Airports Commission

# Economy: Final Delay Impacts Assessment

July 2015

An independent commission appointed by Government

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# Glossary

| | |
|---|---|
| AC | Airports Commission |
| Arrival holding | The practice of holding a flight in an airborne stack, waiting to land |
| ATFM | Air Transport Flow Management |
| ATM | Air Transport Movement |
| Block hours | The industry standard measure of aircraft utilisation, or the time spent by the aircraft flying, taxiing or landing. |
| Carbon-capped forecast | Modelling cases where $CO_2$ emissions in 2050 are limited to 2005 levels, where curation is set to 37.5 $MTCO_2$ |
| Carbon-traded forecast | Modelling case where $CO_2$ emissions are part of an emissions trading scheme, but not limited to a target |
| $CO_2$ | Carbon dioxide |
| Constrained forecasts | Modelling case where passenger and ATM demand must fit available future capacity where no significant additional runway or terminal capacity is added |
| DECC | Department for Energy and Climate Change |
| DfT | Department for Transport |
| Do minimum | The base case with no airport capacity expansion |
| Do something | The scheme case with proposed airport capacity expansion |
| ETS | Emissions Trading Scheme |
| EU | European Union |
| Ground holding | The practice of holding a flight on the ground, ready to depart |
| Helios paper | UK CAA Runway Resilience Study |
| LGW | London Gatwick |
| LGW 2R | London Gatwick Second Runway |
| LHR | London Heathrow |
| LHR ENR | London Extended Northern Runway |
| LHR NWR | London Heathrow North West Runway |
| NPV | Net Present Value |
| PV | Present Value |
| Shadow cost | The extra cost of flying required to reduce passenger demand from above an airport's runway or terminal capacity, to a level that is back within capacity |

| | |
|---|---|
| Taxiing | The practise of holding an aircraft on ground, ready to depart |
| TEAM | Tactically Enhanced Arrival Management |
| TEE | Transport Economic Efficiency |
| UoW paper | The European airline delay cost reference values study conducted by University of Westminster |
| VoT | Value of time |
| WebTAG | Department for Transport Appraisal Guidance |

# 1. Introduction

**1.1** This report sets out the background to and explains the analysis that has been undertaken to estimate the benefits for airlines, passengers and carbon emissions due to a reduction in delays in the UK airport system under the different airport expansion options.

**1.2** This work builds upon preliminary work undertaken for the Airport Commission's *Interim Report*[1] and national consultation[2] on the shortlisted options to expand airport capacity. The previous analysis for the *Interim Report* considered the cost of delays associated with a constrained airport system compared to an unconstrained airport system. The airlines' operating and passenger experience costs were estimated to be £5.1 billion (in Present Value) between 2021 and 2080. The analysis conducted for the national consultation built upon this previous analysis to estimate the benefits of reduced delays as a result of expansion from each of the shortlisted options compared to a no expansion case. It included a larger set of airports, monetised passenger value of time, the costs of carbon emissions and a distinction between summer and winter delay costs.

**1.3** Following the consultation, the Commission has undertaken further work to refine its analysis of the benefits from reduced delays to include the full range of 32 UK airports, to more accurately capture the demand to capacity and delay time relationships, estimate benefits in carbon-capped scenario and use airport-specific passenger values of time. As previously committed, the Commission undertook further work on where UK aviation emissions are constrained to the CCC planning assumption of 37.5Mt$CO_2$. Alongside the carbon-capped work, the Commission has undertaken an assessment of the economic impacts in the case where demand is reduced to the accepted level for each scheme. This is detailed in Appendix A.

**1.4** The Commission's further quality assurance processes have also resulted in corrections being made to the *relative decline of Europe* and *low-cost is king* demand forecasts in the Gatwick Airport Second Runway option. The revised forecasts are contained in *Strategic Fit: Forecasts*. Full details of the updates to the analysis are available in Appendix D.

1 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266670/airports-commission-interim-report-appendix-3.pdf
2 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/372619/AC08_tagged.pdf

**1.5** In its *Interim Report*, the Airports Commission recognised that emerging problems for UK airports cannot be addressed without new infrastructure, but there are opportunities to make better use of existing capacity in the short-term. The suggested optimisation strategy to reduce delays had an estimated net present value (NPV) of £2.3 billion between 2014 and 2030. To this end, progress has been made by the Government and the industry on implementing some measures such as time based separation, airport collaborative decision-making and the establishment of a Senior Delivery Group. However, the Government has yet to make a decision on other key measures such as an early morning smoothing trial or further operational freedoms, reflecting the political difficulties associated with these measures to reduce delays.

**1.6** The benefits of reduced delays at airports due to expansion of runway capacity are additional to other benefits captured in the *Appraisal Framework*, in particular the direct transport economic efficiency (TEE) and frequency benefits. TEE benefits in the appraisal are the benefits to passengers from reduction in shadow costs. Frequency benefits capture the convenience benefits of increased frequency of flights which allows users to be better matched to their preferred travel times and first choice airports.

# 2. Background

## Impacts of delays

**2.1** Delays, cancellations and unreliability impose costs on passengers and airlines and also lead to additional carbon emissions. These are especially acute at airports which run under constraints to runway capacity in relation to the demand.

**2.2** Longer flight times leave passengers spending additional time in the air and cancelled flights cause frustration and wasted journeys. Uncertainty about arrival and departure times leads to inconvenience and can leave travellers stranded on the runway or in the departure lounge. This will lead to the need for increased terminal capacity and better facilities to house delayed passengers.

**2.3** Delays in the system force airlines to account for them and build in buffers in their flight schedules. This creates additional operational costs to the airlines. Under a low-cost carrier model, for example, airlines use their aircraft intensively and plan for several round-trips between destinations across a single day. Delays can severely limit this agility and in some cases lead to cancelled flights, leaving airlines and passengers with additional cost and inconvenience. For airlines operating a hub model, unreliability reduces their ability to schedule connecting flights effectively, which can lead to reduced performance of the airport as an effective hub.

**2.4** Delays also have environmental consequences, for example in terms of increased emissions as aircraft are required to spend time taxiing or in holding stacks awaiting the opportunity to land. They may also have noise impacts on local residents. At Heathrow, for instance, respite from noise is reduced when both runways have to be used for arrivals and departures in order to recover from delays. Gatwick, which uses its single runway for mixed mode operations, does not have this flexibility.

**2.5** Delays to a particular flight at a particular airport can also have knock-on impacts upstream and downstream on other airlines and airports. Furthermore, regular delays at an airport can ultimately lead to reduced number of departures and arrivals planned per hour and further decrease in capacity at the airport.

**2.6** Large number of delays on a regular basis also reduce an airport's resilience to withstand and recover from day-to-day perturbations in operations and large scale disruptions.

## Types of delays

**2.7** Delays are usually categorised into two types – strategic and tactical. Strategic delays are those accounted for in advance and often embedded within flight schedules. Tactical delays are those incurred on the day of operations and not accounted for in schedules.

**2.8** Strategic and tactical delays are not independent since recurring tactical delays will encourage airlines to build in larger buffer times in their flight schedules, as can be expected in a capacity constrained airport with little resilience and spare capacity to absorb unexpected delays.

## Managing delays

**2.9** The runway represents a pinch point in the air traffic network and where demand is approaching capacity, queues can build up.

**2.10** Airports optimise existing capacity using several capacity management techniques. Some common measures are included in **Figure 1** below:

**Figure 1: Common measures of capacity management**


**2.11** Arrival stacking is the practise of managing arrival queues by creating airborne holding stacks. They are used to moderate the demand for the runway, to allow air traffic controllers to sequence aircraft to optimise the throughput of the runway.

**2.12** Tactically enhanced arrivals management, or TEAM, is a temporary measure applied to boost arrivals capacity by allowing a proportion of the arriving aircraft to use the departure runway.

**2.13** The departure flow is moderated similarly by managing the queue to optimise the throughput of the departure runway. Departures are sequenced by managing the time that the aircraft is pushed back (ground holding) and by managing its passage from its stand to the runway after it has pushed back (taxiing) to provide the optimum sequence of aircraft at the departure runway.

**2.14** Air Traffic Flow Management (ATFM) is the practice whereby aircraft that plan to arrive during the period of congestion are held upstream on the ground at their departure airports until the downstream capacity constraint is alleviated. The ATFM system is centrally managed by the Eurocontrol Central Flow Management Unit and is usually restricted to departures from Europe. This regulation imposes an ATFM delay on the affected aircraft which is the difference between the scheduled take-off time as per the aircraft's flight plan and the calculated take-off time.

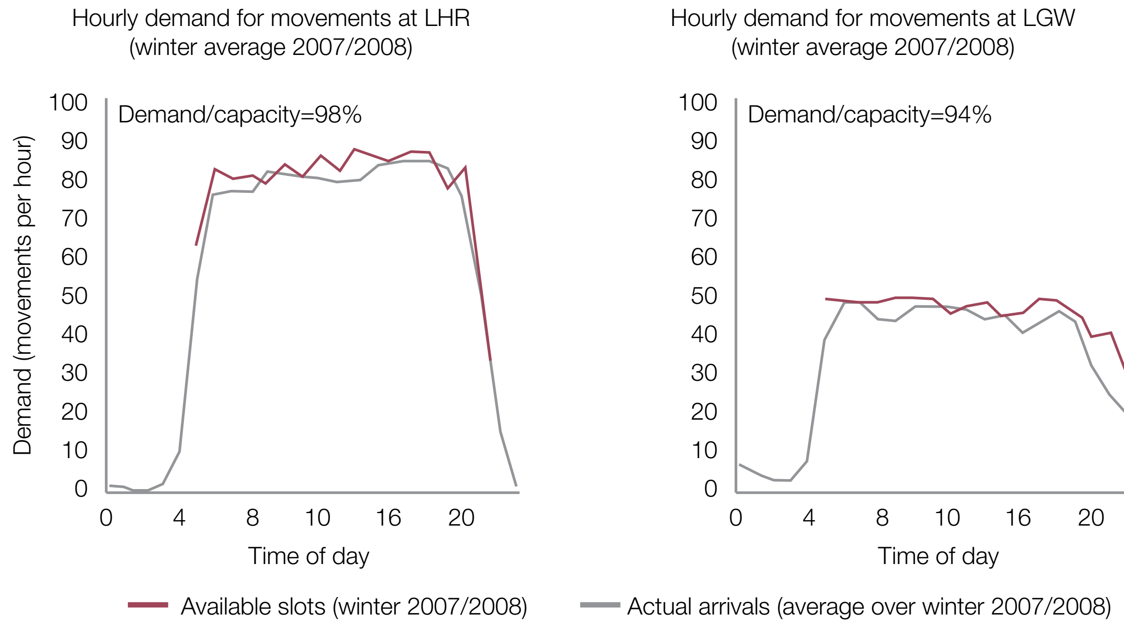
## Heathrow and Gatwick performance

**2.15** Heathrow is one of the world's biggest international airports while Gatwick is cited as the busiest single runway airport in the world. **Figures 2** and **3** below show the capacity utilisation at Heathrow and Gatwick over the summer and winter seasons in 2007/08.

**2.16** Heathrow had a demand to capacity ratio of 98% in the summer months and 97% in the winter months. Over the summer months, Heathrow faces two peaks during the day – early morning and evening. At about 08:00am and 18:00pm, demand exceeds the available capacity. There are similar peaks in the winter season.

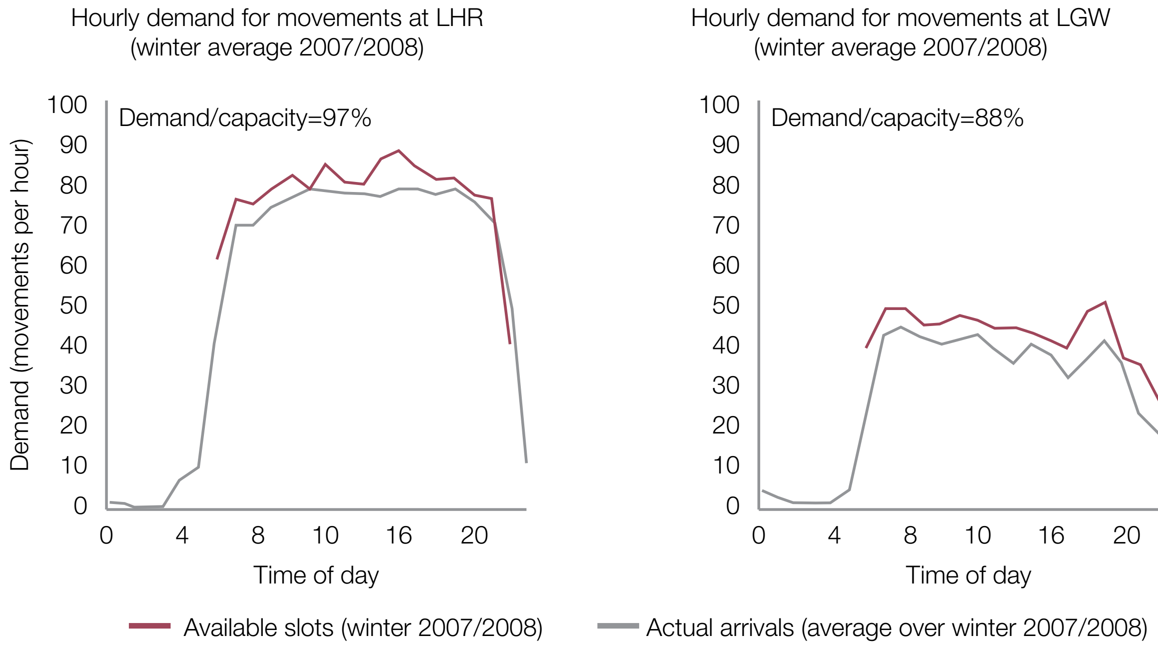
**2.17** In contrast, Gatwick has a demand to capacity ratio of 94% in the summer months and 88% in the winter months. Over the summer months, Gatwick faces three peaks – early morning, late morning and evening. Demand exceeds capacity about noon. While it faces several peaks during the day in the winter months, demand stays below capacity. The number of peaks at Gatwick is symptomatic of the low cost carrier model operated by airlines that served the airport in 2007/08.

## Figure 2: Actual utilisation and available slots at Heathrow and Gatwick in the summer season, 2007




*Source: UK CAA Runway Resilience Study (2008)*

## Figure 3: Actual utilisation and available slots at Heathrow and Gatwick in the summer season, 2007




*Source: UK CAA Runway Resilience Study (2008)*

**2.18** These demand to capacity figures give rise to significant delays, especially at Heathrow. **Tables 1** and **2** below describe the delays felt at Heathrow and Gatwick in summer 2007 and winter 2007/08.[3]

**Table 1: Delay times at Heathrow in 2007/08, split by management techniques**

| (minutes) | | Stack | ATFM | Ground | Pre-startup |
|---|---|---|---|---|---|
| summer | Average | 5.3 | 2.8 | 10.0 | 4.6 |
| | Top-range | 10-15 | 15-25 | 14-22 | 19 |
| winter | Average | 6.0 | 5.3 | 9.2 | 4.4 |
| | Top-range | 15-20 | 35-45 | 14-22 | 18 |

*Source: UK CAA Runway Resilience Study (2008)*

**Table 2: Delay times at Gatwick in 2007/08, split by management techniques**

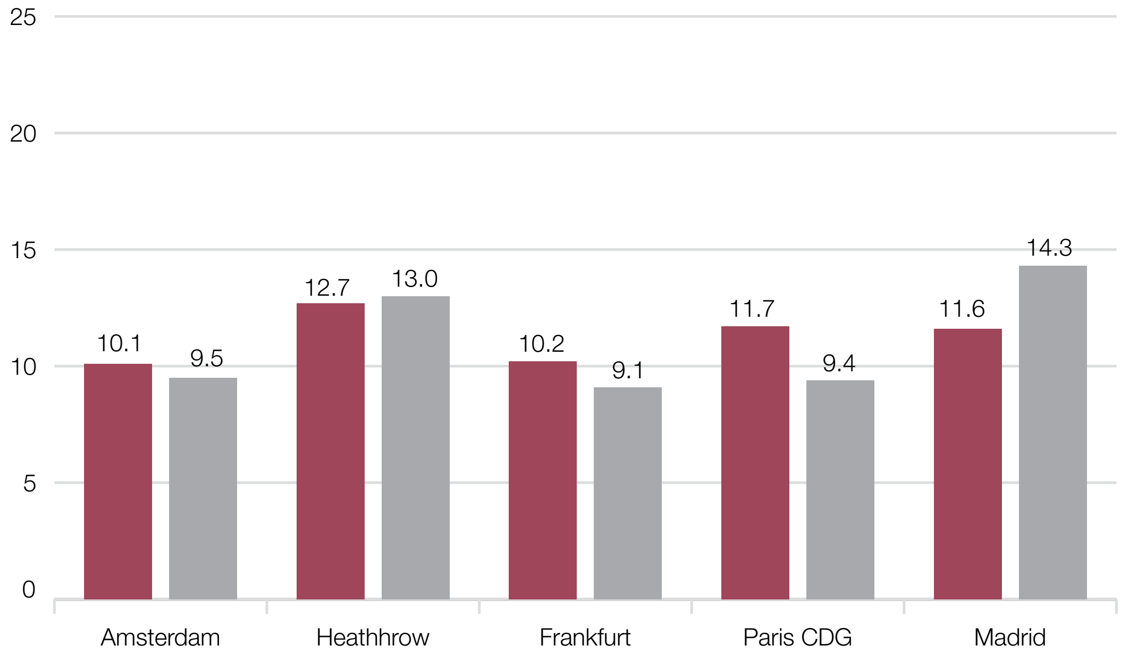
| (minutes) | | Stack | ATFM | Ground | Pre-startup |
|---|---|---|---|---|---|
| summer | Average | 1.2 | 0.4 | 7-8 | 2.2 |
| | Top-range | – | – | 12-18 | 12 |
| winter | Average | 0.8 | 1.0 | 6.9 | 2.2 |
| | Top-range | – | 0-12 | 12-18 | 12 |

*Source: UK CAA Runway Resilience Study (2008)*

**2.19** Historical data on delays suggests that delays at Heathrow are much larger than at Gatwick, especially at arrival. As can be seen in **Figure 4** below, average delays at Heathrow are higher than its other competitor European hubs, apart from average arrival delays at Madrid.

3 UK CAA Runway Resilience Study – Final report (December 2008).

**Figure 4: Average delays at selected European hubs, 2012**




*Source: CODA (December 2013) by Eurocontrol*

# 3. Literature review

**3.1** Although it is widely accepted that delays can mount up at capacity constrained airports, as seen in annual reports published by Eurocontrol Central Office for Delay Analysis,[4] and this can create additional costs for airlines and passengers, the literature on the subject is limited.

**3.2** The DfT WebTAG Aviation Appraisal unit A5.22[5] recognises the costs to passengers of increased journey times from delays at airports, but does not discuss costs of delays to airlines. Thus, the methodology used for the calculation of total delay costs is constructed using the following papers.

## UK CAA Runway Resilience Study[6] (Helios paper)

**3.3** This study, conducted by Helios, XPX Consulting and SH&E Ltd, investigates the runway resilience of Heathrow and Gatwick using data from 2007/08. It conducted operational modelling to determine delay distributions and the relationship with demand to capacity ratios.

**3.4** The relationship this study calculates has been used between demand to capacity ratios and expected delays at Heathrow to estimate the delay profiles at all UK airports under the different expansion schemes.

## Short term measures: technical report undertaken for Airports Commission (Short-term measures report)[7]

**3.5** This report, published by the Airports Commission alongside its *Interim Report*, considers the development and assessment of measures that can be used to make better use of existing airport capacity in the short-term.

**3.6** The analysis of the reduction has been used in delays through short-term measures that can be applied at Heathrow to revise the demand to capacity ratios and delay time relationships at the airport.

4 https://www.eurocontrol.int/sites/default/files/content/documents/official-documents/facts-and-figures/coda-reports/coda-digest-annual-2013.pdf

5 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275398/webtag-tag-unit-a5-2-aviation-appraisal.pdf

6 https://www.caa.co.uk/docs/589/ICF_runway_resilience_final_report_16Feb09.pdf

7 Short term measures paper https://www.gov.uk/government/publications/airports-commission-interim-report

## European airline delay cost reference values[8] (UoW paper)

**3.7** This study, conducted by the Department for Transport Studies at the University of Westminster, is a reference guide for European costs of delays (both strategic and tactical) to airlines, estimated using data on operating costs per block hour.

**3.8** The costs estimated in this study have been used to predict the costs to airlines and carbon costs due to delays under different expansion schemes.

**3.9** Other sources used in this work include assumptions and outputs from the DfT aviation model. More detail on this is included in the following sections.

8 http://www.eurocontrol.int/sites/default/files/content/documents/sesar/business-case/european_airline_delay_cost_reference_values_2011.pdf

# 4. Methodology

**4.1** The analysis focuses on benefits of reduced strategic delays in the UK airport system as a result of expansion for airlines, passengers and carbon emissions. Any assessment of the impacts on noise respite, air quality impacts other than though $CO_2$, or any resilience or reliability benefit from having an airport with extra capacity is out of scope of this analysis.

**4.2** For the purpose of this analysis, arrival and departure delay time resulting from capacity constraints refers to the phases of a flight when an aircraft is held in a stack, waiting to land (arrival holding) or on the ground, ready to depart (ground holding). Other delays caused by, for instance, ATFM and at-gate holding have not been included in this analysis.

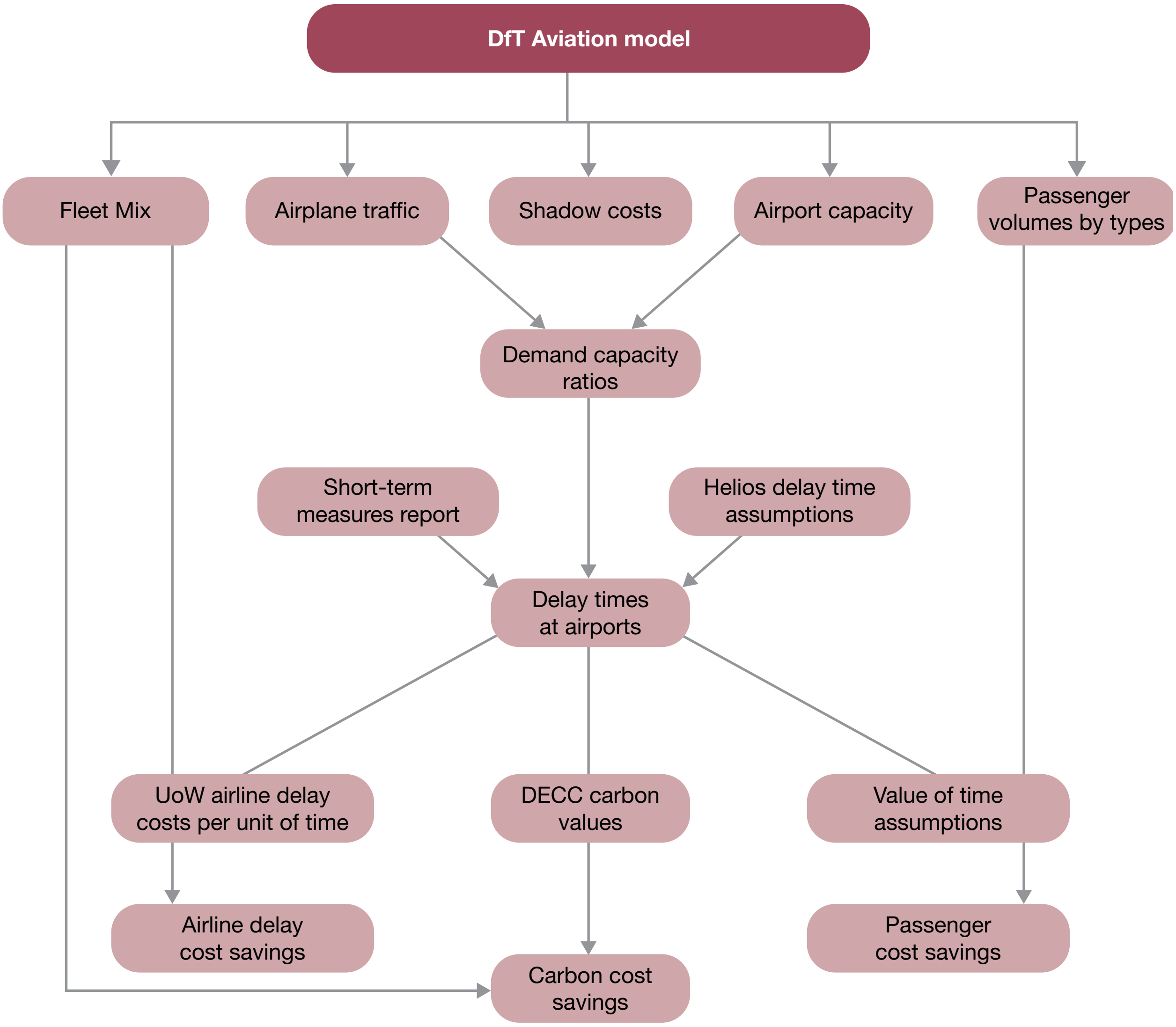
**4.3** Since evidence on realised delay time does not allow one to distinguish between strategic and tactical delays, it is usually assumed that any recurring average annual delay is factored into airline and passenger schedules.[9] Likewise, the following analysis assumes all delay time to be strategic.

**4.4** Due to these limitations, the benefits of reduced delays coming out of this analysis are likely to be an underestimate and should, therefore, be considered a lower bound.

**4.5** **Figure 5** gives a pictorial representation of the methodology used.

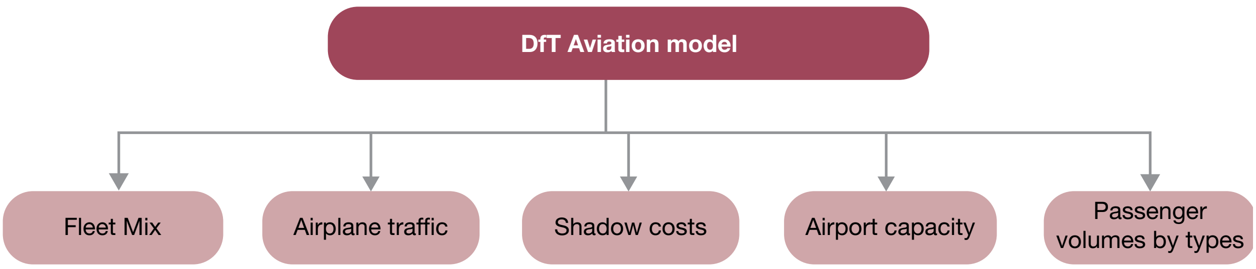
9 UK Runway Resilience Study – Final Report (December 2008)

## Figure 5: Delays Methodology




*Arrows represent direct inputs/outputs while solid lines represent linkages*

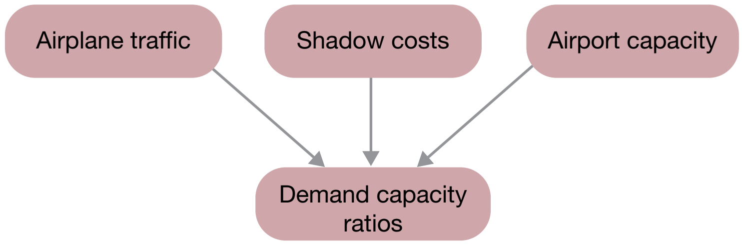
## Figure 6: Outputs from the DfT aviation model



**4.6** As shown in **Figure 6** above, the DfT aviation model[10] provides capacity constrained[11] forecasts of airplane traffic, fleet mixes, shadow costs, passenger volumes split by types of passengers[12] and airport capacity from 2025 to 2085 for all carbon-traded and carbon-capped global scenarios[13] in the baseline and each of the expansion options.

**4.7** Traffic forecasts have been split into summer (seven months) and winter (five months) seasons to make them consistent with the aforementioned studies which suggest that the delay time impacts of capacity constraints differ in the two seasons.

**Figure 7: Demand capacity ratios**




**4.8** As shown in **Figure 7** above, the forecasts of air transport movements (ATMs) and the airport capacity at all airports are used to calculate the demand to capacity ratio at each airport. The demand to capacity ratio is determined to be 1 if shadow costs begin to build up because of the runway being full at any airport. At either Heathrow or Gatwick, shadow costs build-up due to terminal capacity being full is an additional constraint for a demand to capacity ratio of 1.

**4.9** ATMs as an indicator of demand have been used as opposed to passenger numbers. This is because passenger numbers alone will overestimate capacity constraints without the appropriate fleet mix considerations which could be used to serve the excess passenger demand.

## Assumptions on delays

**4.10** Assumptions around the relationships between i) average stack holding and demand/capacity ratio, and ii) average ground holding time and demand/capacity

10 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223839/aviation-forecasts.pdf

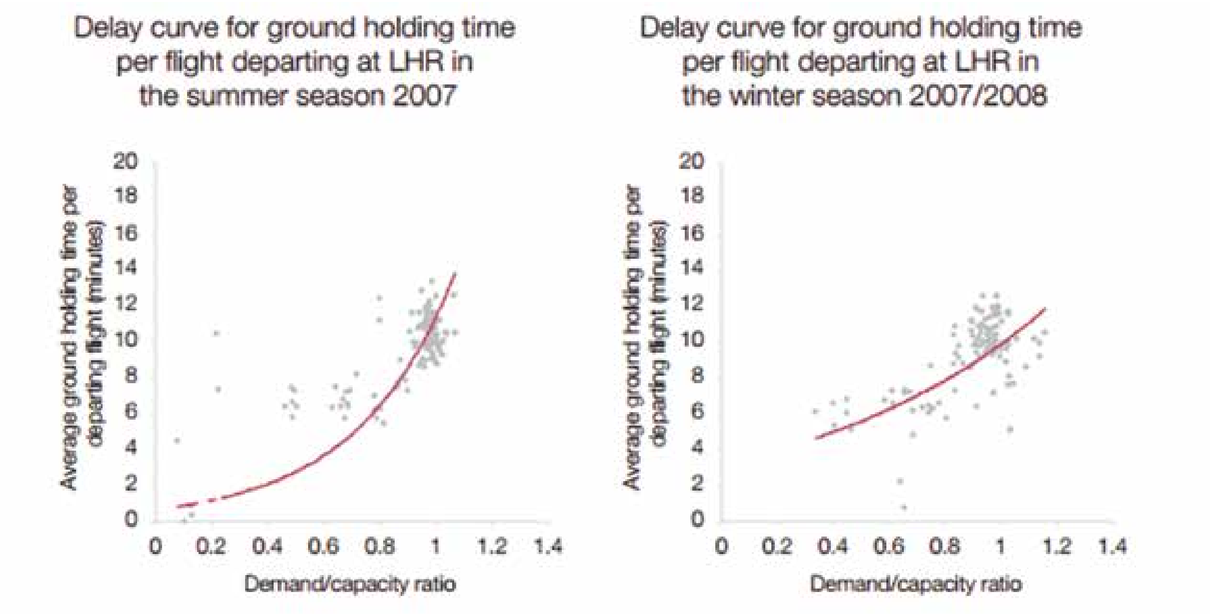
11 Capacity constrained forecasts are outputs from modelling where passenger and ATM demand must fit available future capacity where no significant additional runway or terminal capacity is added. Capacity unconstrained forecasts are outputs from modelling where passenger and ATM demand is not limited by runway or terminal capacity.

12 The various types of passengers considered are UK business, UK leisure, foreign business, foreign leisure and international to international (transfer) passengers.

13 Details on scenarios in Appendix B.

ratio estimated in the Helios report, are shown below in **Figures 4** and **5** respectively.

**Figure 8: Relationship between demand to capacity ratios and average stack holding time**




*Source: UK CAA Runway Resilience Study (2008)*

**4.11** **Figure 8** above shows the relationship between the average stack holding time per flight in minutes (Y-axis) and the demand/capacity ratio (X-axis) at Heathrow in the summer and winter season of 2007.

**4.12** The relationships are split between the summer (7 months from end-March to end-October) and winter months (5 months from end-October to end-March). These differ due to the differences in scheduling limits,[14] which inform the scheduling process performed separately for the summer and winter seasons as well as the variation in weather between the two seasons.

**4.13** Based upon this evidence, it is assumed that arrival delays only occur when an airport's capacity is above or equal to 80%. Further, it is assumed that in summer, there is 0.5 minutes of delay at a demand to capacity ratio of 0.8 which builds up linearly to a maximum delay time of 6 minutes at demand to capacity ratio of 1. Over the winter, the delay times are between 1 and 12 minutes.

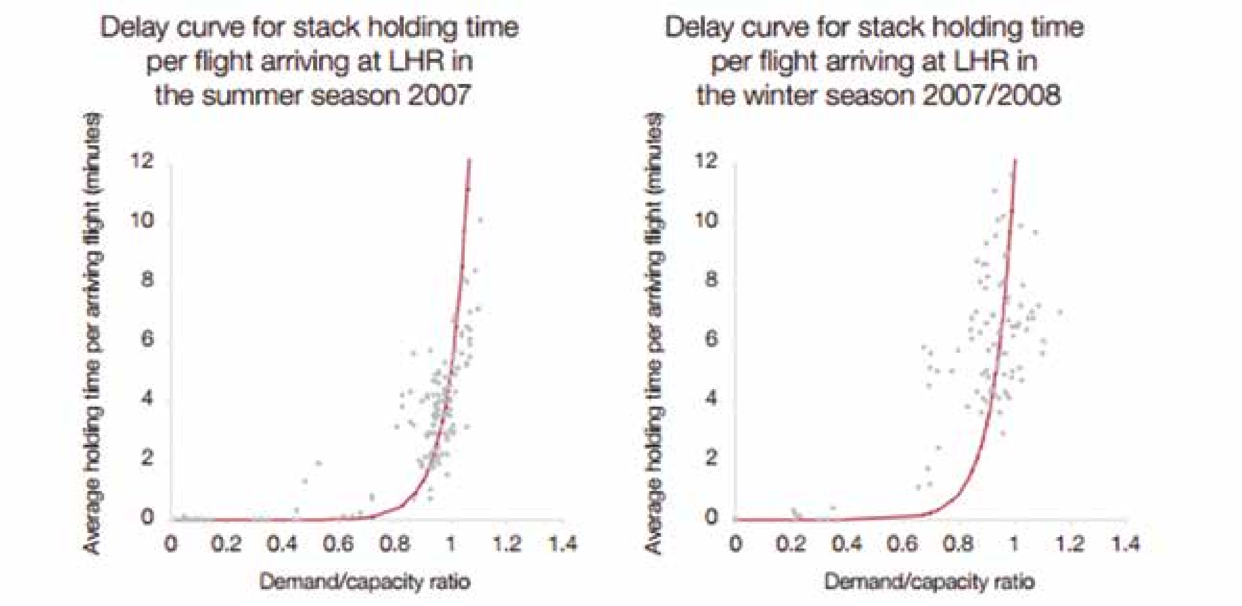
**4.14** Based on the Commission's analysis of possible short term measures to make better use of existing airport capacity as part of the *Interim Report*, it is assumed that Heathrow Airport applies the airport-specific short-term measures proposed by

14 The maximum number of movements per hour and the effective planned capacity of the runways.

the Commission. As a result, the demand to capacity ratio to delay time curve for Heathrow lies below the curves for the other airports at all demand to capacity ratios where delays exist in this analysis.

**4.15** **Figure 9** below shows the relationship between average ground holding time per flight (defined as the difference between actual and perfect taxi time[15]) and the demand/capacity ratio. Note that the Y intercept does not occur at zero. Thus, it is assumed that delay builds up linearly from 0.6 minutes in summer and 3.1 minutes in winter.

**Figure 9: Relationship between demand to capacity ratios and average ground holding time**




*Source: UK CAA Runway Resilience Study (2008)*

**4.16** Based on this, the relationship between average ground holding time per flight and the demand/capacity ratio assumes that departure delays build up consistently from a base of 0.6 minutes and 3.1 minutes in the summer and winter respectively.

**4.17** These delay times are applied equally across all airports that experience a capacity constraint and are based upon evidence of delay times at Heathrow in 2008 presented in the Helios paper. For Heathrow, it is assumed that the airport applies the suggested short-term measures and so the delay curve for Heathrow is below that for other airports at all demand to capacity ratios where delays exist.

**4.18** Using the demand capacity ratios and delay time relationships and applying the short-term measures, average delay times for airports at different demand/capacity

15 Perfect taxi time is the time taken by an airline to taxi from its gate to the runway with no disruption.

ratios were derived (separately for Heathrow and all other airports). This is presented in **Tables 3** and **4** below:

**Table 3: Demand to capacity ratios to delay time relationships (all airports other than Heathrow)**

| ATM to capacity ratios | Summer arrival | Summer departure | Winter arrival | Winter departure |
|---|---|---|---|---|
| 0.00 | 0.00 | 0.60 | 0.00 | 3.10 |
| 0.10 | 0.00 | 1.64 | 0.00 | 3.77 |
| 0.20 | 0.00 | 2.68 | 0.00 | 4.44 |
| 0.30 | 0.00 | 3.72 | 0.00 | 5.11 |
| 0.40 | 0.00 | 4.76 | 0.00 | 5.78 |
| 0.50 | 0.00 | 5.80 | 0.00 | 6.45 |
| 0.60 | 0.00 | 6.84 | 0.00 | 7.12 |
| 0.70 | 0.00 | 7.88 | 0.00 | 7.79 |
| 0.80 | 0.50 | 8.92 | 1.00 | 8.46 |
| 0.90 | 3.25 | 9.96 | 6.50 | 9.13 |
| 1.00 | 6.00 | 11.00 | 12.00 | 9.80 |

**4.19** These relationships are different for Heathrow, as shown in **Table 4** below, because of the application of short-term measures at Heathrow.

**Table 4: Demand to capacity ratios to delay time relationships (all airports other than Heathrow)**

| Demand to capacity ratios | Summer arrival | Summer departure | Winter arrival | Winter departure |
|---|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 0.10 | 0.00 | 0.00 | 0.00 | 0.77 |
| 0.20 | 0.00 | 0.00 | 0.00 | 1.44 |
| 0.30 | 0.00 | 0.69 | 0.00 | 2.11 |
| 0.40 | 0.00 | 1.62 | 0.00 | 2.78 |
| 0.50 | 0.00 | 2.55 | 0.00 | 3.45 |
| 0.60 | 0.00 | 3.48 | 0.00 | 4.12 |
| 0.70 | 0.00 | 4.41 | 0.00 | 4.79 |
| 0.80 | 0.00 | 5.34 | 0.00 | 5.46 |
| 0.90 | 0.00 | 6.27 | 0.00 | 6.13 |
| 1.00 | 0.90 | 7.20 | 2.10 | 6.80 |

**4.20** These relationships, alongside the demand to capacity ratios for each airport in each appraisal year, were used to calculate the delay times at each airport under each scenario for the various expansion schemes as well as for the do-minimum as a comparison.

**4.21** The delay time under each scheme is combined with the airline, passenger and carbon costs per unit (explained below) at each airport to determine the total benefits of any reduction of delays.

## Airline cost savings

**4.22** Capacity constrained airports lead to an expectation of delay by the airlines, as explained in **paragraph 2.8** above. Based on the experience of stack holding and taxiing time during the day at each airport, airlines build a 'buffer' in their schedules.

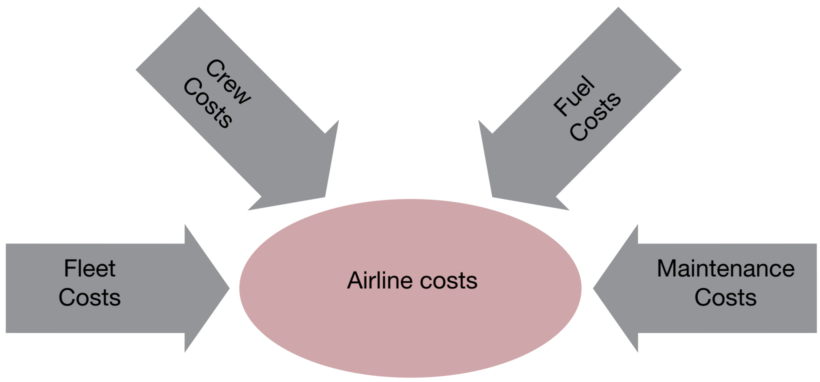
**4.23** Airline costs are the costs accrued by airlines from adding a buffer to their schedules. These costs, termed costs of prevention, include costs at the planning stage such as need for extra crew and aircraft as well as at the operational stage such as cost of excess fuel consumption during stacking and taxiing.

**4.24** The methodology and data used is based on the base case in the UoW paper. The various elements of the airline costs (**paragraph 4.25** to **4.29** below) have been calculated for delays at arrivals and departures and represented in **Figure 10**.

**4.25** Fuel costs are the costs of excess fuel consumption during stack holding and taxiing as well as fuel carriage penalty (see Carbon Costs below). The study provides the best available data on rates of fuel burn and fuel costs. It has sourced its data on fuel burn based on aircraft and engine type from the ICAO Aircraft Engine Emissions Databank and specific engine suppliers. Adjustments had to be made to align the aircraft types considered in the study to the DfT's forecast fleet mix. It is assumed that next generation aircraft are to be 10% more fuel efficient than current aircraft, and next but one generation aircraft are 50% more efficient, in line with EU objectives.[16] Data on cost of fuel is based on 2009 'Rotterdam' spot prices.

**4.26** Maintenance costs are costs to airlines from additional wear and tear of the aircraft and leased equipment, which are estimated by calculating the cost per block hour[17] and then redistributing it across the departure, enroute and arrival stages of a flight. These are based on data collected through interviews with airlines undertaken by Flightpath 2050 (2011).

**Figure 10: Airline costs summary**




**4.27** Fleet costs are the costs of fleet financing the extra aircraft needed, including depreciation, rentals and leases of flight equipment. These values are sourced from airline interviews, Airclaims[18] data and other literature.

**4.28** Crew costs arise from the need to hold additional crew, both on board and on the ground, to service the additional flying time. These are derived in a similar way to maintenance costs from block hour costs from pay deals information from airlines.

**4.29** Further costs to airlines due to passenger rebooking, compensation and care (called passenger hard costs) as well as revenue implications from passenger

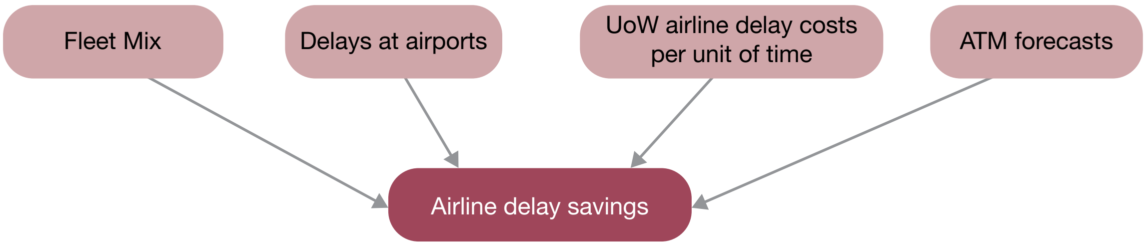
16 Flightpath 2050 (2011) http://ec.europa.eu/transport/modes/air/doc/flightpath2050.pdf
17 Explain Block hours and defined as the time spent off-blocks (ie airport utilisations).
18 www.copybook.com/airport/airclaims

dissatisfaction (passenger soft costs) have not been included due to the risk of double counting with passenger benefits below.

**4.30** Further assumptions have been applied to the costs in the UoW study such that maintenance costs are decreased by 20% with each new generation of aircraft. A conservative approach is taken to the other parameters which remain the same over time as new aircraft enter the fleet but fleet and crew costs decrease by 50% in 2050 due to expectations of productivity increases.

**4.31** All costs available from the UoW study are in Euros and so have been converted to GBP using a conversion rate of 0.8 GBP to 1 Euro. A market price adjustment is applied to these costs, an uplift of 19%, in order to account for indirect taxes as suggested in WebTAG[19]. They have been calculated for 14 aircraft types, which had to be aligned with the DfT forecast fleet mix, as summarised in **Figure 11**.

**Figure 11: Calculation of Airline delays savings**




**4.32** The total airline costs per unit of time at each airport varies based on the fleet mix of the ATMs in use at the airport, forecast by the DfT aviation model. These costs are calculated for each airport in the baseline and various expansion options for three years – 2025, 2040 and 2050, and interpolated in between. Post 2050, these costs are assumed to remain constant.

**4.33** Airline costs per unit time are then combined with delay times per airport and the ATM traffic forecasts[20] to derive a total cost savings to airlines over the appraisal period[21] against the do minimum,[22] as shown in the flowchart above.

**4.34** It is worth noting that the airline cost savings have only been applied to existing ATMs, which are ATMs which would be in use in the do minimum and would still be in use with the expansion.

19 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/372519/TAG_Unit_A1.1_-_Cost_Benefit_Analysis_November2014.pdf

20 The airline cost savings have only been applied to existing airlines.

21 60 year appraisal period starting in 2025 for Gatwick and 2026 for Heathrow schemes.

22 The 'do minimum' is the base case where no runway capacity has been added.

**4.35** Although this analysis has tried to cover as much of the costs to airlines as possible, due to lack of available evidence, it has not been able to cover some other airline costs of delays such as those associated with freighter operations. Further, airport charges have not been included since previous studies show that these are marginal in the context of delays.

**4.36** As explained earlier, these costs to airlines only include the costs of strategic delays. There are also likely to be costs to airlines from tactical and ATFM delays.

## Passenger cost savings

**4.37** Passenger costs are the costs to existing passengers from the increased journey time due to the extra time spent on flights in stack holding and/or taxiing as a result of delays. These benefits capture the traditional journey time savings from transport improvements.

**4.38** Passengers value this extra time which could have been used for other activities such as additional working time or leisure time. This value varies for different types of passengers, most notably leisure and business travellers. These values are estimated using willingness-to-pay techniques where people (and employers for business travellers) are asked how much they would be willing to pay to save an additional unit of time during travel.

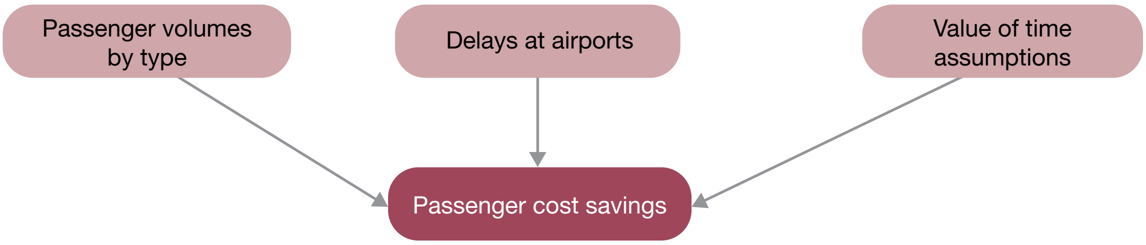
**4.39** The leisure value of time (VoT) comes from the DfT aviation model. Business passenger values of time are further broken down into UK and foreign resident values of time and are based upon data from a 2008 survey at each of the 32 UK airports, shown as a range in **Table 5** below. This is the most comprehensive collection of survey results. A growth index for each VoT (also from the DfT aviation model) is then applied to these so that they can be used in successive years in order to account for increase in GDP and inflation.

**4.40** The values used are presented in **Table 5** below:

**Table 5: Values of time split by type of passenger in 2014**

| Passenger type | Value of time (£/hr.) |
|---|---|
| Leisure passengers[23] | 6.60 |
| UK Business passengers[24] | 21.88 to 60.51 |
| Foreign business passengers | 23.77 to 66.92 |
| I-I passengers | 10.82 to 22.47 |

**Figure 12: Benefits to passengers**




**4.41** As shown in **Figure 12**, the value of time assumptions, passenger volumes and delay times are combined to calculate the benefits to passengers from reduction in delays against the do minimum.

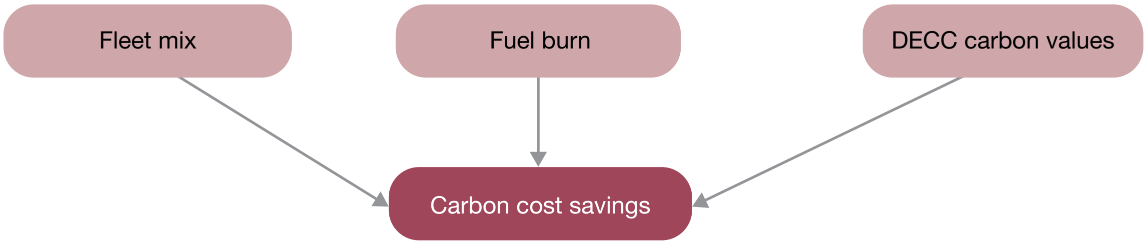
**4.42** It is worth noting that the passenger value of time savings have only been applied to existing passengers, under each type of passenger. These are passengers who would travel in the do minimum and continue to travel after the expansion.

## Carbon cost savings

**4.43** Carbon costs capture the costs of emissions from excess fuel consumption when a flight experiences departure delay, which in turn need to be paid by airlines. This includes not just the direct fuel burn due to departure management, but also a fuel carriage penalty. This is the additional fuel burn which arises from carrying excess fuel between the origin and destination due to the expectation of arrival management at destination.

23 Leisure passenger VoT from DfT Aviation model.
24 UK and foreign residents VoT based upon 2008 survey data at each of the 32 airports.

**Figure 13: Carbon cost savings**




**4.44** Data on the rate of fuel burn for stack holding and taxiing has been taken from the UoW study which has sourced its data based on aircraft and engine type from the ICAO Aircraft Engine Emissions Databank and specific engine suppliers. Adjustments had to be made to align the aircraft types considered in the study to the DfT fleet mix.

**4.45** Fuel burn is then converted to $CO_2$ emissions based on assumptions in DfT aviation forecasts which assume that each additional kilogram of jet fuel (kerosene) emits 3.18 kg of $CO_2e$.

**4.46** It is assumed that next generation aircraft are 10% more fuel efficient (fed in through rates of fuel burn) than current aircraft, and next but one generation aircraft are 50% more efficient, in line with EU objectives.[25]

**4.47** The monetised costs of emissions are based on carbon values from DECC's supplementary Green Book guidance,[26] as used in the DfT aviation model. The carbon costs savings are calculated in relation to the do-minimum.

**4.48** While there are savings in terms of aviation carbon emissions in both carbon-traded and carbon-capped cases, these savings are not additional in the Commission's carbon scenarios whereby these would be part of the trading system. However, these savings do provide benefits to airlines, who are no longer required to purchase as many permits in order to account for emissions from delays.

25 Flightpath (2050) http://ec.europa.eu/transport/modes/air/doc/flightpath2050.pdf
26 Include reference.

## Scheme assessment

**4.49** An assessment of the delay benefits for each of the scheme proposals, compared to the do minimum, is made based on the methodology described above.

**4.50** All benefits are presented in real terms, discounted[27] to 2014 prices using standard Green Book discount rates of 3.5% for the first 30 years and 3.0% after that.

**4.51** The appraisal period is based on the estimated opening year of the individual schemes and standard appraisal period of 60 years. For a second runway at Gatwick, this is 2025 – 2084 and for the two Heathrow schemes, it is the period 2026 – 2085.

27 Costs and benefits that occur in future years are discounted in order to reflect people's preferences for current consumption over future consumption.

# 5. Analysis of results

**5.1** **Tables 6** and **7** below give an indication of the total delay savings for the various expansion schemes under the different scenarios, in the carbon-traded and carbon-capped cases.

**5.2** In order to understand the implications of the CCC's planning assumption for future aviation demand, the Commission developed the carbon-capped approach to forecasting, which treats carbon emissions as a constraint, rather than as an output of the model. The forecasts showed underlying demand growth consistent with the planning assumption of 67% over 2005 levels by 2050.

**5.3** A sensitivity test of the carbon assumptions has been completed known as the demand reduction approach; it can be found in **Annex A**.

**Table 6: Delay benefits under different scenarios, carbon traded**

| Total savings (£ billion, PV, 2014 prices) | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|
| Assessment of need | 2.3 | 0.8 | 1.0 |
| Global Growth | 1.6 | 0.7 | 1.1 |
| Relative decline of Europe | 2.2 | 1.2 | 1.5 |
| Low Cost is King | 0.1 | 0.6 | 0.8 |
| Global Fragmentation | 2.2 | 1.1 | 1.2 |

**Table 7: Delay benefits under different scenarios, carbon capped**

| Total savings (£ billion, PV, 2014 prices) | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|
| Assessment of need | 2.6 | 2.4 | 3.0 |
| Global Growth | 3.2 | 2.9 | 3.6 |
| Relative decline of Europe | 2.7 | 2.5 | 3.0 |
| Low Cost is King | 2.1 | 2.2 | 3.0 |
| Global Fragmentation | 2.7 | 2.3 | 3.0 |

**5.4** The total benefits can be further broken down into savings for airlines and passengers – as seen in **Table 8** below for the *assessment of need*, carbon-traded case. Please note that the total savings do not include the benefits to transfer passengers.

**Table 8: Delay benefits in *assessment of need*, carbon-traded (in £billion, 2014 prices)**

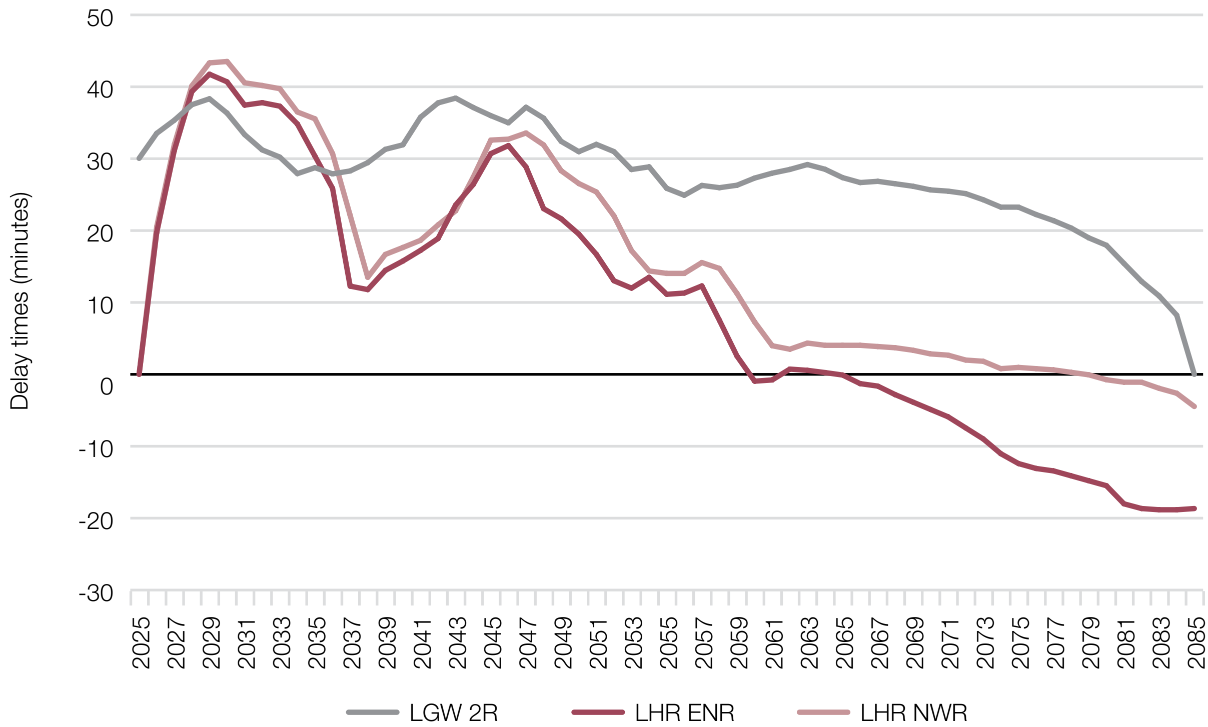
| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.6 | 0.1 | 0.2 |
| | UK Leisure | 0.4 | 0.1 | 0.1 |
| | Foreign Business | 0.2 | 0.1 | 0.2 |
| | Foreign Leisure | 0.1 | 0.0 | 0.0 |
| | I-I | 0.0 | 0.0 | 0.0 |
| | Total | 1.4 | 0.4 | 0.6 |
| Airline savings | | 0.9 | 0.3 | 0.4 |
| **Total savings** | | **2.3** | **0.8** | **1.0** |

**5.5** Similar results on the other global and carbon scenarios are available in **Appendix A**. Across all scenarios, a majority of the benefits accrue to passengers.

**5.6** Delay benefits are driven mainly by delay time savings and the passenger demand. There is an inverse relationship between demand and delay time savings, which is particularly driven by how fast the additional capacity delivered by the scheme fills up and thus delays start to build up at the airports in the system. These savings will accrue to a higher number of people based on the demand.

**5.7** **Figure 14** below shows the delay time savings across all options in the *assessment of need* carbon-traded scenario.

**Figure 14: Delay time savings compared to the do-minimum for all schemes, *assessment of need* carbon-traded**




*Source: Airports Commission analysis*

**5.8** It is helpful to see these in relation to the passenger numbers under the different scenarios, as seen in **Table 9** below.

**Table 9: Passenger numbers (2050) under different scenarios, carbon-traded**

| Total passengers (million) | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|
| Assessment of need | 426 | 430 | 435 |
| Global Growth | 488 | 491 | 496 |
| Relative decline of Europe | 430 | 432 | 435 |
| Low Cost is King | 498 | 489 | 494 |
| Global Fragmentation | 406 | 415 | 420 |

**5.9** These benefits to passengers, airlines and society (through reduction in carbon emissions) are a result of reduction in strategic delays in both arrival and departure due to airport expansion.

**5.10** Due to limitations of data available, this analysis considers all times of the day equally which could potentially be underestimating the costs of strategic delays since delays at peak times can be significantly larger. For instance, delay times in the top end of the range can be two to three times greater than the average. The costs of higher delays at each instance could be exponentially higher.

**5.11** There are additional, and arguably larger, costs of tactical delays which this analysis does not cover. There is a similar story of delays due to ATFM regulations, which is felt particularly by flights from other European destinations. This analysis does not include these costs due to limitations of evidence of reasons for actual delay times at airports.

**5.12** Further, costs to airports of needing to increase terminal capacity and better facilities to house delayed passengers have not been included due to lack of available evidence.

**5.13** Delay times at Heathrow after the application of all short-term measures recommended by the Commission in its *Interim Report* have been considered. The Government is yet to make a decision on some of these measures and thus, the benefits from airport capacity expansion on reduction of delays at Heathrow are underestimated if these short term measures are not fully implemented before the schemes open.

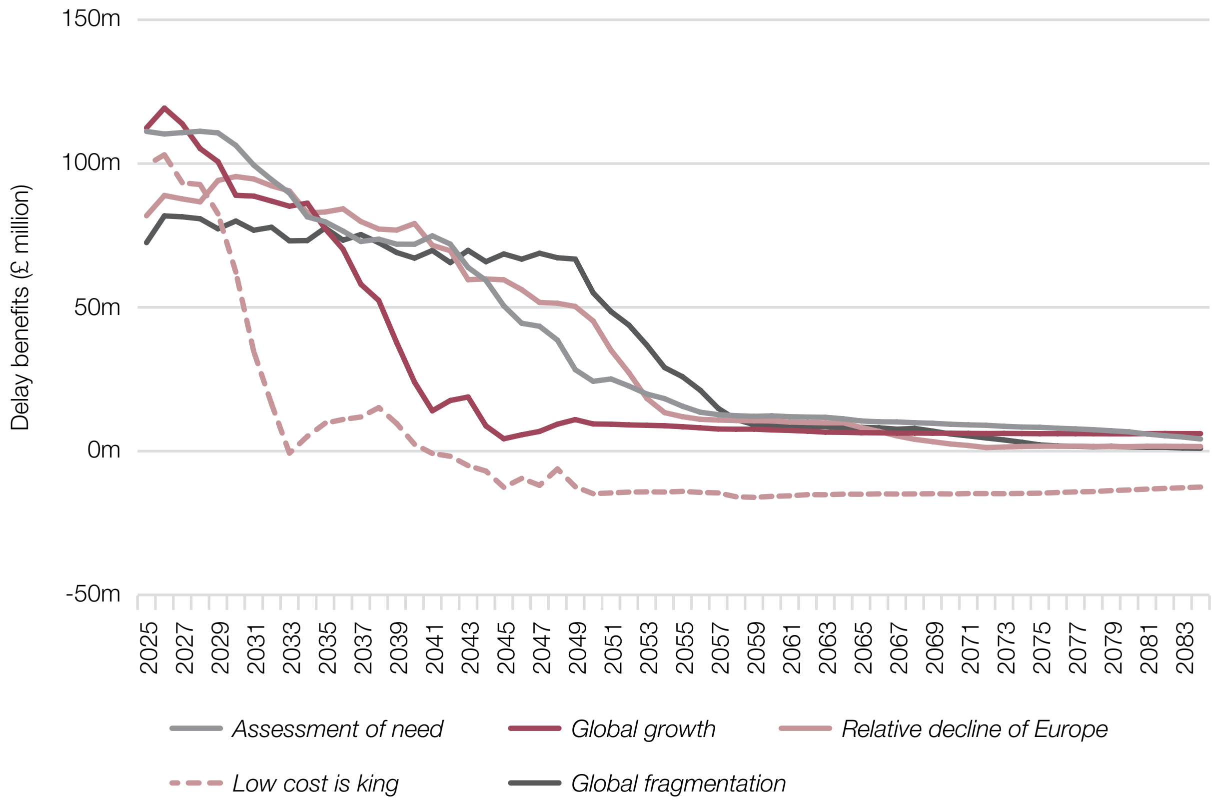
**5.14** As such, the benefits from reduced delays should be considered a lower bound.

## LGW 2R

### Carbon-traded

**5.15** The delay savings under the Gatwick Second Runway expansion scheme are between £0.1 billion in the *low cost is king* carbon-traded scenario and £2.3 billion in the *assessment of need* carbon-traded scenario. The profile of delays savings through time is shown in **Figure 15**.

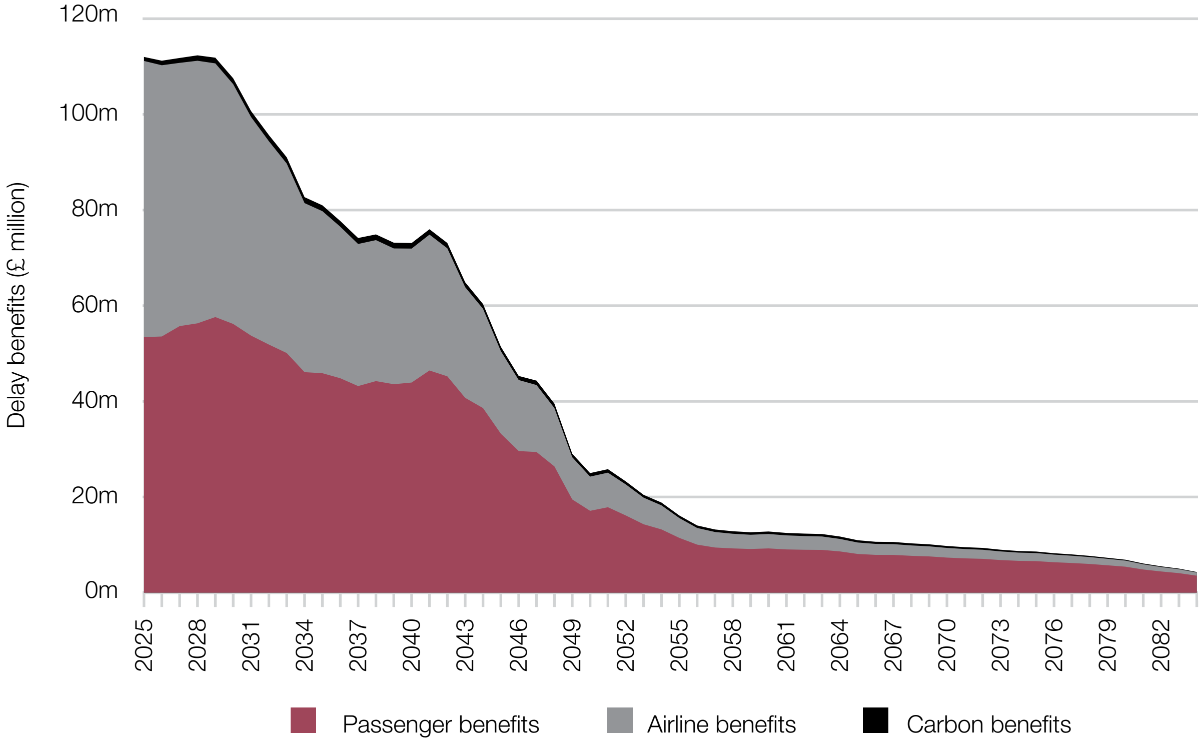
**Figure 15: LGW 2R delay benefits for different scenarios**




*Source: Airports Commission analysis*

**5.16** As mentioned above, the benefits from reduced delays are highest in the *assessment of need* scenario where passenger benefits account for 60% of the total benefits (**Figure 16** below). This follows on from the delay time savings as seen in **Figure 15** above. Due to discounting, delays in later years feed into the total delay benefits to a lesser extent.

**Figure 16: Delay time savings, *assessment of need* carbon-traded**



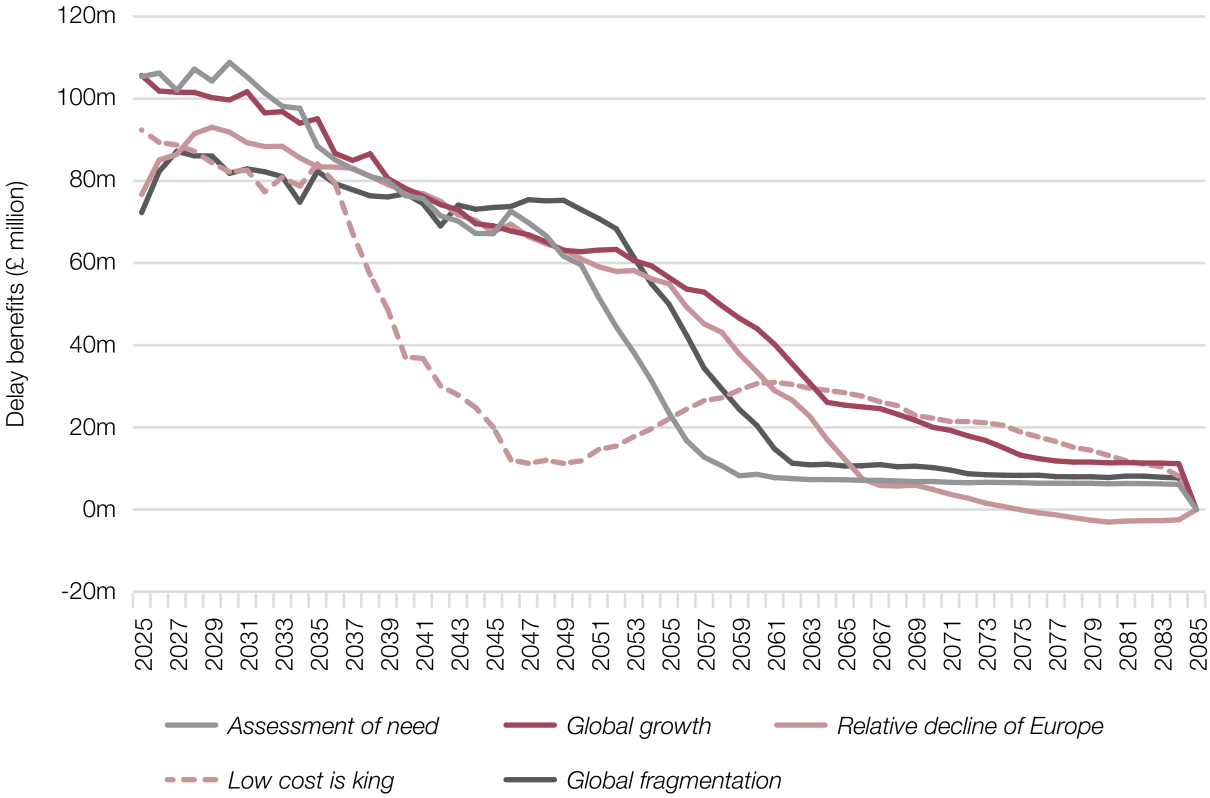

*Source: Airports Commission analysis*

**5.17** As mentioned earlier, delay benefits are driven by a combination of delay time savings and the number of passengers to whom these savings accrue. Delay time savings are higher when the additional capacity remains spare longer and so delays do not start to build up. This is the reason benefits from reduced delays are lowest for the *low cost is king* scenario where large number of passengers lead to the additional capacity filling up quickly, causing delays to occur earlier than in other scenarios.

## Carbon capped

**5.18** The delay savings under the Gatwick Airport Second Runway expansion scheme are between £2.1 billion in the *low cost is king* carbon-capped scenario and £3.2 billion in the *global growth* carbon-capped scenario. The profile of delays savings through time is shown in the figure below.

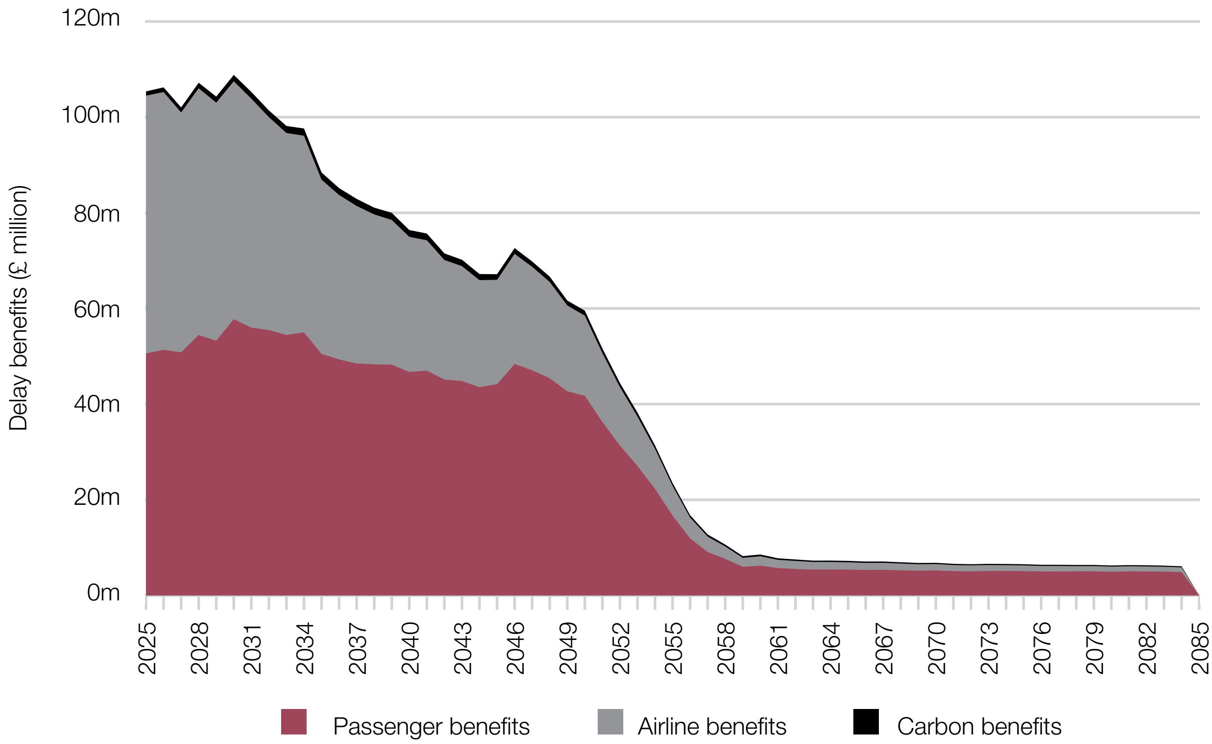
**Figure 17: LGW 2R delay benefits for different scenarios**




*Source: Airports Commission analysis*

**5.19** As mentioned above, the benefits from reduced delays in the carbon-capped case are highest in the *global growth* scenario where passenger benefits account for 64% of the total benefits (**Figure 18** below). This follows on from the delay time savings. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure 18: Delay time savings, *assessment of need* carbon-capped**



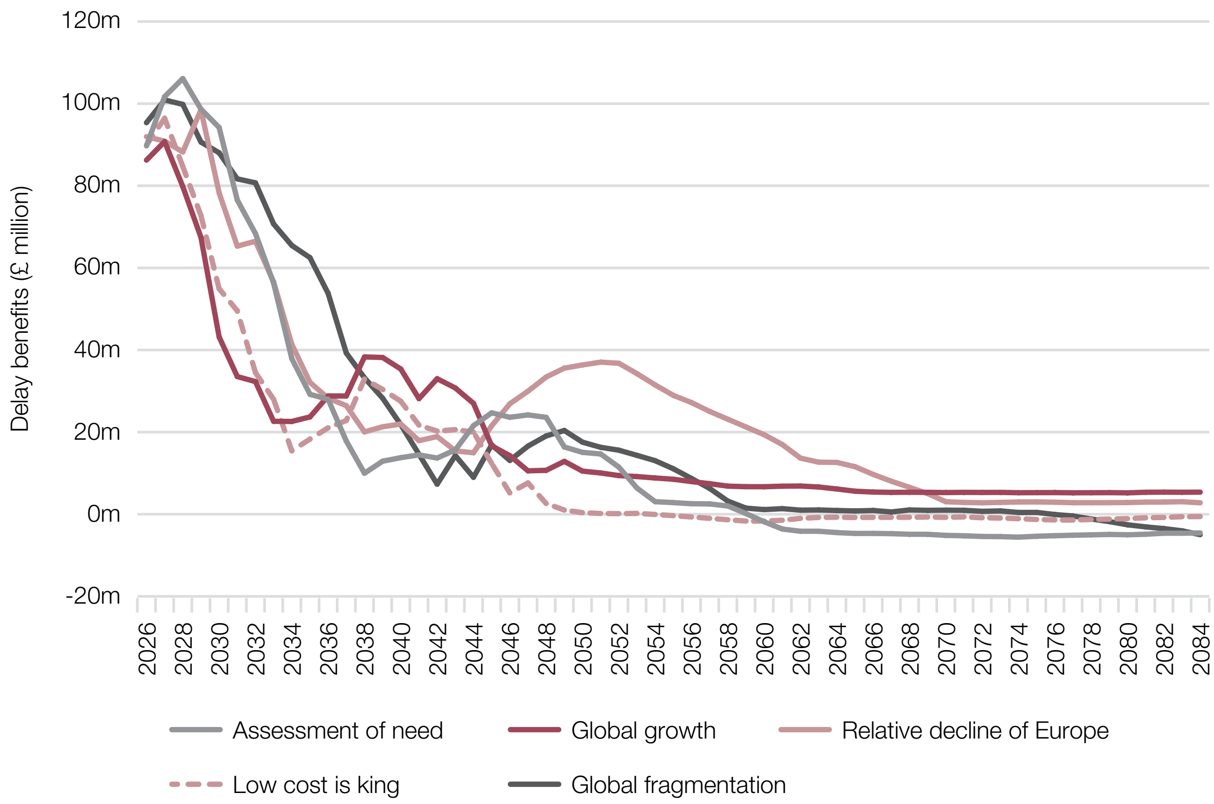

*Source: Airports Commission analysis*

## LHR ENR

### Carbon-traded

**5.20** The delay savings under the Heathrow Airport Extended Northern Runway expansion scheme are between £0.6 billion for *low cost is king* scenario and £1.2 billion for *relative decline of Europe* scenario in carbon-traded case. The profile of delays savings through time is shown in the figure below.

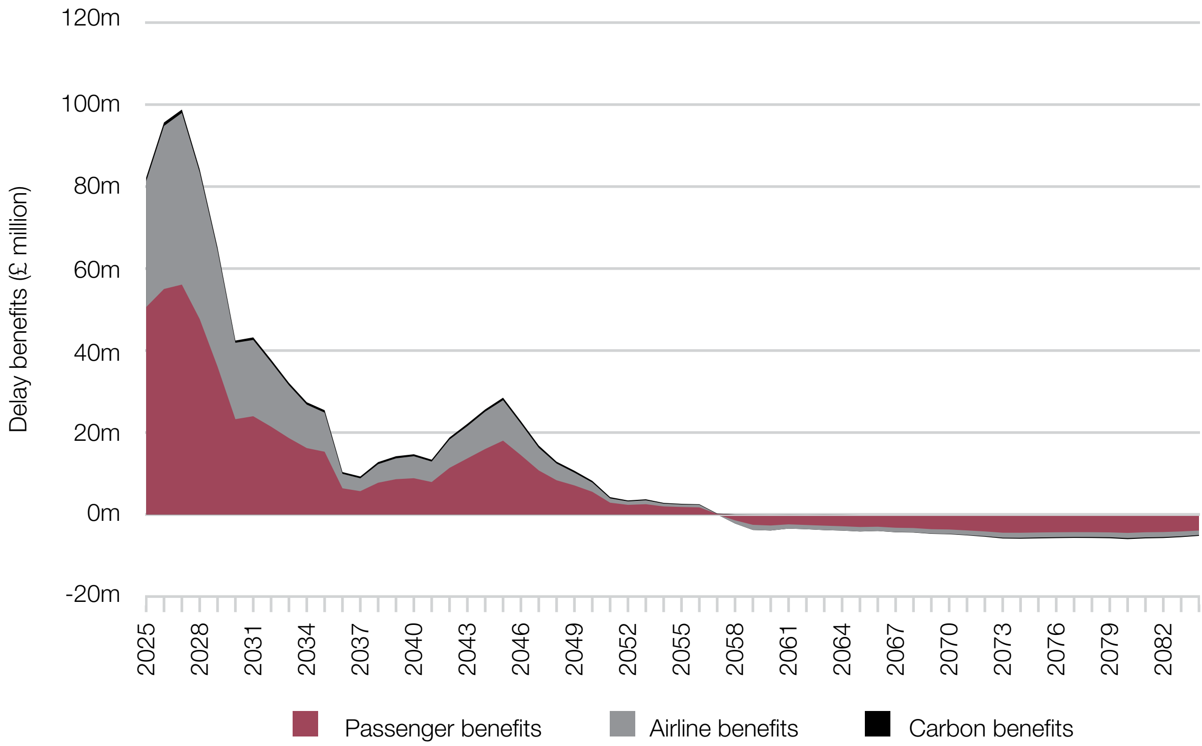
**Figure 19: LHR ENR delay benefits for different scenarios**




*Source: Airport Commission analysis*

**5.21** As shown above, the benefits from reduced delays are highest in the *relative decline of Europe* and *global fragmentation* scenarios where passenger benefits account for 58% and 60% of the total benefits (**Figure 20** below). This follows on from the delay time savings as seen in **Figure 19** above. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure 20: Delay time savings, *assessment of need* carbon traded**



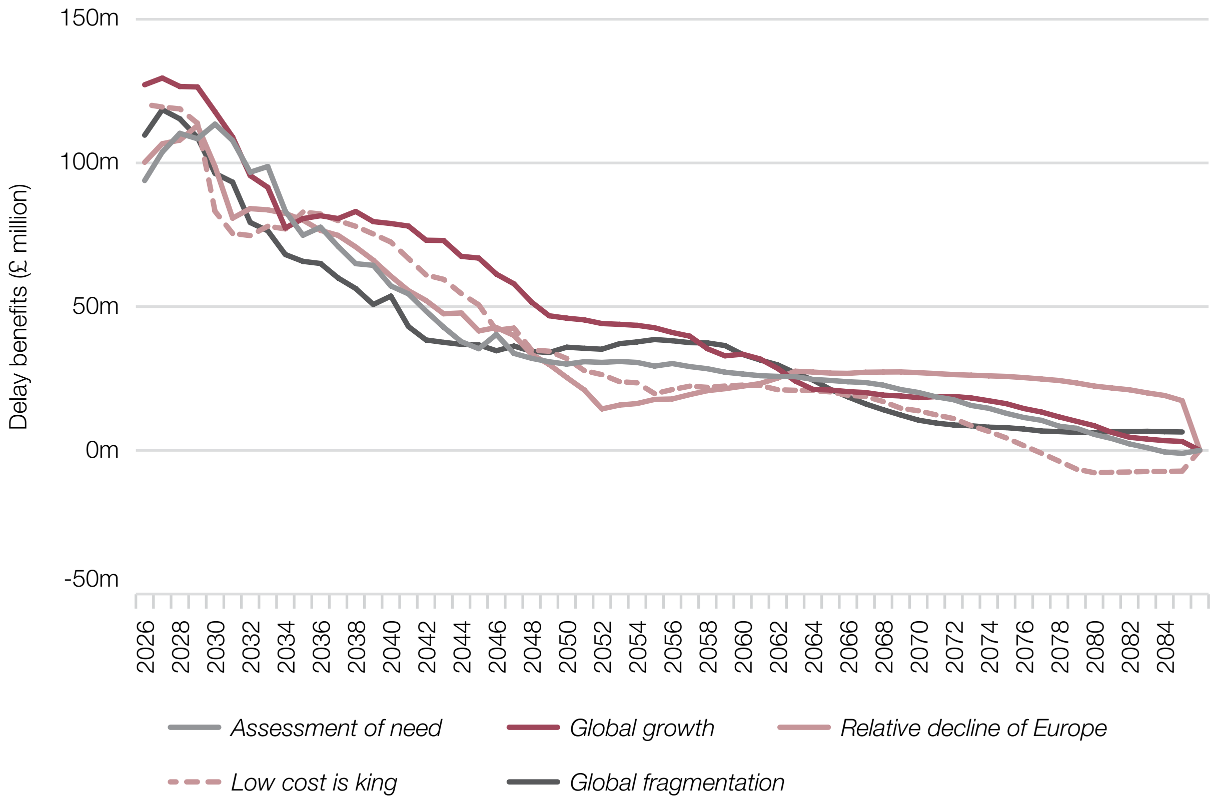

*Source: Airports Commission analysis*

**5.22** As mentioned earlier, delay benefits are driven by a combination of delay time savings and the number of passengers or ATMs that these savings accrue to. Delay time savings are higher when the additional capacity remains spare longer and so delays do not start to build up. This is the reason benefits from reduced delays are lowest for the *low cost is king* scenario where large number of passengers lead to the additional capacity filling up quickly, causing delays to occur earlier than in other scenarios.

## Carbon-capped

**5.23** The delay savings under the Heathrow Airport Extended Northern Runway scheme are between £2.3 billion in the *relative decline of Europe* carbon-capped scenario and £2.9 billion in the *global growth* carbon-capped scenario. The profile of delays savings through time is shown in the figure below.

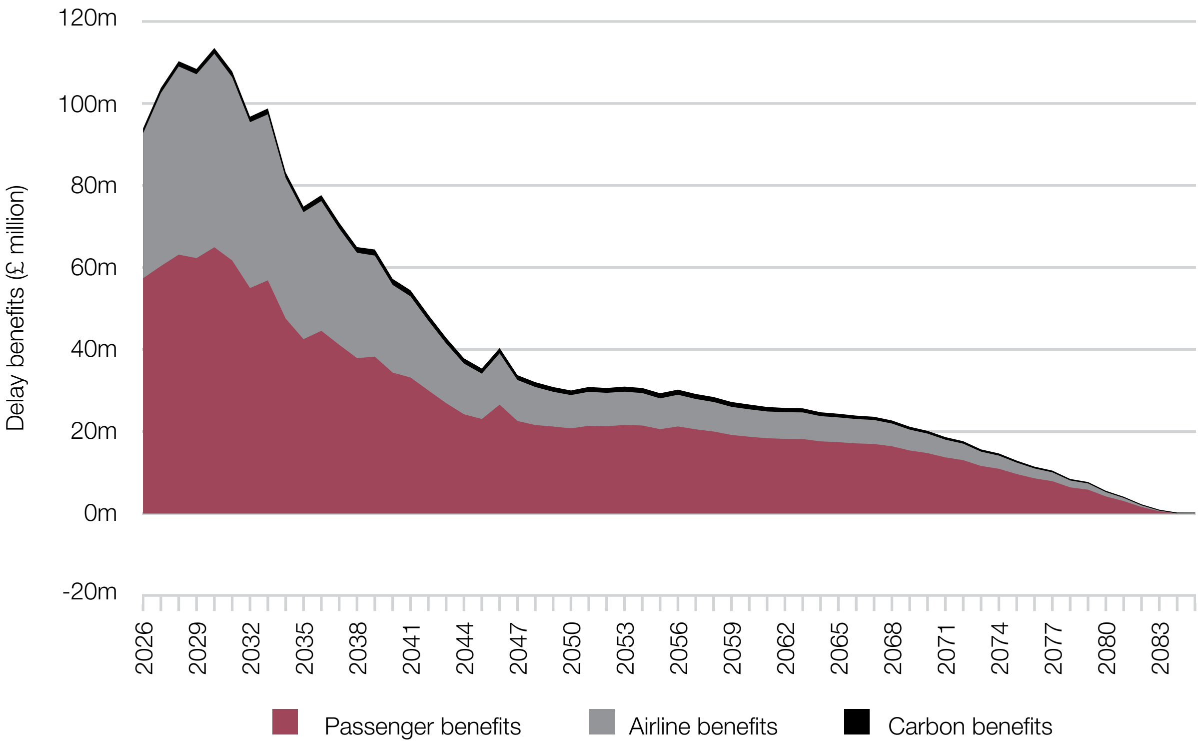
**Figure 21: LHR ENR delay benefits for different scenarios**




*Source: Airports Commission analysis*

**5.24** As mentioned above, the benefits from reduced delays in the carbon-capped case are highest in the *global growth* scenario where passenger benefits account for 64% of the total benefits (**Figure 22** below). This follows on from the delay time savings. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure 22: Delay time savings, *assessment of need* carbon-capped**



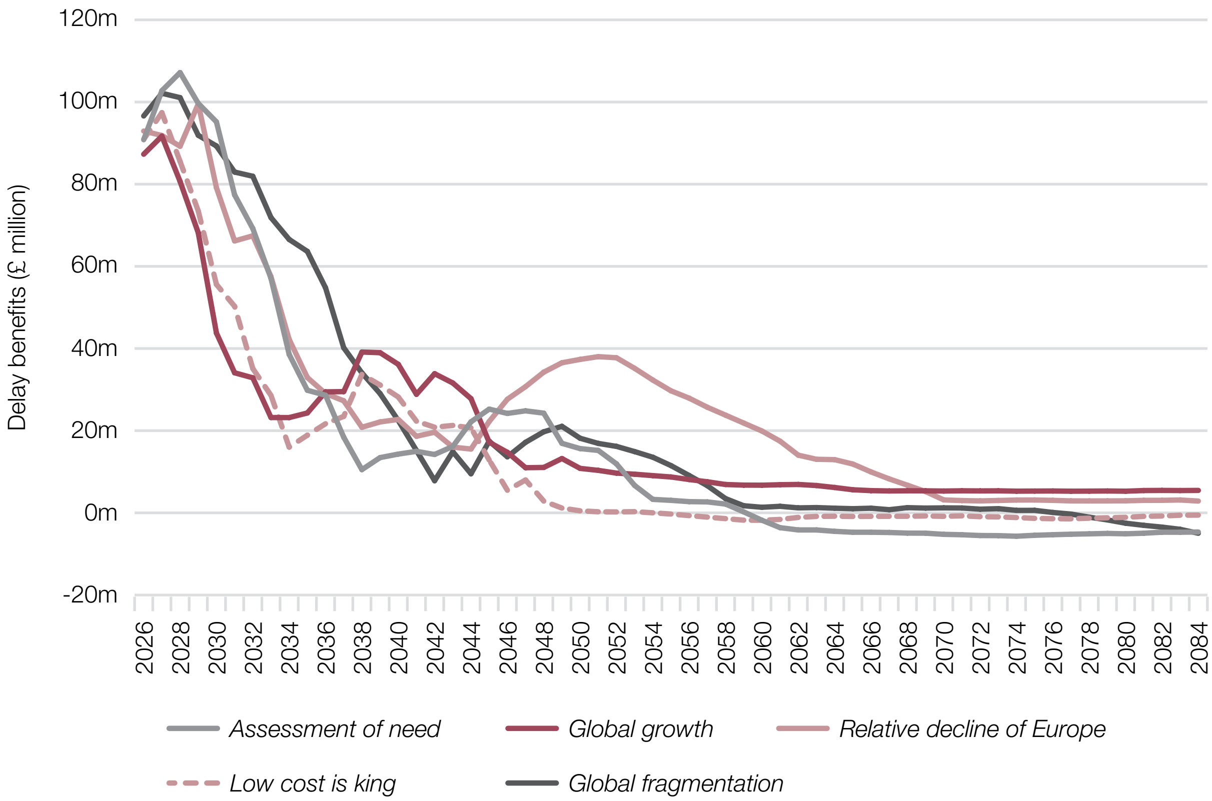

*Source: Airports Commission analysis*

## LHR NWR

### Carbon-traded

**5.25** The delay savings under the Heathrow Airport Northwest Runway expansion scheme are between £0.8 billion for *low cost is king* scenario and £1.5 billion for the *relative decline of Europe* scenario in the carbon-traded case. The profile of delays savings through time is shown in the figure below.

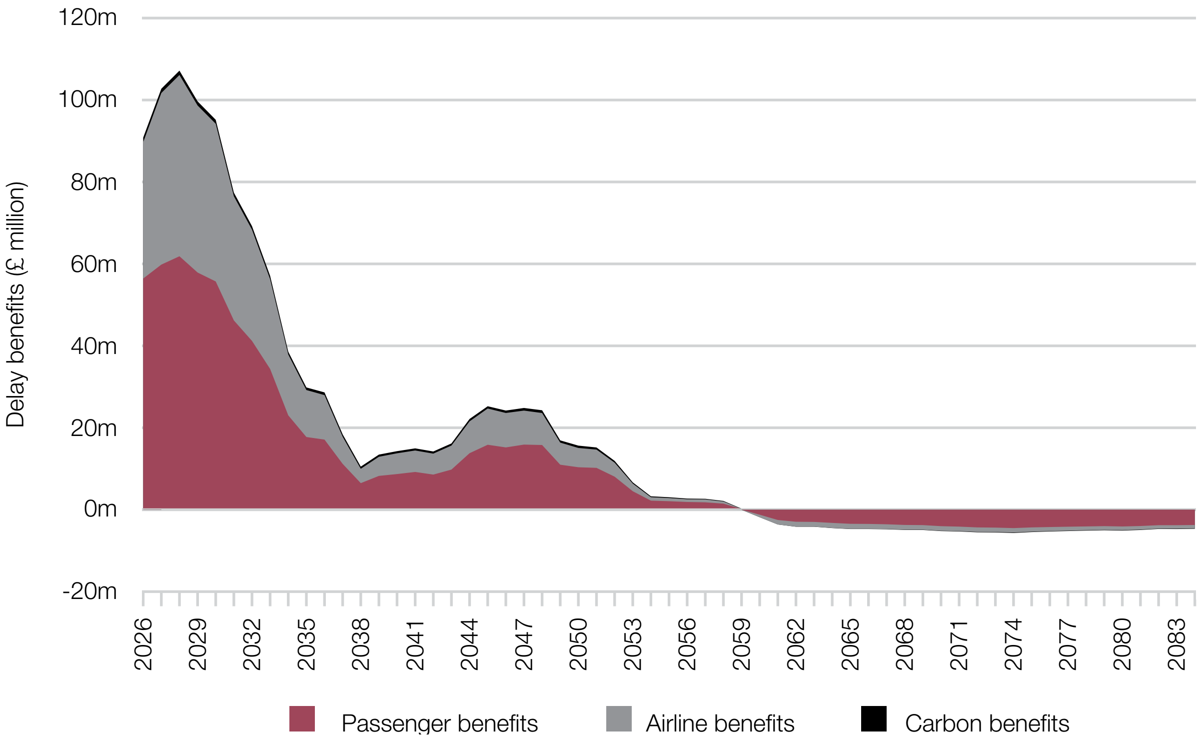
**Figure 23: LHR NWR delay benefits for different scenarios**




*Source: Airports Commission analysis*

**5.26** As shown above, the benefits from reduced delays are highest in the *relative decline of Europe* scenario where passenger benefits account for 63% of the total benefits (**Figure 24** below). This follows on from the delay time savings as seen in **Figure 23** above. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure 24: Delay time savings, *relative decline of Europe***



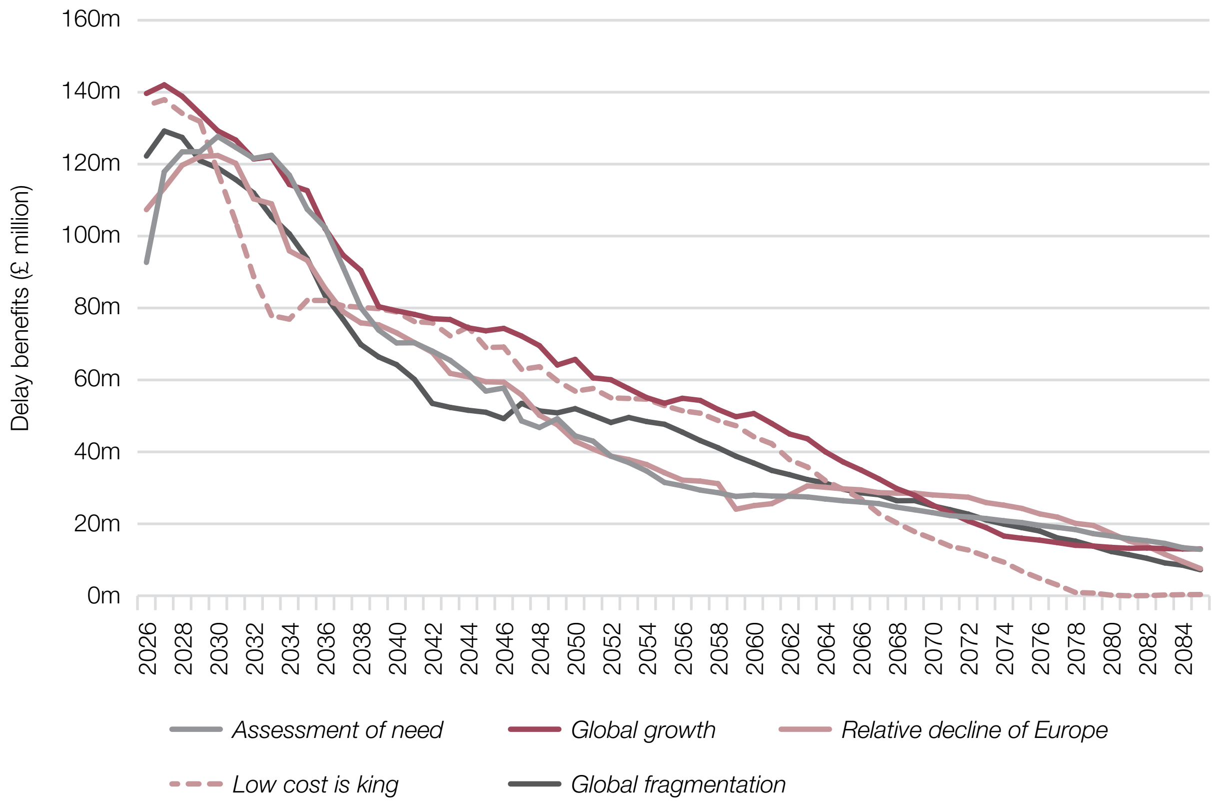

*Source: Airports Commission analysis*

**5.27** As mentioned earlier, delay benefits are driven by a combination of delay time savings and the number of passengers or ATMs that these savings accrue to. Delay time savings are higher when the additional capacity remains spare longer and so delays do not start to build up. This is the reason benefits from reduced delays are lowest for the *low cost is king* scenario where large number of passengers lead to the additional capacity filling up quickly, causing delays to occur earlier than in other scenarios.

## Carbon-capped

**5.28** The delay savings under the Heathrow Airport North West Runway scheme are between £3.0 billion in the *assessment of need, relative decline of Europe, low cost is king* and *global fragmentation* carbon-capped scenarios and £3.6 billion in the *global growth* carbon-capped scenario. The profile of delays savings through time is shown in the figure below.

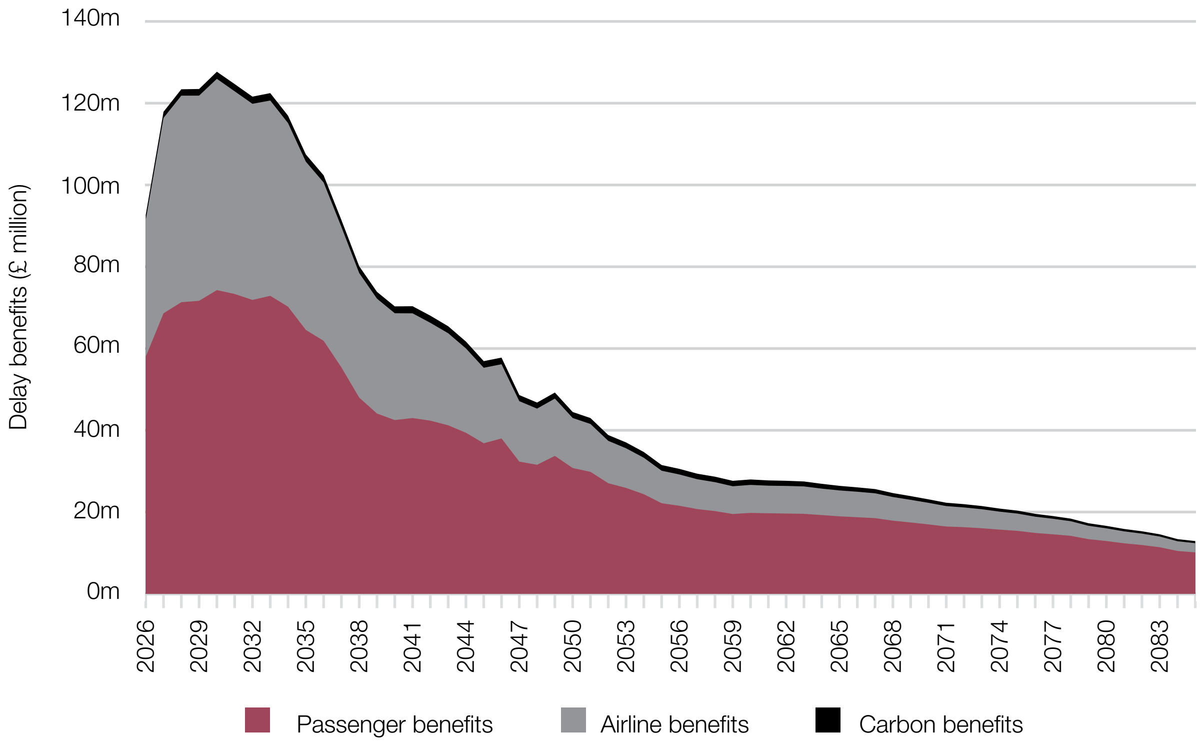
**Figure 25: LHR NWR delay benefits for different scenarios**




*Source: Airports Commission analysis*

**5.29** As mentioned above, the benefits from reduced delays in the carbon-capped case are highest in the *global growth* scenario where passenger benefits account for 66% of the total benefits (**Figure 26** below). This follows on from the delay time savings. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure 26: Delay time savings, *assessment of need* carbon-capped**




*Source: Airports Commission analysis*

# 6. Conclusions

**6.1** A review of literature on implications of delays suggests that delays at airports that function close to their capacity imposes cost to airlines, passengers and the environment. Any increase in runway capacity in the UK airport system is likely to lead to a reduction in delays at airports and thus provide benefits in addition to the transport economic efficiency and frequency benefits.

**6.2** Using a methodology derived from the UK CAA Runway Resilience Study and European airline delay cost reference values paper and inputs from the Department for Transport's aviation model, the benefits accruing to airlines, passengers and the environment through reduction in delay times at airports have been estimated.

**6.3** The Commission has found that the benefits of delays are mainly driven by time savings from reduced delays compared to the base case of no capacity expansion and the demand, given by passenger and ATM volumes. There is an inverse relationship between demand and delay time savings, which is particularly driven by how fast the additional capacity delivered by the scheme fills up and thus, delays start to build up at the airports in the system. These savings will accrue to a larger number of passengers based on the demand.

**6.4** Based on the demand scenario under consideration, the benefits of reduced delays from the Gatwick Airport Second Runway scheme are between £0.1 billion and £2.3 billion. These benefits are between £0.6 billion and £1.2 billion for the Heathrow Airport Extended Northern Runway scheme and £0.8 billion and £1.5 billion for Heathrow Airport Northwest Runway scheme.

**6.5** It is important to consider that these estimates are likely to be a lower bound for benefits of reduction in delays since the potential benefits due to limitations in data have not been included. These include benefits from reduction in tactical and ATFM delays and reduction in costs to airports from need of lower terminal capacity, amongst other things. Another area worth exploring would be the resilience of airports in adverse conditions which is affected by airports operating near capacity.

# Annex A: Carbon sensitivity test – demand reduction

Each scheme limits demand to the level that would reach the CCC planning assumption limit of 37.5Mt$CO_2$ by 2050. Each option has its own baseline in order to maximise its potential separately to operate within the emission limit. All the baselines will have emissions below the trade. It is understood that due to the restrictions, the passenger numbers will be lower than that of the other scenarios. Further details of this test are provided in the *Strategic Fit: Forecasts*.

This sensitivity has been completed for the *assessment of need* and for *low cost is king*, which demonstrates the impacts under a high demand scenario.

## Gatwick Airport Second Runway

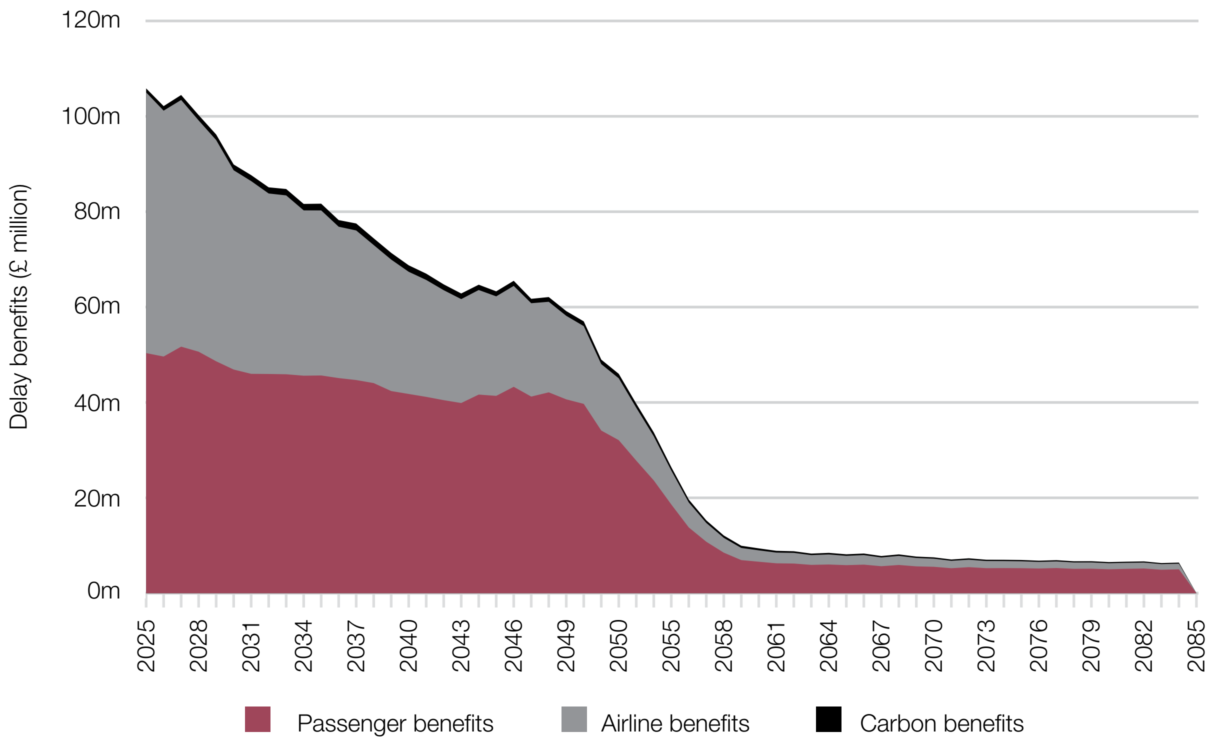
The delay savings under the Gatwick Airport Second Runway scheme are between £1.2 billion in the *low cost is king* demand-reduction scenario and £2.5 billion in the *assessment of need* demand-reduction scenario. The profile of delays savings through time is shown in the figure below.

**Figure A1: LGW 2R delay benefits for different scenarios**


*Source: Airports Commission analysis*

As mentioned above, the benefits from reduced delays in the demand-reduction case are highest in the *assessment of need* scenario where passenger benefits account for 60% of the total benefits (**Figure A2** below). This follows on from the delay time savings. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure A2: Delay time savings, *assessment of need* demand-reduction**

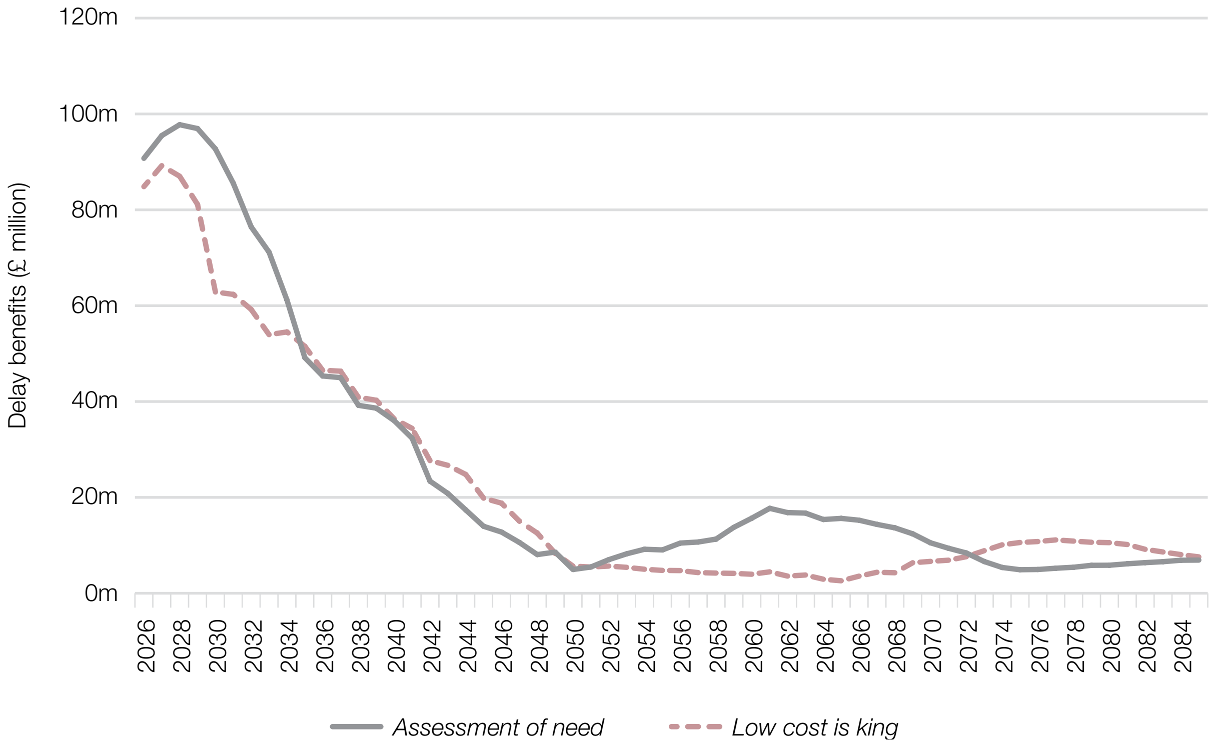



*Source: Airports Commission analysis*

## Heathrow Extended Airport Northern Runway

The delay savings under the Heathrow Airport Extended Northern Runway scheme are between £1.3 billion in the *low cost is king* demand-reduction scenario and £1.5 billion in the *assessment of need* demand-reduction scenario. The profile of delays savings through time is shown in the figure below.

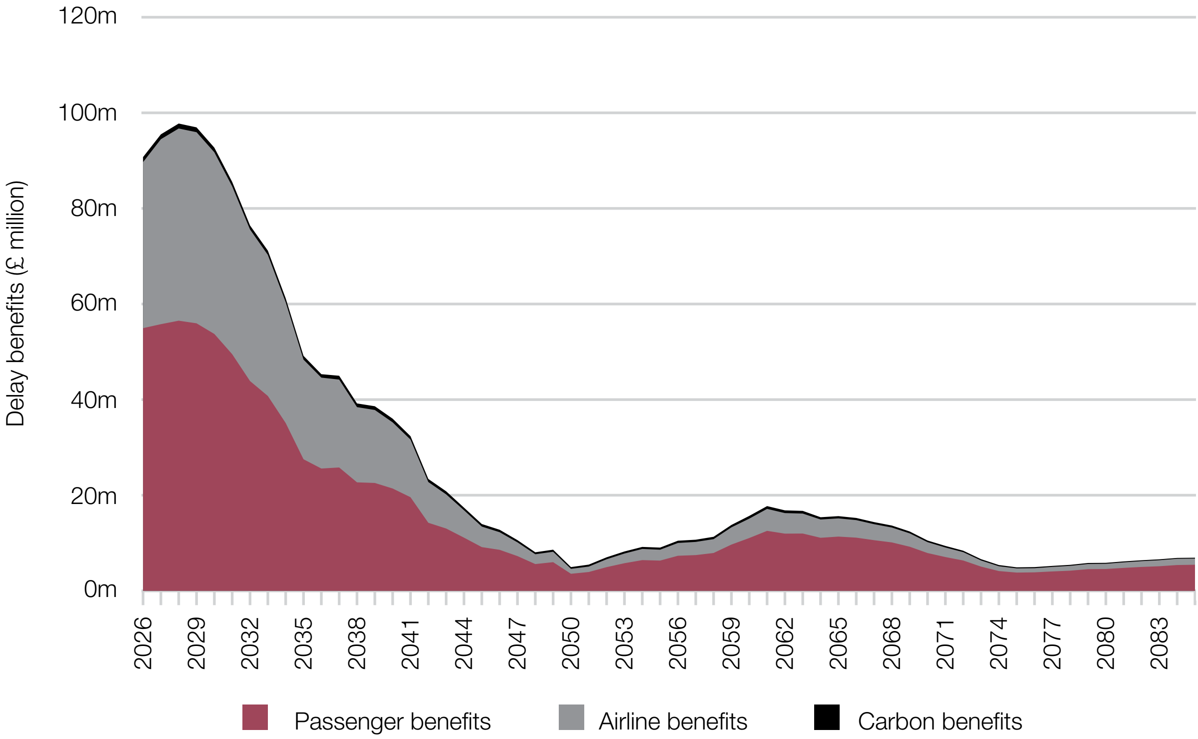
**Figure A3: LHR ENR delay benefits for different scenarios**




*Source: Airports Commission analysis*

As mentioned above, the benefits from reduced delays in the demand-reduction case are highest in the *assessment of need* scenario where passenger benefits account for 62% of the total benefits (**Figure A4** below). This follows on from the delay time savings. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure A4: Delay time savings, *assessment of need* demand-reduction**

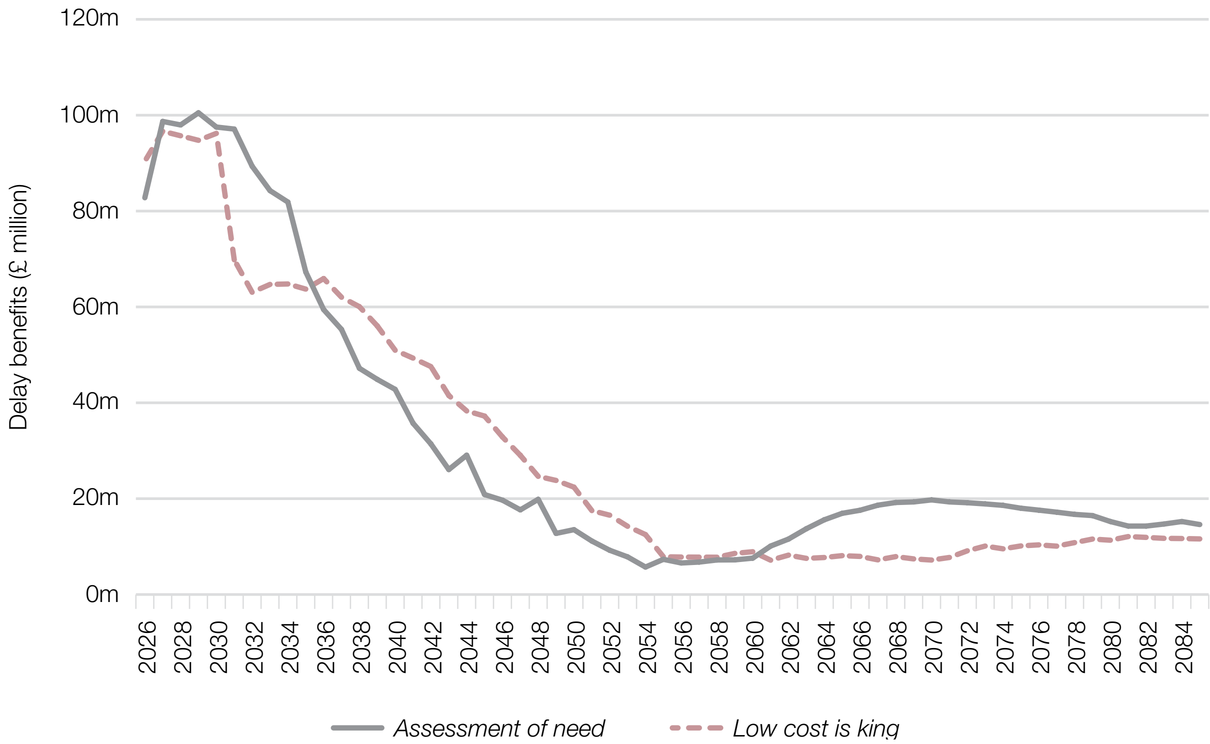



*Source: Airports Commission analysis*

## Heathrow Airport Northwest Runway

The delay savings under the Heathrow Airport Northwest Runway scheme are between £1.8 billion in the *low cost is king* demand-reduction scenario and £1.9 billion in the *assessment of need* demand-reduction scenario. The profile of delays savings through time is shown in the figure below.

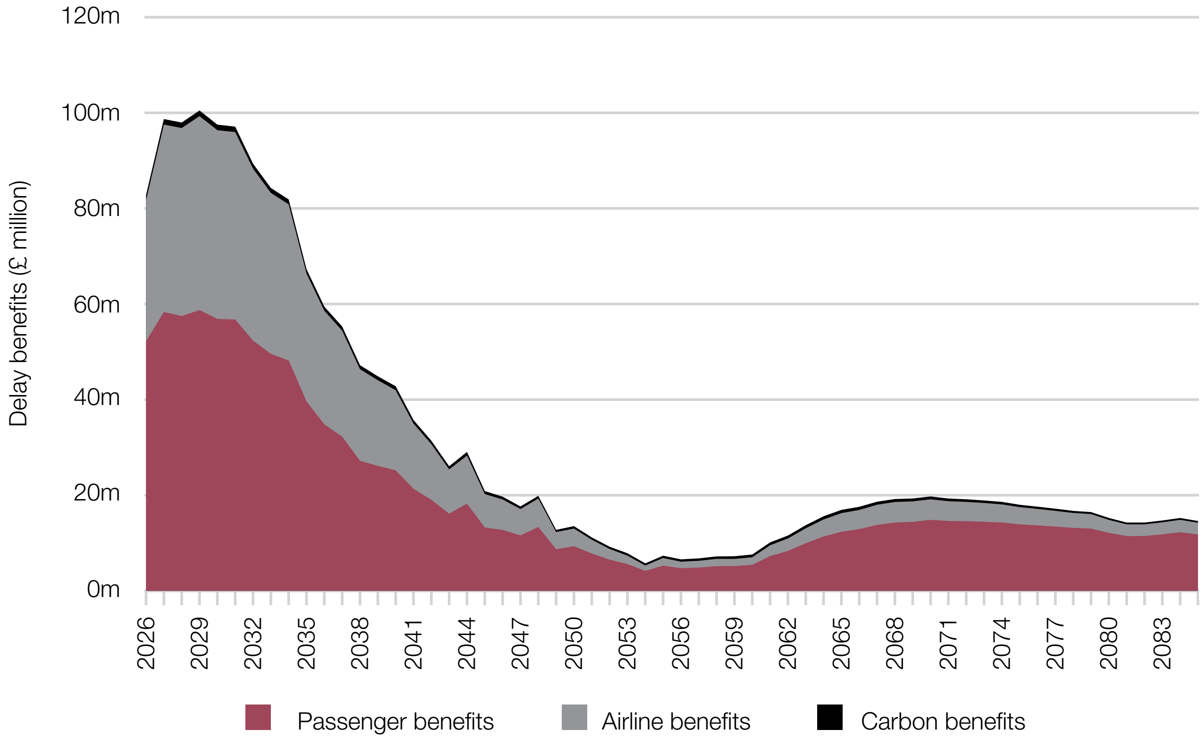
**Figure A5: LHR NWR delay benefits for different scenarios**




*Source: Airports Commission analysis*

As mentioned above, the benefits from reduced delays in the demand-reduction case are highest in the *assessment of need* scenario where passenger benefits account for 64% of the total benefits (**Figure A6** below). This follows on from the delay time savings. Due to discounting, delays in later years feed into the delay benefits to a lesser extent.

**Figure A6: Delay time savings, *assessment of need* demand-reduction**




*Source: Airports Commission analysis*

# Annex B: Delay benefits for different global scenarios and carbon cases

## Carbon-traded

### Table B1: Delay benefits in *assessment of need*, carbon-traded (in £billion, 2014 prices)

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.6 | 0.1 | 0.2 |
| | UK Leisure | 0.4 | 0.1 | 0.1 |
| | Foreign Business | 0.2 | 0.1 | 0.2 |
| | Foreign Leisure | 0.1 | 0.0 | 0.0 |
| | I-I | 0.0 | 0.0 | 0.1 |
| | Total | 1.4 | 0.4 | 0.6 |
| Airline savings | | 0.9 | 0.3 | 0.4 |
| Carbon saving | | 0.0 | 0.0 | 0.0 |
| **Total savings** | | **2.4** | **0.8** | **1.0** |

### Table B2: Delay benefits in *global growth*, carbon-traded (in £billion, 2014 prices)

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.4 | 0.2 | 0.3 |
| | UK Leisure | 0.3 | 0.1 | 0.2 |
| | Foreign Business | 0.2 | 0.1 | 0.1 |
| | Foreign Leisure | 0.1 | 0.0 | 0.1 |
| | I-I | 0.0 | 0.0 | 0.0 |
| | Total | 1.0 | 0.4 | 0.7 |
| Airline savings | | 0.7 | 0.3 | 0.4 |
| Carbon saving | | 0.0 | 0.0 | 0.0 |
| **Total savings** | | **1.7** | **0.7** | **1.1** |

### Table B3: Delay benefits in *relative decline of Europe*, carbon-traded (in £billion, 2014 prices)

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.6 | 0.3 | 0.4 |
| | UK Leisure | 0.4 | 0.2 | 0.2 |
| | Foreign Business | 0.2 | 0.2 | 0.2 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.0 | 0.0 |
| | Total | 1.3 | 0.7 | 1.0 |
| Airline savings | | 0.9 | 0.4 | 0.5 |
| Carbon saving | | 0.0 | 0.0 | 0.0 |
| **Total savings** | | **2.2** | **1.2** | **1.5** |

### Table B4: Delay benefits in *low cost is king*, carbon-traded (in £billion, 2014 prices)

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | -0.1 | 0.1 | 0.2 |
| | UK Leisure | 0.0 | 0.1 | 0.1 |
| | Foreign Business | 0.0 | 0.1 | 0.1 |
| | Foreign Leisure | 0.0 | 0.0 | 0.0 |
| | I-I | 0.0 | 0.0 | 0.0 |
| | Total | -0.1 | 0.3 | 0.4 |
| Airline savings | | 0.2 | 0.2 | 0.3 |
| Carbon saving | | 0.0 | 0.0 | 0.0 |
| **Total savings** | | **0.1** | **0.6** | **0.8** |

**Table B5: Delay benefits in *global fragmentation*, carbon-traded (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.6 | 0.3 | 0.3 |
| | UK Leisure | 0.4 | 0.1 | 0.1 |
| | Foreign Business | 0.2 | 0.1 | 0.2 |
| | Foreign Leisure | 0.1 | 0.0 | 0.0 |
| | I-I | 0.0 | 0.1 | 0.1 |
| | Total | 1.3 | 0.6 | 0.8 |
| Airline savings | | 0.9 | 0.4 | 0.5 |
| Carbon saving | | 0.0 | 0.0 | 0.0 |
| **Total savings** | | **2.3** | **1.0** | **1.3** |

## Carbon-capped

**Table B6: Delay benefits in *assessment of need*, carbon-capped (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.7 | 0.7 | 0.9 |
| | UK Leisure | 0.4 | 0.4 | 0.4 |
| | Foreign Business | 0.3 | 0.3 | 0.4 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.1 | 0.1 |
| | Total | 1.6 | 1.5 | 1.9 |
| Airline savings | | 1.0 | 0.8 | 1.0 |
| Carbon saving | | 0.0 | 0.1 | 0.1 |
| **Total savings** | | **2.6** | **2.4** | **3.0** |

**Table B7: Delay benefits in *global growth*, carbon-capped (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 1.0 | 0.9 | 1.2 |
| | UK Leisure | 0.5 | 0.4 | 0.5 |
| | Foreign Business | 0.4 | 0.4 | 0.4 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.1 | 0.1 |
| | Total | 2.1 | 1.9 | 2.4 |
| Airline savings | | 1.1 | 1.0 | 1.1 |
| Carbon saving | | 0.1 | 0.1 | 0.1 |
| **Total savings** | | **3.2** | **2.9** | **3.6** |

**Table B8: Delay benefits in *relative decline of Europe*, carbon-capped (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.7 | 0.8 | 0.9 |
| | UK Leisure | 0.5 | 0.4 | 0.5 |
| | Foreign Business | 0.3 | 0.3 | 0.3 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.0 | 0.1 |
| | Total | 1.7 | 1.6 | 1.9 |
| Airline savings | | 1.0 | 0.9 | 1.0 |
| Carbon saving | | 0.0 | 0.1 | 0.1 |
| **Total savings** | | **2.7** | **2.5** | **3.0** |

**Table B9: Delay benefits in *low cost is king*, carbon-capped (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.6 | 0.7 | 1.0 |
| | UK Leisure | 0.3 | 0.3 | 0.4 |
| | Foreign Business | 0.2 | 0.3 | 0.4 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.0 | 0.1 |
| | Total | 1.3 | 1.4 | 2.0 |
| Airline savings | | 0.8 | 0.8 | 1.0 |
| Carbon saving | | 0.1 | 0.1 | 0.1 |
| **Total savings** | | **2.1** | **2.2** | **3.0** |

**Table B10: Delay benefits in *global fragmentation*, carbon-capped (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.7 | 0.7 | 0.9 |
| | UK Leisure | 0.5 | 0.4 | 0.5 |
| | Foreign Business | 0.3 | 0.2 | 0.3 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.0 | 0.1 |
| | Total | 1.6 | 1.4 | 1.9 |
| Airline savings | | 1.0 | 0.8 | 1.0 |
| Carbon saving | | 0.1 | 0.1 | 0.1 |
| **Total savings** | | **2.7** | **2.3** | **3.0** |

**Table B11: Delay benefits in *assessment of need*, demand reduction sensitivity (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.6 | 0.5 | 0.6 |
| | UK Leisure | 0.4 | 0.2 | 0.3 |
| | Foreign Business | 0.3 | 0.2 | 0.2 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.1 | 0.1 |
| | Total | 1.5 | 0.9 | 1.2 |
| Airline savings | | 0.9 | 0.5 | 0.6 |
| Carbon saving | | 0.0 | 0.0 | 0.0 |
| **Total savings** | | **2.5** | **1.5** | **1.9** |

**Table B12: Delay benefits in *low cost is king*, carbon-capped sensitivity (in £billion, 2014 prices)**

| | | LGW 2R | LHR ENR | LHR NWR |
|---|---|---|---|---|
| Passenger savings | UK Business | 0.3 | 0.4 | 0.5 |
| | UK Leisure | 0.2 | 0.2 | 0.3 |
| | Foreign Business | 0.1 | 0.1 | 0.2 |
| | Foreign Leisure | 0.1 | 0.1 | 0.1 |
| | I-I | 0.0 | 0.0 | 0.1 |
| | Total | 0.7 | 0.8 | 1.1 |
| Airline savings | | 0.5 | 0.5 | 0.7 |
| Carbon saving | | 0.0 | 0.0 | 0.0 |
| **Total savings** | | **1.2** | **1.3** | **1.8** |

# Annex C: Global scenarios and Carbon cases

A1. Five possible scenarios of future demand are considered and are briefly described below.

| | |
|---|---|
| *Assessment of need* | This scenario is consistent with the forecasts underpinning the Commission's assessment of need. Future demand is primarily determined by past trends and the central projections published by sources such as the Office for Budgetary Responsibility, OECD and IMF. |
| *Global growth* | This scenario sees higher global growth in demand for air travel in the future.<br><br>It adopts higher passenger demand from all world regions, coupled with lower operating costs and assumes any actions to manage carbon emissions from aviation (see below) are taken at the global level. |
| *Relative decline of Europe* | This scenario sees higher relative growth of passenger demand in emerging economies in the future compared to the growth in the developed world.<br><br>It adopts higher passenger demand from newly industrialised and developing countries, a strengthened position of Far and Middle Eastern aviation hubs and airlines, and assumes any actions to manage carbon emissions from aviation are taken at the global level. |
| *Low-cost is king* | This scenario sees the low cost carriers strengthening their position in the short-haul market and capturing a substantial share of the long-haul market.<br><br>As with *global growth*, it also sees higher passenger demand from all world regions, lower operating costs, and assumes any actions to manage carbon emissions from aviation are taken at the global level. |

| | |
|---|---|
| *Global fragmentation* | This scenario sees economies close themselves off by adopting more conditional and interventionist national policies.<br><br>As a result, there is a decline in passenger demand from all world regions, coupled with higher operating costs and no global carbon agreement is reached, leading to the UK introducing unilateral measures on carbon emissions from aviation. |

A2. The Commission has forecast demand based on different approaches to handling carbon emissions from aviation:

- 'Carbon-traded' – These cases assume that carbon emissions from flights departing UK airports are traded at the European level until 2030 and then as part of a liberal global carbon market. As such these forecasts assume that the total emissions allowed beyond 2030 in the global market are set with reference to stabilisation targets and that society seeks to make reductions where they are most desirable or efficient across the global economy. This market would be established under a future international agreement that aims for a global temperature increase of equal, or close to, 2°C and aims to ensure that a 4°C global temperature increase is reached only with very low probability (less than 1%). Therefore, it is assumed that any aviation emissions target can be met in part through buying credits from other sectors. The carbon-traded case assumes that carbon is traded at a price equal to DECC's central long run forecast of carbon prices (September 2013 version) for appraisal.
- 'Carbon-capped' – These cases represent the level of aviation demand consistent with the Committee on Climate Change's current assessment of how UK climate change targets can most effectively be met. These forecasts increase the costs of carbon to ensure demand for aviation in the UK is reduced to stay within this planning assumption and as such assume no trading of aviation emissions either within the UK economy or internationally e.g. such as under an EU Emissions Trading Scheme or any international global agreement to tackle these emissions.

- 'Demand Reduction'- For this approach, a set of forecasts have been prepared in which underlying demand is reduced to a level at which overall UK aviation emissions with expansion would not exceed 37.5 $MtCO_2$ (and hence lower emissions are seen in the 'do minimum' forecast). Whilst conceptually this would be consistent with UK aviation being subject to some form of international trading scheme, no trading or purchase of offsets has been included to allow UK aviation emissions to rise above 37.5$MtCO_2$. Further details of this approach are contained in *Economy: Transport Economic Efficiency Impacts* and *Strategic Fit: Forecasts.*[28]

28 *Strategic Fit: Forecasts* – https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/374660/AC05-forecasts.pdf

# Annex D: Changes in the delays model since consultation

| Category | Old version | New version |
|---|---|---|
| Demand to capacity (D/C) ratios | ATM demand to runway capacity ratio but equal to 1 if airport has runway or terminal shadow costs | Same as before for all airports expect Heathrow and Gatwick. ATM demand to runway capacity ratio but equal to 1 if airport has runway shadow costs for Heathrow and Gatwick. |
| Delay times | Delay time relationships read up to 1 decimal place | Delay time relationships read up to 2 decimal places |
| | Helios model relationship netting off reduced delays from short term measures as per LeighFisher report across D/C ratios where delays exist, for all airports. | Helios model netting off reduced delays from short term measures as per LeighFisher report only for Heathrow. Helios model relationship for all other airports. |
| Passenger benefits | Benefits accrue to min (DM,DS) passengers with DS journey purposes | Benefits accrue to min (DM,DS) passengers at aggregated journey purpose level |
| | Benefits to I-Is not included | Includes benefits to I-Is |
| VoT | Business VoT same across all airports = weighted average of business VoT for each airport | Business VoT different across all airports as per 2008 study |
| Airline benefits | 2020, 2030, 2050 fleet mix used | 2025, 2040, 2050 fleet mix used |
| | Does not include market price adjustments for airline costs | Includes market price adjustments for airline costs |
| | 'Others' category in fleet mix with no costs | 'Others' category reassigned to Turboprop fleet type with costs |
| Carbon benefits | 2020, 2030, 2050 fleet mix used | 2025, 2040, 2050 fleet mix used |
| $CO_2e$ emissions | 1 kg of jet fuel = 3.15 kg of $CO_2e$ | 1 kg of jet fuel = 3.18 kg of $CO_2e$ |

| Category | Old version | New version |
|---|---|---|
| Airports considered | Only airports that reached over 80% D/C ratios up to 2050 – Heathrow, Gatwick, Stansted, Luton, London City, Aberdeen, Belfast City, Birmingham, Edinburgh, Manchester, Newquay and Southend | All airports in the UK airport system |

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