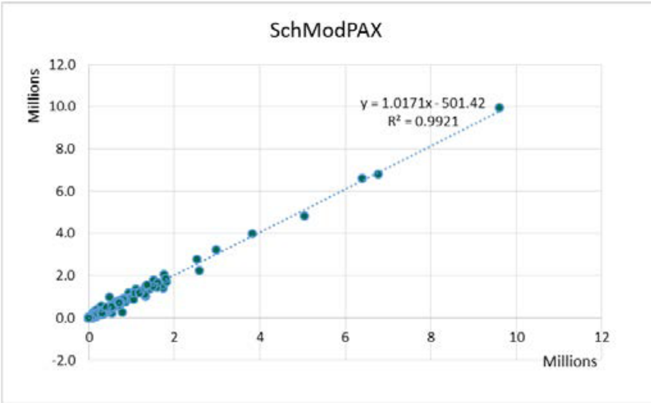
Table 49 Validation of international charter services

All Domestic	2016	Passengers mppa			2016	ATMs 000s			2016	Loads (passengers / ATM)	
mppa	Actuals	Modelled	Difference		Actuals	Modelled	Difference		Actuals	Modelled	Difference
Gatwick	**2.9**	2.9	0.0	-1%	**22.5**	22.3	-0.2	-1%	**129**	128	-1
Heathrow	**4.6**	4.1	-0.6	-12%	**37.2**	33.6	-3.6	-10%	**125**	122	-3
London City	**1.1**	0.8	-0.2	-22%	**19.2**	14.6	-4.6	-24%	**55**	57	2
Luton	**1.0**	0.9	-0.1	-6%	**8.2**	7.4	-0.7	-9%	**123**	127	4
Stansted	**2.0**	1.9	-0.1	-4%	**19.2**	16.1	-3.1	-16%	**105**	120	15
London	**11.6**	10.7	-1.0	-8%	**106.3**	94.0	-12.3		**110**	113	4
Aberdeen	**2.0**	1.7	-0.3	-16%	**63.4**	55.8	-7.6	-12%	**32**	30	-2
Belfast International	**3.5**	3.6	0.0	1%	**27.5**	27.2	-0.3	-1%	**129**	131	2
Belfast City	**2.4**	2.5	0.1	2%	**39.0**	40.5	1.5	4%	**62**	61	-1
Birmingham	**1.2**	1.1	-0.1	-6%	**20.4**	17.2	-3.2	-16%	**60**	66	7
Bournemouth	**0.0**	0.0	0.0		**.2**	.1	-0.1		**37**	39	2
Bristol	**1.2**	1.2	-0.1	-6%	**10.3**	9.3	-1.0	-10%	**119**	124	5
Cardiff	**0.2**	0.2	0.0	-15%	**5.2**	5.7	0.5		**41**	32	-9
East Midlands	**0.4**	0.3	0.0	-4%	**14.5**	6.7	-7.8	-54%	**25**	51	26
Edinburgh	**5.2**	4.7	-0.5	-9%	**62.5**	52.3	-10.1	-16%	**83**	90	7
Exeter	**0.3**	0.3	0.0	-12%	**7.9**	6.5	-1.3	-17%	**43**	46	2
Glasgow	**4.2**	3.8	-0.5	-11%	**51.2**	46.9	-4.2	-8%	**83**	80	-3
Humberside	**0.1**	0.1	0.0		**6.7**	5.8	-0.9		**8**	9	1
Inverness	**0.7**	0.7	-0.1	-9%	**9.9**	10.2	0.3	3%	**72**	64	-8
Leeds-Bradford	**0.4**	0.4	0.0	6%	**8.8**	6.5	-2.3	-27%	**44**	63	19
Liverpool	**0.9**	0.9	0.0	0%	**10.7**	10.7	0.0	0%	**81**	81	0
Manchester	**2.2**	2.1	-0.1	-5%	**32.4**	32.4	0.0	0%	**67**	64	-3
Newcastle	**1.1**	1.0	-0.1	-11%	**14.4**	11.6	-2.8	-19%	**78**	86	8
Newquay	**0.3**	0.4	0.1	20%	**6.4**	7.2	0.8		**48**	51	3
Norwich	**0.2**	0.2	0.0	-15%	**24.3**	20.0	-4.3	-18%	**9**	10	0
Southend	**0.0**	0.0	0.0		**.1**	.0	0.0		**45**	38	-7
Southampton	**0.8**	0.9	0.0	5%	**15.4**	16.7	1.3	8%	**55**	53	-2
Durham Tees Valley	**0.0**	0.0	0.0		**1.7**	.9	-0.8		**13**	17	4
Blackpool	**0.0**	0.0	0.0		**6.7**	.0	-6.7		**5**	0	-5
Doncaster Sheffield	**0.0**	0.0	0.0		**.2**	.0	-0.2		**50**	16	-34
Prestwick	**0.0**	0.0	0.0		**.0**	.0	0.0		**19**	0	-19
Non-London total	**27.6**	25.8	-1.7	-6%	**439.8**	**390.3**	-49.5	-11%	**63**	66	4
Total	**39.2**	36.5	-2.7	-7%	**546.1**	**484.3**	-61.8	-11%	**72**	75	4

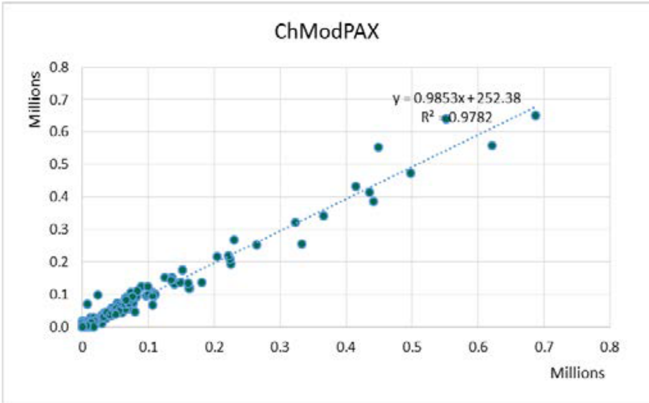
Passenger percentages only shown for airports with more than 200,000 passengers
ATM percentages only shown for airports with more than 7,500 ATMs

Table 50 Validation of all scheduled domestic services

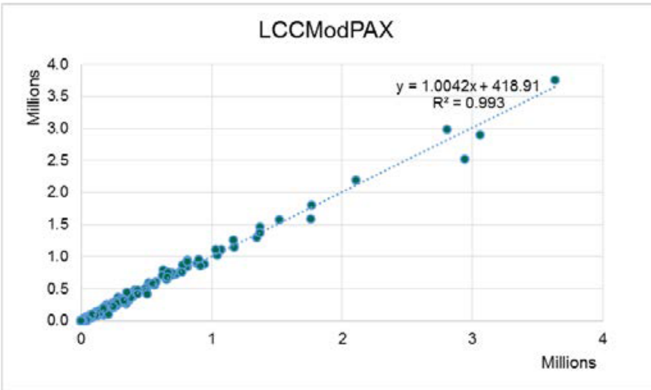
International scheduled passengers



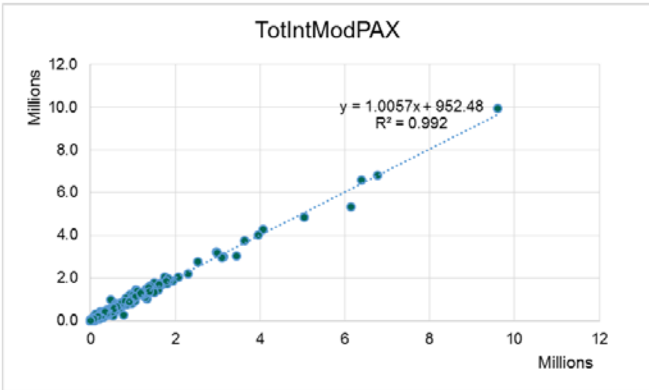
International charter passengers



International LCC passengers



Total International passengers



All Domestic passengers

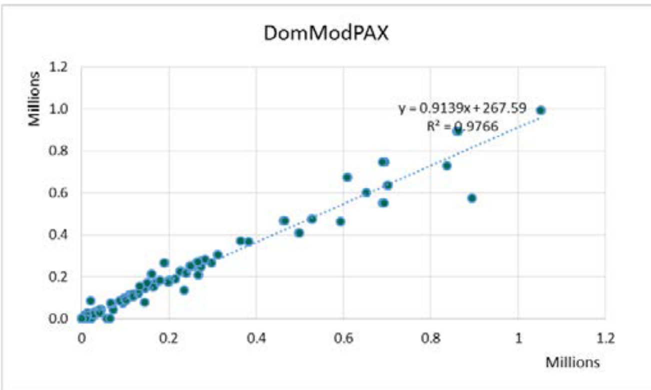
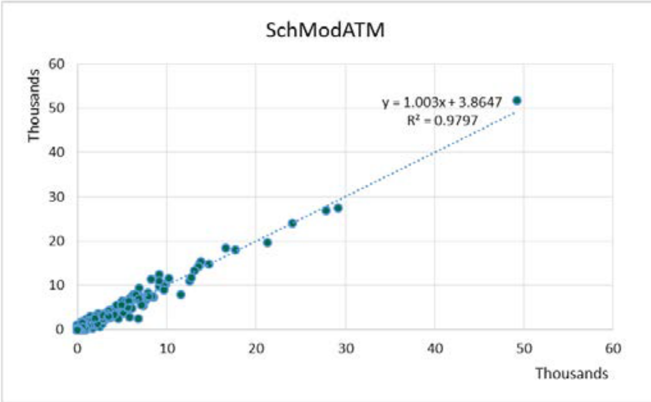
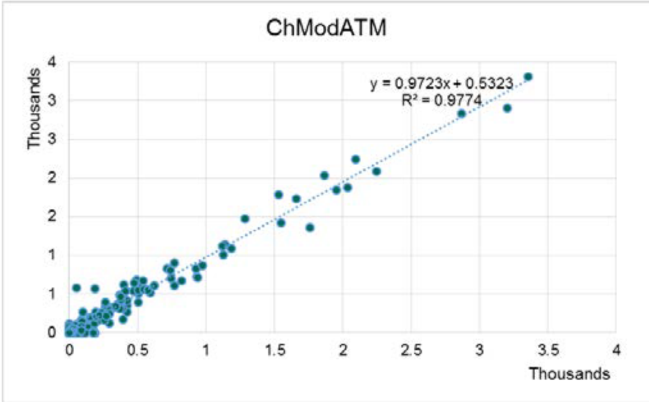


Figure A.1 Observed versus modelled route passengers by airline market type

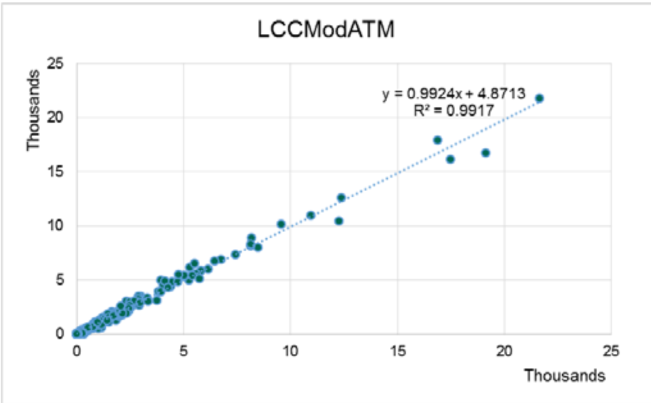
International scheduled ATMs



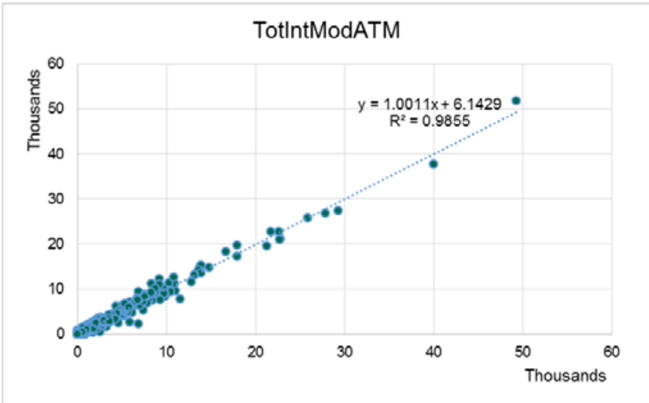
International charter ATMs



International LCC ATMs



Total International ATMs



All Domestic ATMs

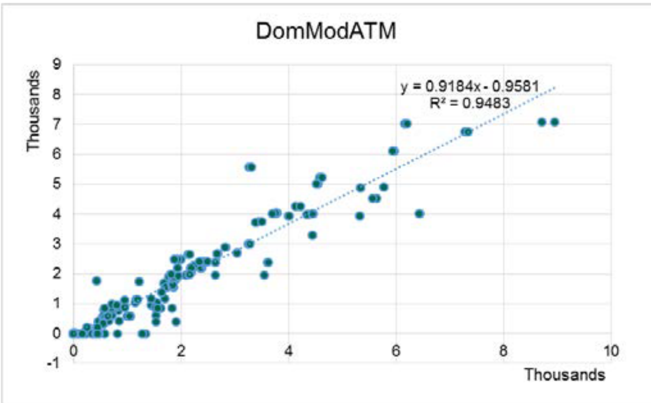


Figure A.2 Observed versus modelled route ATMs by airline market type

Annex B: NAPDM input data

	GDP growth (%)					
	UK	WE	OECD	NIC	LDC	Consumer expenditure growth (%)
2016	1.6	2.4	1.7	3.6	3.2	2.4
2017	1.8	2.2	2.3	3.5	4.3	0.4
2018	1.4	2.1	2.4	4.4	4.1	-0.2
2019	1.5	2.0	2.1	4.4	4.3	0.6
2020	1.7	2.0	1.9	4.4	4.4	0.6
2021	1.8	1.9	1.8	4.4	4.5	0.7
2022	2.0	1.8	1.8	4.4	4.5	2.0
2023	2.0	2.2	2.4	4.6	4.0	2.0
2024	2.1	2.2	2.4	4.6	3.9	2.1
2025	2.2	2.2	2.4	4.5	3.8	2.2
2026	2.2	2.2	2.4	4.4	3.7	2.2
2027	2.2	2.2	2.4	4.4	3.5	2.2
2028	2.2	2.2	2.4	4.3	3.4	2.2
2029	2.2	2.1	2.3	4.3	3.3	2.2
2030	2.1	2.1	2.3	4.2	3.2	2.1
2031	2.1	2.1	2.2	4.2	3.1	2.1
2032	2.1	2.0	2.2	4.1	2.9	2.1
2033	2.1	2.0	2.2	4.1	2.8	2.1
2034	2.1	1.9	2.1	4.0	2.7	2.1
2035	2.1	1.9	2.1	4.0	2.6	2.1
2036	2.1	1.8	2.0	3.9	2.4	2.1
2037	2.1	1.7	2.0	3.8	2.3	2.1
2038	2.2	1.7	2.0	3.7	2.2	2.2
2039	2.2	1.6	1.9	3.7	2.1	2.2
2040	2.3	1.6	1.9	3.6	2.0	2.3
2041	2.3	1.5	1.8	3.5	1.9	2.3
2042	2.2	1.5	1.8	3.4	1.8	2.2
2043	2.2	1.5	1.8	3.3	1.7	2.2
2044	2.2	1.4	1.8	3.2	1.7	2.2
2045	2.2	1.4	1.7	3.1	1.6	2.2
2046	2.1	1.4	1.7	3.0	1.6	2.1
2047	2.1	1.4	1.7	3.0	1.6	2.1
2048	2.1	1.4	1.7	2.9	1.5	2.1
2049	2.1	1.4	1.7	2.8	1.5	2.1
2050	2.1	1.4	1.7	2.8	1.5	2.1

All growth figures are annual and in real terms
As with previous forecasts, figures are adjusted to use an RPI-based deflator to be consistent with the underlying econometrics
WE, NIC, LDC and OECD are defined in Chapter 2

Table 51 Economic forecasts input data, central demand

	Exchange rate (£ / $)	Oil price ($ / barrel)	Carbon price (£ / t CO2)	One-way APD rate (average) Domestic	WE	OECD	NIC	LDC
2016	1.34	45	4	13	6	39	41	33
2017	1.25	45	4	13	6	39	41	33
2018	1.26	48	4	13	6	39	41	33
2019	1.28	50	4	13	6	39	41	33
2020	1.30	53	5	13	6	39	41	33
2021	1.31	56	12	13	6	39	41	33
2022	1.31	58	19	13	6	39	41	33
2023	1.31	61	26	13	6	39	41	33
2024	1.31	64	34	13	6	39	41	33
2025	1.31	67	41	13	6	39	41	33
2026	1.31	69	48	13	6	39	41	33
2027	1.31	72	56	13	6	39	41	33
2028	1.31	75	63	13	6	39	41	33
2029	1.31	77	70	13	6	39	41	33
2030	1.31	80	77	13	6	39	41	33
2031	1.31	80	85	13	6	39	41	33
2032	1.31	80	92	13	6	39	41	33
2033	1.31	80	99	13	6	39	41	33
2034	1.31	80	106	13	6	39	41	33
2035	1.31	80	113	13	6	39	41	33
2036	1.31	80	120	13	6	39	41	33
2037	1.31	80	128	13	6	39	41	33
2038	1.31	80	135	13	6	39	41	33
2039	1.31	80	142	13	6	39	41	33
2040	1.31	80	149	13	6	39	41	33
2041	1.31	80	156	13	6	39	41	33
2042	1.31	80	164	13	6	39	41	33
2043	1.31	80	171	13	6	39	41	33
2044	1.31	80	178	13	6	39	41	33
2045	1.31	80	185	13	6	39	41	33
2046	1.31	80	192	13	6	39	41	33
2047	1.31	80	200	13	6	39	41	33
2048	1.31	80	207	13	6	39	41	33
2049	1.31	80	214	13	6	39	41	33
2050	1.31	80	221	13	6	39	41	33

All figures are in 2016 prices

Exchange rates are used to turn dollar oil prices into pound sterling

APD is paid only when departing a UK airport. As presented here, international rates are halved to show the one-way average. Domestic return passengers pay APD twice, and so such rates are not halved

WE, NIC, LDC and OECD are defined in Chapter 2

Table 52 Oil price, carbon price and APD inputs, central demand

	Growth in airline "other" costs (%)	Fuel efficiency index (seat km / fuel usage), 2016=1 Domestic	WE	OECD	NIC	LDC
2016	-0.89	1.00	1.00	1.00	1.00	1.00
2017	-0.85	0.98	1.00	1.00	1.00	1.01
2018	-0.82	0.96	1.01	0.95	0.98	0.97
2019	-0.79	0.97	1.01	0.95	0.97	0.96
2020	-0.76	0.96	1.01	0.95	0.97	0.96
2021	-0.74	0.94	1.01	0.96	0.97	0.96
2022	-0.71	0.94	1.01	0.97	0.97	0.96
2023	-0.69	0.94	1.01	0.98	0.98	0.97
2024	-0.67	0.95	1.02	0.99	0.99	0.97
2025	-0.65	0.94	1.02	1.02	1.01	0.98
2026	-0.63	0.94	1.03	1.04	1.03	0.99
2027	-0.62	0.96	1.05	1.04	1.05	1.00
2028	-0.60	0.98	1.06	1.05	1.07	1.01
2029	-0.59	1.00	1.08	1.06	1.09	1.01
2030	-0.57	1.01	1.09	1.08	1.12	1.03
2031	0.00	1.01	1.10	1.10	1.13	1.05
2032	0.00	1.02	1.12	1.11	1.13	1.07
2033	0.00	1.01	1.13	1.12	1.13	1.08
2034	0.00	1.02	1.14	1.13	1.15	1.08
2035	0.00	1.03	1.16	1.15	1.17	1.09
2036	0.00	1.03	1.17	1.17	1.19	1.11
2037	0.00	1.04	1.17	1.19	1.23	1.13
2038	0.00	1.04	1.18	1.22	1.27	1.15
2039	0.00	1.05	1.19	1.24	1.32	1.16
2040	0.00	1.05	1.19	1.26	1.35	1.18
2041	0.00	1.08	1.21	1.32	1.49	1.22
2042	0.00	1.08	1.22	1.34	1.54	1.23
2043	0.00	1.08	1.22	1.35	1.59	1.23
2044	0.00	1.09	1.22	1.37	1.65	1.24
2045	0.00	1.09	1.22	1.38	1.70	1.25
2046	0.00	1.10	1.22	1.40	1.74	1.26
2047	0.00	1.10	1.23	1.41	1.78	1.27
2048	0.00	1.11	1.23	1.41	1.81	1.28
2049	0.00	1.13	1.24	1.42	1.83	1.28
2050	0.00	1.14	1.24	1.43	1.85	1.29

Growth figures are annual and are in real terms
WE, NIC, LDC and OECD are defined in Chapter 2

Table 53 Fuel efficiency and other airline costs, central demand

	Fuel	Carbon	Other	APD	Total fare
2016	23	1	83	11	117
2017	21	1	81	11	114
2018	22	1	81	11	114
2019	23	1	80	11	114
2020	24	1	79	11	114
2021	25	2	78	11	116
2022	25	4	77	11	117
2023	26	5	76	11	118
2024	27	6	76	11	120
2025	28	8	75	11	121
2026	28	9	75	11	123
2027	29	10	74	11	124
2028	30	11	74	11	126
2029	30	12	73	11	127
2030	31	13	73	11	128
2031	31	14	73	11	129
2032	31	15	73	11	130
2033	31	16	73	11	131
2034	30	17	73	11	132
2035	30	18	73	11	132
2036	29	19	73	11	133
2037	29	20	73	11	133
2038	29	21	73	11	133
2039	28	22	73	11	134
2040	28	22	73	11	134
2041	26	22	73	11	133
2042	26	23	73	11	133
2043	26	24	73	11	134
2044	26	25	73	11	134
2045	25	25	73	11	135
2046	25	26	73	11	135
2047	25	27	73	11	136
2048	25	28	73	11	136
2049	24	28	73	11	137
2050	24	29	73	11	137

All figures are in 2016 prices, and in £ per passenger

Fare are for a single one-way journey; they are national averages weighted by the number of passengers in each market

Table 54 Components of weighted average fare, central demand

Annex C: Unconstrained forecasts

C.1 The unconstrained forecasts represent underlying estimates of demand in the absence of airport capacity constraints.

C.2 For transparency, the numbers presented in this annex are direct unrounded model outputs, although it should be noted that this does not reflect the level of uncertainty around the forecast. While the low-high set of demand scenarios adopted represents a range of outcomes at the national level, there may be additional factors that need to be taken into account when considering the degree of uncertainty at the level of particular airports.

mppa	2016	2020 Unconstrained			2030 Unconstrained			2040 Unconstrained			2050 Unconstrained		
	central	low	central	high	low	central	high	low	central	high	low	central	high
International													
UK business													
WE	15.0	15.7	16.1	16.4	18.9	20.4	21.3	22.3	25.0	26.7	25.5	29.6	32.2
OECD	1.8	1.9	1.9	2.0	2.1	2.4	2.5	2.3	2.8	3.1	2.4	3.2	3.8
NIC	1.8	1.7	2.0	2.1	2.4	2.8	3.4	3.0	3.8	5.1	3.6	4.7	7.3
LDC	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.5	0.3	0.4	0.6
All long haul	3.7	3.8	4.1	4.3	4.7	5.5	6.3	5.6	6.9	8.7	6.3	8.4	11.6
UK business total	18.7	19.4	20.2	20.8	23.7	25.9	27.6	27.8	31.9	35.4	31.8	38.0	43.8
UK leisure													
WE	89.7	94.7	99.4	105.4	118.3	123.2	129.3	146.1	147.6	154.1	176.8	173.8	180.6
OECD	9.1	10.1	10.7	11.3	12.4	13.7	14.7	14.7	16.6	18.1	16.9	19.7	21.8
NIC	12.4	13.3	14.3	15.7	16.9	17.9	18.8	21.8	22.1	22.8	28.9	28.5	29.0
LDC	0.8	0.9	1.0	1.2	1.0	1.3	1.6	1.3	1.7	2.2	1.6	2.1	2.9
All scheduled long haul	22.3	24.2	26.0	28.1	30.4	32.9	35.1	37.7	40.4	43.0	47.4	50.4	53.7
Short haul charter	10.7	8.6	9.1	9.6	6.0	6.3	6.6	7.5	7.6	7.9	9.2	9.1	9.4
Long haul charter	2.1	1.7	1.8	2.0	1.2	1.3	1.5	1.5	1.7	1.9	1.9	2.2	2.5
All charter	12.8	10.3	10.9	11.6	7.2	7.6	8.1	9.0	9.3	9.9	11.1	11.2	11.9
All short haul	100.4	103.3	108.5	115.0	124.3	129.5	135.9	153.6	155.2	162.1	186.0	182.8	190.0
All long haul	24.4	25.9	27.8	30.1	31.6	34.2	36.6	39.3	42.1	44.9	49.3	52.5	56.2
UK leisure total	124.8	129.2	136.3	145.1	155.9	163.7	172.5	192.9	197.3	207.0	235.3	235.4	246.1
Foreign business													
WE	13.4	13.9	14.3	14.5	16.4	17.6	18.3	18.9	21.0	22.3	21.4	24.6	26.6
OECD	1.7	1.8	1.8	1.9	1.9	2.1	2.2	2.0	2.3	2.5	2.1	2.6	2.8
NIC	1.5	1.7	1.7	1.8	2.2	2.4	2.9	2.7	3.2	4.3	3.1	3.9	6.2
LDC	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
All long haul	3.3	3.6	3.7	3.8	4.2	4.6	5.2	4.9	5.7	7.0	5.4	6.7	9.2
Foreign business total	16.7	17.5	17.9	18.3	20.6	22.2	23.5	23.8	26.7	29.4	26.8	31.3	35.8
Foreign leisure													
WE	39.5	40.1	42.2	45.0	46.5	48.6	51.3	57.1	57.7	60.4	68.2	67.0	69.9
OECD	6.2	6.5	6.9	7.2	6.8	7.5	8.0	7.1	8.1	8.9	7.4	8.8	9.8
NIC	5.2	5.7	6.0	6.4	6.6	7.2	8.3	7.5	8.5	10.7	8.5	9.9	13.6
LDC	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.5	0.6	0.7	0.5	0.6	0.8
All long haul	11.8	12.7	13.3	14.1	13.9	15.2	16.9	15.2	17.2	20.3	16.4	19.3	24.2
Foreign leisure total	51.2	52.7	55.5	59.1	60.4	63.8	68.2	72.3	74.9	80.7	84.6	86.3	94.1
Intl-intl transfers	23.9	33.2	35.5	38.8	38.4	42.6	47.7	42.0	48.0	55.6	45.2	52.7	57.9
UK resident international	143.5	148.7	156.5	165.9	179.5	189.6	200.1	220.7	229.2	242.4	267.1	273.4	290.0
Foreign resident internatio	91.8	103.4	109.0	116.2	119.4	128.6	139.4	138.1	149.6	165.7	156.6	170.2	187.8
International total	**235.3**	**252.1**	**265.5**	**282.1**	**298.9**	**318.2**	**339.5**	**358.8**	**378.8**	**408.1**	**423.7**	**443.6**	**477.8**
Domestic (Internal "end-to-end")													
Domestic business	14.0	14.0	14.9	15.5	15.2	17.4	18.8	16.0	19.2	21.7	18.1	22.5	26.4
Domestic leisure	15.0	14.9	15.6	16.4	17.0	18.2	19.1	19.8	21.2	22.1	24.1	25.6	26.6
Others	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Domestic total	**31.3**	**31.2**	**32.8**	**34.2**	**34.6**	**38.0**	**40.2**	**38.2**	**42.7**	**46.2**	**44.5**	**50.4**	**55.3**
Total													
Total	**266.6**	**283.3**	**298.4**	**316.3**	**333.5**	**356.1**	**379.7**	**396.9**	**421.5**	**454.3**	**468.2**	**494.0**	**533.2**

Millions of terminal passengers per annum (mppa)

International Tables count domestic-international transfers both at the airport of origin and twice at the hub transfer airport

Scheduled figures include both 'full service' and 'low cost' airlines

The domestic section are only passengers beginning and ending a journey in the UK (excluding Channel Isles) and excludes those passengers using domestic services to connect to international flights

'Others' - normally passengers going from a UK airport in the model to a UK airport not in the model (e.g. oil rig traffic at Aberdeen)

2016 is modelled (constrained) validation version

Table 55 Passenger demand by purpose and world region, unconstrained capacity

	International - Direct								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	160.0	160.0	160.0	36.6	36.6	36.6	196.6	196.6	196.6
2020	158.9	166.1	174.9	36.3	38.6	41.3	195.2	204.8	216.2
2030	187.1	196.2	206.2	42.3	46.5	51.6	229.4	242.7	257.8
2040	231.8	238.6	250.3	52.7	58.9	68.2	284.5	297.4	318.5
2050	280.7	284.3	298.4	64.8	73.3	88.1	345.5	357.6	386.5

	via hubs								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	5.7	5.7	5.7	4.4	4.4	4.4	10.1	10.1	10.1
2020	6.5	6.9	7.4	4.7	5.0	5.4	11.2	11.9	12.8
2030	7.5	7.8	8.1	5.0	5.4	5.6	12.5	13.1	13.7
2040	7.5	7.5	7.9	4.8	5.2	5.1	12.3	12.7	12.9
2050	7.3	7.1	7.3	4.9	5.2	5.1	12.2	12.3	12.4

	International-international transfers								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	10.7	10.7	10.7	13.6	13.6	13.6	24.3	24.3	24.3
2020	15.1	16.2	17.7	18.1	19.3	21.0	33.2	35.5	38.8
2030	17.2	19.1	21.6	21.2	23.4	26.0	38.4	42.6	47.7
2040	18.6	21.3	25.3	23.4	26.7	30.3	42.0	48.0	55.6
2050	20.0	23.3	26.5	25.2	29.3	31.4	45.2	52.7	57.9

	Total international								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	176.4	176.4	176.4	54.6	54.6	54.6	231.0	231.0	231.0
2020	180.6	189.3	200.1	59.0	62.9	67.7	239.6	252.2	267.8
2030	211.8	223.1	236.0	68.5	75.3	83.2	280.3	298.4	319.2
2040	257.9	267.5	283.5	81.0	90.7	103.5	338.8	358.1	387.0
2050	308.0	314.7	332.1	94.9	107.9	124.6	402.9	422.6	456.7

2016 is modelled
'Via hubs' domestic-international transfers: outbound international leg only counted at Heathrow, Gatwick, Manchester or Stansted
'Via hubs' including UK passengers using Paris CDG, Amsterdam, Frankfurt or Dubai
International-international transfers based on destination of outbound leg

Table 56 International terminal passengers by length of haul, unconstrained capacity

	Domestic passengers											
	Internal			*international transfers*			"others"			Total		
	low	central	high	*low*	*central*	*high*	low	central	high	low	central	high
2016	29.0	29.0	29.0	*5.5*	*5.5*	*5.5*	2.3	2.3	2.3	36.8	36.8	36.8
2020	28.8	30.5	31.8	*12.5*	*13.3*	*14.3*	2.3	2.3	2.3	43.7	46.2	48.5
2030	32.2	35.6	37.9	*18.6*	*19.7*	*20.3*	2.3	2.3	2.3	53.2	57.7	60.6
2040	35.9	40.4	43.8	*19.9*	*20.7*	*21.1*	2.3	2.3	2.3	58.1	63.4	67.3
2050	42.2	48.1	53.0	*20.7*	*21.0*	*21.1*	2.3	2.3	2.3	65.3	71.4	76.4

2016 is modelled

Domestic-international transfers: inbound/outbound domestic leg at UK originating airport and domestic hub leg counted at Heathrow, Gatwick, Manchester or Stansted

Domestic-international transfers: are indicative as based on unconstrained assignment and included only to complete national terminal passenger total - see constrained tables for forecasts

'Others' - normally passengers going from a UK airport in the model to a UK airport not in the model (e.g. oil rig traffic at Aberdeen)

Table 57 Breakdown of domestic passenger demand, unconstrained capacity, mppa

mppa	2016		2030 Unconstrained						2050 Unconstrained					
NAPDM Regions	**mppa**	**share**	mppa	share	mppa	share	mppa	share	mppa	share	mppa	share	mppa	share
WE	**165.3**	**62%**	194.6	58%	204.0	57%	214.4	56%	288.0	62%	291.4	59%	305.7	57%
OECD	**17.9**	**7%**	20.5	6%	22.6	6%	24.2	6%	26.2	6%	31.2	6%	34.9	7%
NIC	**21.3**	**8%**	25.0	7%	27.0	8%	30.3	8%	40.9	9%	44.0	9%	53.8	10%
LDC	**1.8**	**1%**	1.9	1%	2.2	1%	2.6	1%	2.6	1%	3.4	1%	4.5	1%
International total	**206.3**	**77%**	241.9	73%	255.9	72%	271.5	71%	357.7	76%	369.9	75%	398.8	75%
Domestic EE	***29.0***	***11%***	*32.2*	*10%*	*35.6*	*10%*	*37.9*	*10%*	*42.2*	*9%*	*48.1*	*10%*	*53.0*	*10%*
Dom-intl transfer	***5.2***	***2%***	*18.6*	*6%*	*19.7*	*6%*	*20.3*	*5%*	*20.7*	*4%*	*21.0*	*4%*	*21.1*	*4%*
Others	***2.3***	***1%***	*2.3*	*1%*	*2.3*	*1%*	*2.3*	*1%*	*2.3*	*0%*	*2.3*	*0%*	*2.3*	*0%*
Domestic Total	***36.5***	***14%***	*53.2*	*16%*	*57.7*	*16%*	*60.6*	*16%*	*65.3*	*14%*	*71.4*	*14%*	*76.4*	*14%*
II	**23.9**	**9%**	38.4	12%	42.6	12%	47.7	13%	45.2	10%	52.7	11%	57.9	11%
Total	**266.6**	**100%**	333.5	100%	356.1	100%	379.7	100%	468.2	100%	494.0	100%	533.2	100%

Table 58 Passenger forecasts by destination, unconstrained capacity, mppa

Annex D: Constrained passenger forecasts

	International - Direct								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	159.5	159.5	159.5	36.6	36.6	36.6	196.2	196.2	196.2
2030	190.5	199.5	208.6	44.8	49.3	54.0	235.3	248.8	262.6
2040	234.0	238.9	247.4	55.7	62.1	70.6	289.7	301.0	318.0
2050	274.2	274.2	279.2	67.8	76.3	89.8	342.0	350.5	369.0

	via hubs								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	5.7	5.7	5.7	4.4	4.4	4.4	10.1	10.1	10.1
2030	2.8	3.0	3.5	2.4	2.4	3.0	5.2	5.5	6.5
2040	2.0	2.1	3.0	1.6	1.6	2.1	3.7	3.6	5.1
2050	2.0	2.3	5.3	1.3	1.5	2.1	3.4	3.8	7.4

	International-international transfers								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	10.5	10.5	10.5	13.4	13.4	13.4	23.9	23.9	23.9
2030	8.0	7.8	7.6	11.5	10.9	10.8	19.4	18.7	18.4
2040	5.2	4.5	4.3	7.9	6.9	6.3	13.1	11.4	10.7
2050	2.0	2.0	2.6	3.2	2.9	3.6	5.3	4.9	6.3

	Total international								
	Short haul mppa			Long haul mppa			Total mppa		
	low	central	high	low	central	high	low	central	high
2016	175.7	175.7	175.7	54.4	54.4	54.4	230.1	230.1	230.1
2030	201.3	210.3	219.8	58.7	62.7	67.7	260.0	273.0	287.5
2040	241.2	245.5	254.7	65.2	70.6	79.1	306.4	316.0	333.8
2050	278.2	278.5	287.2	72.3	80.7	95.5	350.6	359.2	382.7

2016 is modelled
'Via hubs' domestic-international transfers: outbound international leg only counted at Heathrow, Gatwick, Manchester or Stansted
'Via hubs' including UK passengers using Paris CDG, Amsterdam, Frankfurt or Dubai
International-international transfers based on destination of outbound leg

Table 59 International passenger demand by length of haul, baseline capacity

mppa	2016	2030 Base			2040 Base			2050 Base		
	central	low	central	high	low	central	high	low	central	high
International										
UK business										
WE	15.0	18.7	20.1	21.0	21.9	24.4	25.8	24.5	28.3	30.2
OECD	1.8	2.1	2.4	2.5	2.3	2.8	3.1	2.4	3.2	3.7
NIC	1.8	2.4	2.8	3.4	3.0	3.7	5.1	3.6	4.7	7.2
LDC	0.2	0.2	0.3	0.3	0.3	0.3	0.5	0.3	0.4	0.6
All long haul	3.7	4.7	5.4	6.3	5.5	6.9	8.7	6.3	8.4	11.6
UK business total	18.7	23.4	25.6	27.2	27.5	31.3	34.5	30.8	36.6	41.8
UK leisure										
WE	89.7	110.0	114.4	120.0	135.6	135.5	139.8	160.0	155.4	157.7
OECD	9.1	10.7	11.8	12.6	12.7	14.4	15.7	14.8	17.3	19.0
NIC	12.4	14.1	14.9	16.0	18.5	18.8	19.9	25.1	24.7	25.8
LDC	0.8	0.9	1.1	1.4	1.1	1.4	1.8	1.3	1.8	2.4
All scheduled long haul	22.3	25.7	27.8	30.0	32.3	34.6	37.4	41.2	43.7	47.2
Short haul charter	10.7	6.0	6.3	6.5	7.5	7.5	7.7	8.9	8.6	8.8
Long haul charter	2.1	1.2	1.3	1.5	1.5	1.7	1.9	1.9	2.1	2.4
All charter	12.8	7.2	7.6	8.0	9.0	9.2	9.6	10.7	10.7	11.2
All short haul	100.4	116.0	120.6	126.6	143.0	142.9	147.5	168.8	164.0	166.5
All long haul	24.4	26.8	29.1	31.4	33.8	36.3	39.3	43.1	45.9	49.6
UK leisure total	124.8	142.8	149.7	158.0	176.8	179.3	186.8	211.9	209.9	216.1
Foreign business										
WE	13.4	16.2	17.4	18.0	18.7	20.8	22.0	21.0	24.1	25.9
OECD	1.7	1.9	2.1	2.2	2.0	2.3	2.5	2.1	2.5	2.8
NIC	1.5	2.2	2.4	2.9	2.7	3.1	4.3	3.1	3.9	6.2
LDC	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
All long haul	3.3	4.2	4.6	5.2	4.8	5.6	7.0	5.4	6.6	9.2
Foreign business total	16.7	20.4	22.0	23.2	23.6	26.4	29.0	26.4	30.7	35.1
Foreign leisure										
WE	39.5	43.9	45.8	48.2	53.1	53.4	55.5	62.3	60.6	62.3
OECD	6.2	6.1	6.8	7.2	6.5	7.4	8.0	6.7	7.9	8.8
NIC	5.2	6.0	6.5	7.6	6.9	7.7	9.9	7.8	9.1	12.8
LDC	0.4	0.4	0.5	0.6	0.5	0.5	0.7	0.5	0.6	0.8
All long haul	11.8	12.5	13.7	15.4	13.8	15.6	18.6	15.0	17.6	22.4
Foreign leisure total	51.2	56.4	59.5	63.6	66.9	69.0	74.1	77.2	78.2	84.7
Intl-intl transfers	23.9	19.4	18.7	18.4	13.1	11.4	10.7	5.3	4.9	6.3
UK resident international	143.5	166.2	175.3	185.2	204.3	210.6	221.3	242.7	246.5	257.9
Foreign resident internatio	91.8	96.2	100.2	105.2	103.5	106.8	113.8	108.9	113.9	126.1
International total	**235.3**	**262.4**	**275.5**	**290.4**	**307.8**	**317.4**	**335.1**	**351.6**	**360.4**	**384.0**
Domestic (Internal "end-to-end")										
Domestic business	14.0	15.2	17.4	18.8	16.0	19.2	21.6	17.9	22.3	26.0
Domestic leisure	15.0	17.0	18.2	19.0	19.7	20.9	21.6	23.3	24.6	25.0
Others	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Domestic total	**31.3**	**34.6**	**37.9**	**40.1**	**38.0**	**42.5**	**45.5**	**43.5**	**49.2**	**53.4**
Total										
Total	**266.6**	**297.0**	**313.4**	**330.5**	**345.8**	**359.8**	**380.7**	**395.2**	**409.5**	**437.4**

Millions of terminal passengers per annum (mppa)

International figures count domestic-international transfers both at the airport of origin and twice at the hub transfer airport

Scheduled figures include both 'full service' and 'low cost' airlines

The domestic section are only passengers beginning and ending a journey in the UK (excluding Channel Isles) and excludes those passengers using domestic services to connect to international flights

'Others' - normally passengers going from a UK airport in the model to a UK airport not in the model (e.g. oil rig traffic at Aberdeen)

2016 is modelled

Table 60 Breakdown of passenger demand by purpose and world region, baseline capacity, mppa

	internal			*international transfers*			'others'			total		
	low	central	high	*low*	*central*	*high*	low	central	high	low	central	high
2016	29.0	29.0	29.0	*5.2*	*5.2*	*5.2*	2.3	2.3	2.3	36.5	36.5	36.5
2030	32.2	35.6	37.8	*2.4*	*2.5*	*2.9*	2.3	2.3	2.3	37.0	40.5	43.0
2040	35.7	40.1	43.2	*1.4*	*1.3*	*1.3*	2.3	2.3	2.3	39.4	43.8	46.9
2050	41.2	46.8	51.1	*1.0*	*1.2*	*1.3*	2.3	2.3	2.3	44.6	50.4	54.7

2016 is modelled

Domestic-international transfers: inbound/outbound domestic leg at UK originating airport and domestic hub leg counted at Heathrow, Gatwick, Manchester or Stansted

'Others' are generally flights between a modelled UK airport and a small UK destination not in the model e.g. oil rig.

Table 61 Breakdown of domestic passenger demand, baseline capacity, mppa

	2016		2030						2050					
			low		central		high		low		central		high	
	mppa	share	mppa	share	mppa	share	mppa	share	mppa	share	mppa	share	mppa	share
WE	165.3	62%	193.3	65%	202.5	65%	212.2	64%	276.2	70%	276.5	68%	284.5	65%
OECD	17.9	7%	20.4	7%	22.6	7%	24.2	7%	26.0	7%	31.0	8%	34.5	8%
NIC	21.3	8%	24.9	8%	26.9	9%	30.2	9%	40.5	10%	43.5	11%	53.1	12%
LDC	1.8	1%	1.9	1%	2.2	1%	2.6	1%	2.6	1%	3.3	1%	4.3	1%
International total	206.3	77%	240.5	81%	254.2	81%	269.1	81%	345.3	87%	354.3	87%	376.4	86%
Domestic EE	*29.0*	*11%*	*32.2*	*11%*	*35.6*	*11%*	*37.8*	*11%*	*41.2*	*10%*	*46.8*	*11%*	*51.1*	*12%*
Dom-intl transfer	*5.2*	*2%*	*2.4*	*1%*	*2.5*	*1%*	*2.9*	*1%*	*1.0*	*0%*	*1.2*	*0%*	*1.3*	*0%*
Others	*2.3*	*1%*	*2.3*	*1%*	*2.3*	*1%*	*2.3*	*1%*	*2.3*	*1%*	*2.3*	*1%*	*2.3*	*1%*
Domestic total	*36.5*	*14%*	*37.0*	*12%*	*40.5*	*13%*	*43.0*	*13%*	*44.6*	*11%*	*50.4*	*12%*	*54.7*	*13%*
II	23.9	9%	19.4	7%	18.7	6%	18.4	6%	5.3	1%	4.9	1%	6.3	1%
Total	266.6	100%	297.0	100%	313.4	100%	330.5	100%	395.2	100%	409.5	100%	437.4	100%

II - international-international transfers at a UK hub airport

Table 62 Passenger demand by destination, baseline capacity

mppa	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	43.4	45.0	45.4	48.8	50.2	49.8	53.8	52.0	52.0	54.7
Heathrow	76.0	86.6	86.2	85.9	89.4	89.6	90.5	90.9	93.4	97.2
London City	4.0	6.7	6.5	6.6	6.6	6.5	6.5	6.5	6.4	6.6
Luton	14.5	17.9	18.0	18.1	18.2	18.2	18.0	17.9	18.1	18.1
Stansted	24.5	23.6	31.0	35.4	35.2	35.4	35.3	35.2	35.5	35.0
London	162.5	179.8	187.1	194.7	199.5	199.4	204.1	202.5	205.4	211.6
Aberdeen	2.6	2.7	2.9	3.1	3.1	3.4	3.5	3.7	4.0	4.3
Belfast International	5.1	5.9	6.4	6.6	7.1	7.8	8.3	8.5	9.2	10.0
Belfast City	2.7	2.9	3.2	3.6	3.4	3.8	4.1	4.1	4.6	5.0
Birmingham	12.3	16.2	18.2	20.2	22.9	27.4	29.9	31.3	32.9	35.8
Bournemouth	0.6	0.1	0.2	1.3	0.5	0.7	4.5	4.4	4.4	4.5
Bristol	7.6	8.3	9.5	9.8	9.9	10.0	10.0	10.1	10.2	10.1
Cardiff	1.4	0.8	0.8	0.9	1.1	1.1	1.4	2.8	3.0	5.8
Durham Tees Valley	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.9
Doncaster Sheffield	1.2	0.3	0.6	1.0	0.3	0.6	0.8	0.4	0.4	1.6
East Midlands	4.8	6.4	6.3	6.9	7.9	8.7	9.9	10.2	10.0	10.0
Edinburgh	11.8	12.1	12.5	13.3	14.5	15.4	16.1	16.7	17.6	19.3
Exeter	0.8	0.6	0.7	0.7	0.8	1.0	1.0	3.4	3.1	3.6
Glasgow	8.2	11.1	12.2	12.9	12.3	13.1	14.3	14.3	15.3	16.0
Humberside	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.6	0.6
Inverness	0.7	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.1
Leeds-Bradford	3.4	6.9	7.2	7.5	8.1	8.2	7.9	8.0	7.9	8.1
Liverpool	4.8	4.2	4.2	4.5	4.8	5.0	6.0	9.3	8.4	12.4
Manchester	26.8	29.0	30.8	32.5	36.8	38.6	41.5	46.0	50.3	54.7
Newcastle	4.7	4.4	4.7	4.9	4.8	5.0	5.5	5.8	6.0	6.4
Newquay	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.4	0.5	0.5
Norwich	0.5	0.4	0.5	0.5	0.6	0.8	0.9	1.4	2.0	3.2
Prestwick	0.8	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Southampton	2.0	2.5	3.0	3.1	4.8	7.1	7.0	7.1	7.1	6.8
Southend	0.7	0.7	0.8	0.9	0.8	1.1	2.1	2.9	5.1	5.0
Non London Total	104.2	117.1	126.3	135.8	146.4	160.4	176.6	192.6	204.2	225.8
Total	266.6	297.0	313.4	330.5	345.8	359.8	380.7	395.2	409.5	437.4
Paris	65.2	72.1	76.4	85.4	83.4	89.1	109.0	95.9	106.4	118.0
Amsterdam	63.6	69.2	73.5	82.5	80.4	85.8	108.3	93.8	105.1	118.2
Frankfurt	61.3	70.9	82.2	96.3	90.1	102.8	111.2	108.2	110.0	114.2
Dubai	83.6	109.9	118.1	136.1	124.0	139.9	182.4	139.5	164.8	251.1
Overseas Hubs Total	273.8	322.0	350.2	400.3	377.8	417.6	510.9	437.4	486.3	601.5

2016 is modelled

Output terminal capacities may exceed input terminal capacity if runway is also overloaded

Table 63 Passenger demand by airport, baseline capacity, mppa

Low demand scenario

	2016	2030	2040	2050
Heathrow	100%	100%	100%	100%
Gatwick	100%	100%	100%	100%
Stansted	70%	67%	100%	100%
Luton	81%	100%	100%	100%
London City	80%	100%	100%	100%
London	93%	96%	100%	100%
Manchester	89%	76%	67%	84%
Birmingham	50%	59%	79%	100%
Bristol	76%	83%	100%	100%
East Midlands	79%	64%	79%	100%
Southampton	82%	84%	69%	100%

High demand scenario

	2016	2030	2040	2050
Heathrow	100%	100%	100%	100%
Gatwick	100%	100%	100%	100%
Stansted	70%	100%	100%	100%
Luton	81%	100%	100%	100%
London City	80%	100%	100%	100%
London	93%	100%	100%	100%
Manchester	89%	86%	75%	100%
Birmingham	50%	72%	100%	100%
Bristol	76%	100%	100%	100%
East Midlands	79%	69%	100%	100%
Southampton	82%	100%	100%	100%

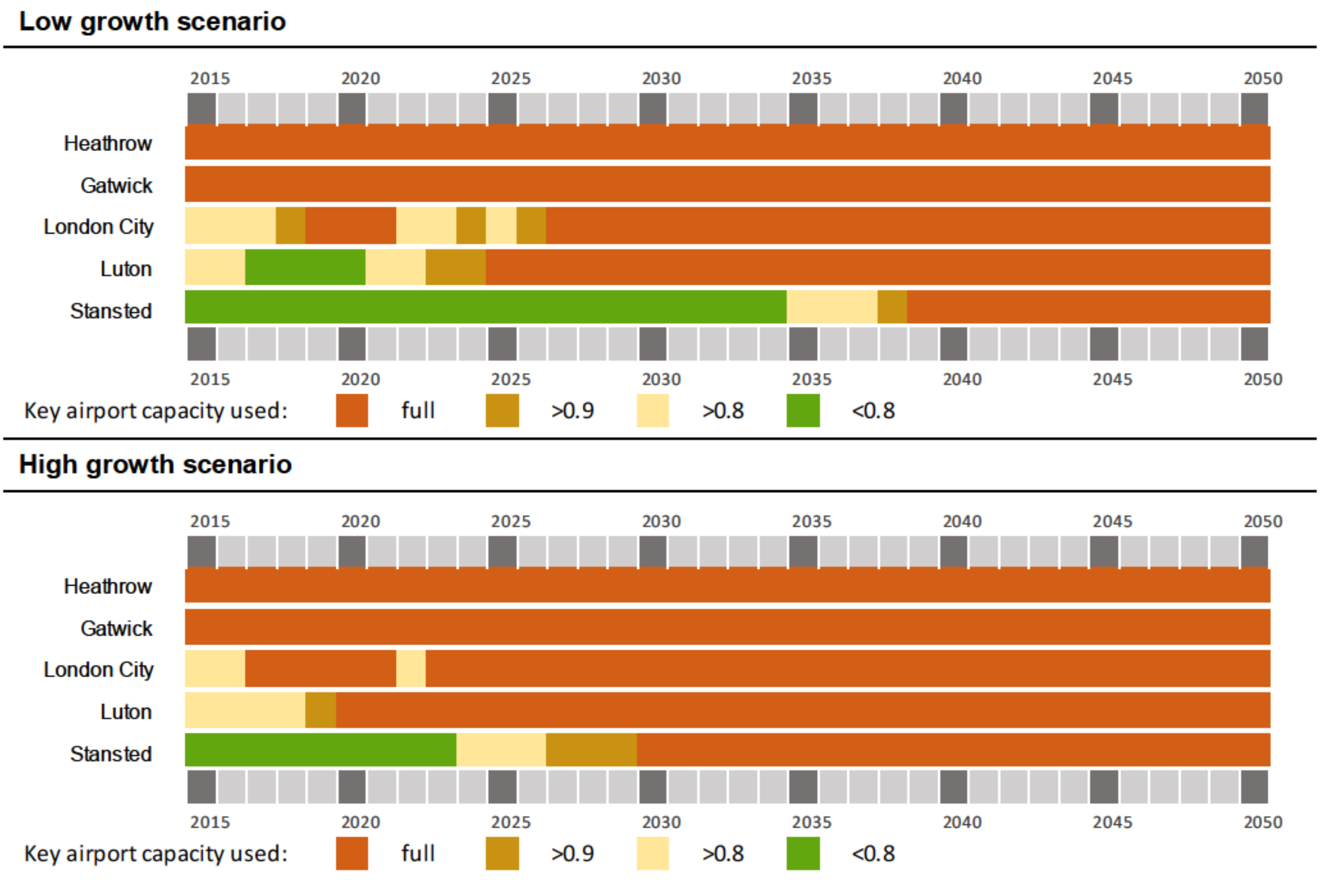
2016 is modelled

The proportions shown relate to the higher of the terminal capacity or runway capacity used

The London total proportions relate to a weighted average by number of passengers

Runway capacity is assumed to increase at Manchester; so lower utilisation figures reflect an increase in capacity rather than a decrease in demand

Table 64 Proportion of capacity used by airport, baseline capacity



The proportions shown relate to the higher of the terminal capacity or runway capacity used

Luton's capacity increases in 2017

London City's capacity increases in 2022

Figure D.1 Timeline of London airports capacity filling, baseline capacity

Gatwick Second Runway

	LGW 2R mppa									
mppa	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	43	53	58	62	69	74	86	86	99	103
Heathrow	76	86	85	87	87	89	90	91	90	94
London City	4	7	7	7	7	7	7	7	7	6
Luton	15	18	18	18	18	18	18	18	18	18
Stansted	25	21	25	29	29	32	35	35	35	35
London	162	184	192	202	209	220	235	237	249	256
annual grow th rate		0.9%	1.2%	1.6%	1.3%	1.4%	1.5%	1.2%	1.2%	0.9%
Birmingham	12	16	18	19	22	24	25	30	30	32
Bristol	8	8	9	10	10	10	10	10	10	10
East Midlands	5	6	6	7	7	8	9	9	10	10
Edinburgh	12	12	13	13	14	16	17	17	18	20
Glasgow	8	11	12	13	13	13	14	15	15	16
Liverpool	5	4	4	5	5	5	6	8	9	10
Manchester	27	29	31	32	37	38	40	43	44	51
Newcastle	5	4	5	5	5	5	5	6	6	6
Larger regional airport total	81	91	97	103	112	118	126	138	142	155
Other regional	23	25	27	30	29	32	36	38	42	51
Total outside London	104	116	124	133	141	150	162	176	183	206
annual grow th rate		0.8%	1.3%	1.8%	2.0%	1.9%	1.9%	2.2%	2.1%	2.4%
Total	**267**	**300**	**317**	**336**	**351**	**370**	**397**	**413**	**432**	**462**
annual grow th rate		0.8%	1.2%	1.7%	1.6%	1.6%	1.7%	1.6%	1.6%	1.5%

Heathrow Extended Northern Runway

	LHR ENR mppa									
mppa	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	43	43	45	45	50	49	52	52	51	55
Heathrow	76	123	125	125	125	128	128	128	128	132
London City	4	5	5	6	7	7	6	7	7	7
Luton	15	18	18	18	18	18	18	18	18	18
Stansted	25	19	23	30	28	33	35	35	35	35
London	162	207	216	224	228	235	239	240	239	246
annual grow th rate		1.7%	2.0%	2.3%	1.0%	0.8%	0.7%	0.5%	0.2%	0.3%
Birmingham	12	15	16	17	18	22	26	29	32	33
Bristol	8	8	9	10	10	10	10	10	10	10
East Midlands	5	6	7	7	9	8	9	10	10	10
Edinburgh	12	12	13	14	15	16	16	17	19	19
Glasgow	8	11	12	13	12	12	14	14	14	16
Liverpool	5	4	5	5	5	5	6	8	8	10
Manchester	27	27	30	32	35	38	40	43	46	53
Newcastle	5	5	5	5	5	5	5	6	6	6
Larger regional airport total	81	88	95	101	109	117	127	137	145	158
Other regional	23	26	27	30	29	31	37	41	45	56
Total outside London	104	113	122	131	138	147	164	178	190	214
annual grow th rate		0.6%	1.1%	1.6%	2.0%	1.9%	2.3%	2.6%	2.6%	2.7%
Total	**267**	**320**	**337**	**355**	**366**	**382**	**402**	**418**	**429**	**460**
annual grow th rate		1.3%	1.7%	2.1%	1.3%	1.3%	1.3%	1.3%	1.2%	1.4%

Heathrow Northwest Runway

	LHR NWR mppa									
mppa	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	43	42	45	45	50	50	52	51	52	52
Heathrow	76	131	132	130	132	135	136	136	136	142
London City	4	4	4	5	7	7	7	7	7	6
Luton	15	17	18	18	18	18	18	18	18	18
Stansted	25	19	22	28	27	32	35	35	35	35
London	162	214	222	227	234	241	247	246	248	253
annual grow th rate		2.0%	2.2%	2.4%	0.9%	0.8%	0.8%	0.5%	0.3%	0.2%
Birmingham	12	14	15	17	17	21	25	29	31	33
Bristol	8	8	9	10	10	10	10	10	10	10
East Midlands	5	6	7	7	9	8	8	10	10	10
Edinburgh	12	12	13	14	15	16	17	17	19	19
Glasgow	8	11	12	12	12	12	14	14	14	16
Liverpool	5	4	5	5	5	5	6	9	8	9
Manchester	27	28	29	31	35	37	40	42	45	52
Newcastle	5	5	5	5	5	5	6	6	6	6
Larger regional airport total	81	87	94	100	109	116	125	136	143	156
Other regional	23	25	27	30	29	31	36	40	44	54
Total outside London	104	113	121	130	138	146	161	176	187	211
annual grow th rate		0.6%	1.1%	1.6%	2.0%	1.9%	2.1%	2.5%	2.5%	2.7%
Total	**267**	**326**	**343**	**358**	**371**	**387**	**408**	**423**	**435**	**464**
annual grow th rate		1.5%	1.8%	2.1%	1.3%	1.2%	1.3%	1.3%	1.2%	1.3%

2016 is modelled

Output terminal capacities may exceed input terminal capacity if runway is overloaded

Table 65 Passenger demand by airport, mppa

Annex E: Constrained ATM & CO_2 forecasts

	Base ATMs									
ATM 000s	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	277	278	282	288	294	292	296	296	297	300
Heathrow	476	489	485	482	491	489	490	490	492	484
London City	74	99	98	101	97	96	100	100	94	105
Luton	101	118	119	121	116	115	115	114	115	123
Stansted	173	153	198	223	207	212	211	208	212	210
London	1101	1138	1182	1214	1205	1205	1213	1209	1211	1223
Aberdeen	73	75	78	80	80	84	87	87	92	99
Belfast International	42	43	47	48	48	52	56	57	61	68
Belfast City	43	45	47	50	48	50	52	52	55	58
Birmingham	104	122	135	148	163	195	205	207	206	204
Bournemouth	3	1	4	14	9	10	48	53	52	58
Bristol	58	59	67	69	69	69	70	73	78	75
Cardiff	17	14	14	15	17	19	23	33	38	62
Durham Tees Valley	3	1	1	1	1	1	1	5	5	7
Doncaster Sheffield	9	4	6	11	4	6	9	6	7	17
East Midlands	58	82	79	86	92	99	108	116	120	124
Edinburgh	109	114	116	121	128	130	135	146	143	152
Exeter	12	10	11	12	12	15	14	31	28	32
Glasgow	76	87	94	97	86	96	100	94	103	108
Humberside	9	9	9	9	10	9	9	10	13	15
Inverness	11	13	13	13	13	14	15	15	16	16
Leeds-Bradford	28	42	44	46	46	46	44	46	47	47
Liverpool	40	34	34	36	35	37	42	62	56	78
Manchester	196	200	211	221	237	247	262	282	310	336
Newcastle	41	38	40	42	40	43	46	47	49	52
Newquay	8	8	9	10	9	9	9	8	9	10
Norwich	24	24	24	25	27	29	31	37	45	60
Prestwick	5	1	1	1	1	1	1	1	1	1
Southampton	42	49	57	57	81	108	106	109	106	104
Southend	7	7	7	9	8	11	21	28	49	49
Non London Total	1018	1080	1148	1220	1265	1380	1494	1605	1690	1831
Total	2119	2218	2330	2434	2471	2584	2707	2814	2901	3054
Paris	458	468	490	535	537	562	662	615	659	696
Amsterdam	468	477	501	550	548	575	704	638	695	757
Frankfurt	453	485	550	629	596	668	706	701	702	707
Dubai	420	507	540	608	558	618	782	612	715	1060
Oversea Hub Total	1800	1937	2080	2323	2238	2423	2855	2565	2772	3220

2016 is modelled

Baseline: no new runways

Passenger and freighter ATMs

To allow the model to converge when constrained ATMs at airports can be allowed to exceed input capacity by up to 2.5%

Table 66 ATMs by airport, thousands, baseline capacity

Gatwick Second Runway

ATM 000s	2016	2030			2040			2050		
	LGW 2R ATMs									
	central	low	central	high	low	central	high	low	central	high
Gatwick	277	323	350	374	409	435	494	511	567	576
Heathrow	476	488	482	486	482	489	482	489	479	473
London City	74	99	99	102	99	98	104	98	100	102
Luton	101	118	118	120	115	114	114	112	113	114
Stansted	173	135	162	187	171	190	206	204	207	208
London	1101	1162	1211	1268	1275	1326	1400	1415	1467	1473
annual growth rate		0.4%	0.7%	1.0%	0.9%	0.9%	1.0%	1.0%	1.0%	0.5%
Birmingham	104	118	131	140	155	168	177	206	205	207
Bristol	58	58	64	69	72	70	71	72	73	75
East Midlands	58	81	78	84	87	87	110	106	113	121
Edinburgh	109	112	119	121	123	135	142	140	148	159
Glasgow	76	88	93	99	91	90	95	100	100	102
Liverpool	40	34	34	36	36	37	41	53	58	66
Manchester	196	199	210	220	237	244	255	268	273	311
Newcastle	41	38	41	42	40	42	46	47	48	53
Larger regional airport total	682	729	771	809	840	873	935	993	1018	1095
Other regional	336	339	359	392	373	400	444	461	493	592
Total outside London	1018	1068	1130	1201	1213	1273	1379	1455	1511	1687
Total	**2119**	**2230**	**2341**	**2469**	**2489**	**2599**	**2779**	**2870**	**2978**	**3160**
annual growth rate		0.4%	0.7%	1.1%	1.1%	1.1%	1.2%	1.4%	1.4%	1.3%

Heathrow Extended Northern Runway

ATM 000s	2016	2030			2040			2050		
	LHR ENR ATMs									
	central	low	central	high	low	central	high	low	central	high
Gatwick	277	264	278	275	294	292	300	297	290	308
Heathrow	476	705	713	710	706	711	704	715	706	695
London City	74	77	80	93	101	101	106	102	105	98
Luton	101	115	116	119	114	114	112	112	113	113
Stansted	173	125	148	188	161	191	207	200	203	211
London	1101	1285	1335	1385	1375	1409	1429	1426	1417	1426
annual growth rate		1.1%	1.4%	1.6%	0.7%	0.5%	0.3%	0.4%	0.1%	0.0%
Birmingham	104	112	120	127	132	158	181	196	208	205
Bristol	58	56	61	67	66	69	66	71	73	75
East Midlands	58	76	80	83	97	93	101	108	114	124
Edinburgh	109	114	123	126	133	144	142	154	162	158
Glasgow	76	86	90	95	86	87	97	99	95	108
Liverpool	40	34	36	36	37	38	40	55	54	69
Manchester	196	187	204	218	230	243	256	267	289	324
Newcastle	41	38	41	42	41	44	46	48	49	51
Larger regional airport total	682	705	755	794	824	876	930	997	1043	1114
Other regional	336	335	351	379	361	384	450	475	530	649
Total outside London	1018	1040	1106	1173	1184	1260	1380	1472	1573	1763
Total	**2119**	**2324**	**2441**	**2557**	**2560**	**2669**	**2809**	**2899**	**2990**	**3189**
annual growth rate		0.7%	1.0%	1.4%	1.0%	0.9%	0.9%	1.3%	1.1%	1.3%

2016 is modelled

Passenger and freighter ATMs

To allow the model to converge when constrained ATMs at airports can be allowed to exceed input capacity by up to 2.5%

Heathrow Northwest Runway

ATM 000s	2016	2030			2040			2050		
	LHR NWR ATMs									
	central	low	central	high	low	central	high	low	central	high
Gatwick	277	259	276	277	291	295	300	297	297	291
Heathrow	476	754	753	741	748	752	751	755	757	756
London City	74	72	73	86	102	102	108	101	103	105
Luton	101	111	115	116	112	113	113	111	112	110
Stansted	173	125	145	181	157	184	206	199	204	211
London	1101	1321	1363	1401	1410	1446	1479	1464	1472	1473
annual growth rate		1.3%	1.5%	1.7%	0.7%	0.6%	0.5%	0.4%	0.2%	0.0%
Birmingham	104	108	118	126	126	150	173	193	205	207
Bristol	58	56	60	66	70	69	67	70	72	72
East Midlands	58	77	80	80	100	95	96	111	113	115
Edinburgh	109	114	122	126	133	147	144	153	160	161
Glasgow	76	86	91	94	86	86	96	101	97	107
Liverpool	40	33	36	36	37	39	41	58	55	64
Manchester	196	189	200	215	229	242	255	259	282	321
Newcastle	41	39	41	42	42	43	47	47	48	50
Larger regional airport total	682	702	747	788	823	871	918	992	1032	1098
Other regional	336	332	350	381	359	380	435	462	508	625
Total outside London	1018	1034	1097	1169	1182	1251	1353	1455	1540	1722
Total	**2119**	**2356**	**2459**	**2570**	**2592**	**2697**	**2832**	**2919**	**3013**	**3195**
annual growth rate		0.8%	1.1%	1.4%	1.0%	0.9%	1.0%	1.2%	1.1%	1.2%

2016 is modelled

Passenger and freighter ATMs

To allow the model to converge when constrained ATMs at airports can be allowed to exceed input capacity by up to 2.5%

Table 67 ATMs by airport

000s ATMs	International Scheduled	International LCC	International Charter	Domestic	Freighters	Totals
			low			
2016	998	514	69	484	53	2119
2020	985	508	57	520	53	2123
2030	1070	561	40	541	53	2266
2040	1229	637	49	562	53	2531
2050	1385	765	57	626	53	2886
			central			
2016	998	514	69	484	53	2119
2020	1026	533	60	520	53	2191
2030	1124	590	42	541	53	2350
2040	1286	656	49	562	53	2607
2050	1433	771	56	626	53	2939
			high			
2016	998	514	69	484	53	2119
2020	1078	563	63	520	53	2278
2030	1177	618	44	541	53	2434
2040	1358	682	51	562	53	2707
2050	1513	805	57	626	53	3054

Only ATMs at airports in the aviation model

2016 is modelled

ATMs exclude general aviation, air taxis, positional, diplomatic, military and other miscellaneous flights

Table 68 ATMs by operator type, baseline capacity

	Base MtCO2									
	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	4.5	3.0	3.6	4.7	2.9	3.3	4.5	2.7	3.0	3.9
Heathrow	19.5	19.6	20.0	20.7	17.8	18.2	19.0	15.0	15.9	18.0
London City	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3
Luton	1.0	1.1	1.0	1.0	1.0	0.9	0.8	0.8	0.8	0.7
Stansted	1.3	1.2	1.6	1.8	1.5	1.5	1.5	1.4	1.5	1.4
London	26.5	25.1	26.4	28.5	23.4	24.2	26.2	20.1	21.4	24.3
Belfast International	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Birmingham	1.2	1.5	1.7	1.9	1.9	2.2	2.5	2.1	2.2	2.7
Bristol	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.5	0.4
East Midlands	0.3	0.5	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.7
Edinburgh	0.7	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.8
Glasgow	0.6	0.8	0.9	1.0	0.8	0.9	1.0	0.8	0.9	0.9
Liverpool	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.4
Manchester	3.2	3.3	3.7	4.0	3.8	4.2	4.7	4.3	4.8	5.9
Newcastle	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.3
Larger regional	7.2	7.7	8.4	9.1	8.8	9.7	10.7	10.0	10.6	12.5
Aberdeen	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Belfast City	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Blackpool	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bournemouth	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.3	0.3	0.3
Cardiff	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3
Coventry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Doncaster Sheffield	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Exeter	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.2
Humberside	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inverness	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leeds-Bradford	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Newquay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norwich	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3
Prestwick	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Southampton	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.3	0.3
Southend	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2
Durham Tees Valley	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Other airports	0.9	0.9	0.9	1.1	1.2	1.4	1.7	2.0	2.2	2.6
All regional	8.0	8.6	9.4	10.2	10.0	11.1	12.4	12.1	12.8	15.1
Ground (APUs)	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
Freighters	1.0	1.1	1.1	1.1	1.0	1.0	1.0	0.8	0.8	0.8
Residual	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total UK	37.3	36.6	38.6	41.6	36.3	38.1	41.4	35.0	37.0	42.1

Departing commercial passenger flights only
Ground APUs, freighters and the residual correction to baseline bunker fuel outturn cannot robustly be allocated around the airports
All figures are modelled

Table 69 Carbon emissions by airport, baseline capacity, $MtCO_2$

Gatwick Second Runway

	LGW 2R MtCO2									
	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	4.5	4.1	4.9	5.6	4.2	5.4	6.6	5.0	6.8	7.7
Heathrow	19.5	19.3	19.6	21.1	17.5	18.2	19.5	15.2	15.7	17.5
London City	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.3
Luton	1.0	1.1	1.1	1.1	1.0	0.9	0.9	0.9	0.8	0.8
Stansted	1.3	1.0	1.3	1.5	1.3	1.4	1.6	1.5	1.6	1.5
London	26.5	25.8	27.1	29.6	24.3	26.3	28.9	22.8	25.1	27.8
All regional	8.0	8.4	9.1	9.9	9.6	10.2	11.3	10.9	11.3	13.6
Ground (APUs)	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7
Freighters	1.0	1.1	1.1	1.1	1.0	1.0	1.0	0.8	0.8	0.8
Residual	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total UK	37.3	37.0	39.1	42.4	36.7	39.3	43.1	36.5	39.3	44.3

Heathrow Extended Northern Runway

	LHR ENR MtCO2									
	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	4.5	2.7	3.0	3.5	2.7	2.8	3.5	2.5	2.7	3.2
Heathrow	19.5	25.4	26.3	26.9	22.7	23.4	24.1	19.2	19.3	21.3
London City	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.2
Luton	1.0	1.1	1.1	1.0	1.0	0.9	0.9	0.9	0.8	0.8
Stansted	1.3	0.9	1.1	1.5	1.1	1.4	1.5	1.4	1.4	1.5
London	26.5	30.2	31.6	33.1	27.8	28.8	30.2	24.3	24.6	27.0
All regional	8.0	7.2	8.2	9.2	8.5	10.0	11.2	10.5	11.8	14.1
Ground (APUs)	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.7
Freighters	1.0	1.1	1.1	1.1	1.0	1.0	1.0	0.8	0.8	0.8
Residual	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total UK	37.3	40.4	42.8	45.2	39.2	41.7	44.4	37.6	39.2	44.0

Heathrow Northwest Runway

	LHR NWR MtCO2									
	2016	2030			2040			2050		
	central	low	central	high	low	central	high	low	central	high
Gatwick	4.5	2.6	2.9	3.5	2.7	2.8	3.4	2.3	2.7	2.9
Heathrow	19.5	26.4	27.3	27.5	23.6	24.3	25.2	20.1	20.3	22.2
London City	0.2	0.1	0.1	0.2	0.3	0.2	0.3	0.3	0.3	0.2
Luton	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8
Stansted	1.3	0.9	1.1	1.4	1.1	1.4	1.5	1.4	1.5	1.5
London	26.5	31.1	32.5	33.7	28.6	29.7	31.3	25.0	25.5	27.6
All regional	8.0	7.1	8.0	9.0	8.3	9.8	11.0	10.3	11.6	13.7
Ground (APUs)	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7
Freighters	1.0	1.1	1.1	1.1	1.0	1.0	1.0	0.8	0.8	0.8
Residual	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total UK	37.3	41.2	43.5	45.7	39.8	42.3	45.1	38.1	39.9	44.1

Departing commercial passenger flights only
Ground APUs, freighters and the residual correction to baseline bunker fuel outturn cannot robustly be allocated around the airports
All figures are modelled

Table 70 Carbon emissions by airport, MtCO2

Annex F: Aircraft distance flown outputs

		Baseline	LGW 2R	LHR ENR	LHR NWR
2016	Domestic	187	187	187	187
	Short-haul	1,862	1,862	1,862	1,862
	Long-haul	1,597	1,597	1,597	1,597
	Total	3,646	3,646	3,646	3,646
2030	Domestic	207	211	223	226
	Short-haul	2,126	2,129	2,183	2,191
	Long-haul	1,723	1,731	1,931	1,968
	Total	4,056	4,071	4,337	4,385
2040	Domestic	215	219	226	230
	Short-haul	2,468	2,446	2,496	2,509
	Long-haul	1,923	1,983	2,179	2,225
	Total	4,607	4,648	4,901	4,964
2050	Domestic	237	246	253	253
	Short-haul	2,847	2,884	2,894	2,907
	Long-haul	2,157	2,280	2,347	2,416
	Total	5,242	5,410	5,494	5,576

Table 71 Aircraft distance flown, million kilometres

		Baseline	LGW 2R	LHR ENR	LHR NWR
2016	Domestic	22,345	22,345	22,345	22,345
	Short-haul	338,243	338,243	338,243	338,243
	Long-haul	538,431	538,431	538,431	538,431
	Total	899,020	899,020	899,020	899,020
2030	Domestic	24,610	25,173	28,112	29,065
	Short-haul	399,976	401,490	415,875	418,742
	Long-haul	601,264	607,440	687,396	702,033
	Total	1,025,850	1,034,104	1,131,383	1,149,840
2040	Domestic	26,681	27,496	27,811	28,547
	Short-haul	473,205	478,347	489,950	493,213
	Long-haul	680,655	703,020	781,471	799,394
	Total	1,180,540	1,208,863	1,299,232	1,321,153
2050	Domestic	30,675	32,231	31,700	31,879
	Short-haul	542,162	562,318	563,500	568,465
	Long-haul	784,375	818,370	850,709	875,139
	Total	1,357,213	1,412,919	1,445,908	1,475,482

Table 72 Seat distance flown, million kilometres

		Baseline	LGW 2R	LHR ENR	LHR NWR
2016	Domestic	16,805	16,805	16,805	16,805
	Short-haul	283,216	283,216	283,216	283,216
	Long-haul	403,067	403,067	403,067	403,067
	Total	703,088	703,088	703,088	703,088
2030	Domestic	18,792	19,310	21,134	21,815
	Short-haul	340,830	342,080	350,950	352,748
	Long-haul	464,982	471,911	532,532	544,289
	Total	824,605	833,302	904,615	918,851
2040	Domestic	20,253	21,160	20,955	21,445
	Short-haul	401,837	408,874	414,946	417,393
	Long-haul	525,277	546,227	604,178	617,975
	Total	947,367	976,261	1,040,080	1,056,813
2050	Domestic	23,307	24,880	23,749	23,893
	Short-haul	460,238	480,657	476,197	480,291
	Long-haul	604,084	636,159	655,953	674,972
	Total	1,087,629	1,141,695	1,155,899	1,179,156

Table 73 Passenger distance flown, million kilometres

		Baseline	LGW 2R	LHR ENR	LHR NWR
2016	Domestic	119	119	119	119
	Short-haul	182	182	182	182
	Long-haul	337	337	337	337
	Total	247	247	247	247
2030	Domestic	119	119	126	129
	Short-haul	188	189	190	191
	Long-haul	349	351	356	357
	Total	253	254	261	262
2040	Domestic	124	126	123	124
	Short-haul	192	196	196	197
	Long-haul	354	355	359	359
	Total	256	260	265	266
2050	Domestic	129	131	125	126
	Short-haul	190	195	195	196
	Long-haul	364	359	362	362
	Total	259	261	263	265

Table 74 Passenger aircraft sizes, average seats (implied), central demand