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Development and Assessment of Airport Capacity Options

Short Term Options: Technical Report

Prepared for:

Airports Commission

9 December 2013

Document control sheet

Client: Airports Commission
Project: Development and Assessment of Airport Capacity Options
Document Title: Short term options: Technical report

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9 December 2013				
Document status: Final				

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1. INTRODUCTION

Introduction

A consortium of consultancies was appointed by the Airports Commission ("the Commission"), through a contract with Jacobs, to support and advise the Commission in its consideration of potential options for making best use of existing airport capacity in the short and medium term.

This technical report considers the approach taken in the assessment of the short and medium term options. The approach taken in the assessment of long term options is reported separately.

This report describes the methods used to quantify the operational, environmental, and economic impacts, where possible, of the various measures submitted to the Commission for making best use of existing capacity in the short and medium term. The results and conclusions are presented separately in the scenario templates (see below). The principal objective of the assessment was to provide an indication of the overall effectiveness of measures in contributing towards either a more efficient aviation sector, or to produce benefits from more capacity. The approach has drawn heavily on previous work and used standard, accepted industry approaches to give broad, high level strategic estimates of the impacts. The methods used were necessarily bespoke to the measures being assessed meaning sometimes that the results are not directly comparable with each other and with those generated in parallel work. Additionally, in many cases, it has not been possible to quantify results due to lack of data on which to base analyses. This report describes in detail the methods used to assess the impacts for those measures that were possible to quantify; where quantification was not possible, the impacts were described qualitatively in the templates. In addition, the limited timescales available for review and assessment meant that existing tools and techniques had to be used and precluded the development of large scale modelling and simulation tools that would be needed to assess some of the potential measures in greater detail.

Overview of scenarios tested

Data were consolidated and presented to the Airports Commission in a series of "templates" presenting the key points and providing information to the Commission in support of its sifting process and decision making. Templates were produced at two levels:

- **measures templates:** consolidating the proposals contained in each of the more than 70 submissions made to the Commission for consideration, into similar sets of measures classified in nine broad areas[1]. The impacts of each of the measures proposed were considered qualitatively in the first instance in the measures templates;
- **scenario templates**: constructing six potential future scenarios by combining the measures, as described below.

From the measures templates, a core package was constructed of short-term measures focused on enhancing resilience. Five additional scenarios were also compiled for testing the full range of options available compared to the core package. These scenarios were based on different combinations of the measures submitted to the Airports Commission. The components comprising each scenario are contained in the scenario templates published alongside this technical report. Once the scenarios had been constructed, the quantified impact of the individual measures were used as building blocks to quantify the combined impact of each of the scenarios, noting that in some cases, measures might be mutually exclusive or one might replace or subsume another over time. The impacts of the core package were quantified against a 2008 baseline and the impact of each of the scenarios was then compared to the core package as well as the 2008 baseline.

The scenarios that were assessed were as follows.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226831/final-summary-short-medium-term-options.pdf

Core package of short term options

Many of the core package measures are for application at Heathrow only. The individual measures included in the core package of short term options were:

- Network level airport collaborative decision making (A-CDM);
- Implementation of on-going major programmes e.g. the Future Airspace Strategy (FAS) and the London Airspace Management Programme (LAMP);
- En-route arrival management;
- Civil/military airspace optimization;
- Creation of a known-surveillance environment;
- Optimisation of departure separation using advanced aircraft capability;
- Distributing departure routes within noise preferential route (NPR) swaths;
- Incentivisation of arrival punctuality;
- Review of triggers for application of low visibility procedures (LVP);
- Enhanced information exchange between all airfields;
- Local A-CDM;
- Reduced engine taxi;
- Use of electric vehicles airside;
- Local capacity management cell;
- Time-based separations (TBS);
- Operational freedoms at Heathrow, comprising the following main components:
  - tactically enhanced arrivals management (TEAM[2]);
  - tactically enhanced departures (TED[3]);
  - early vectoring of departures;
  - tactical management of A380s in the arrival stream;
  - use of the southern runway for Terminal 4 arrivals.
- Use of a single runway for early morning arrivals at Heathrow;
- Independent parallel approaches at Heathrow;
- Removal of the westerly preference at Heathrow;
- Application of an alternation regime on easterlies at Heathrow;
- Operation to an optimised daily service plan;
- Fifth freedom air services rights;
- Reliever airport concept;
- Incentivising quieter aircraft;
- Steeper approaches;
- Compensation packages;
- Service prioritization;

[2] allocating arrivals to the departure runway to improve arrival efficiency
[3] allocating departures to the arrival runway to improve departure efficiency

- Dual approaches to a single runway;
- Marketing regional airports as destinations;
- Tactical use of Northolt for domestic connectivity.

Scenario 1: maximum capacity

This scenario considered the following measures over and above those included in the core package of short term measures designed to enhance capacity in the short-term, specifically at Heathrow:

- Introduction of mixed mode operations for Heathrow runways to increase capacity considering scenarios with a revised planning cap of 500,000 air transport movements (ATMs), 515,000 ATMs or 520,000 ATMs;
- Removal of the night flights cap at Heathrow, Gatwick and Stansted;
- Four tracking of the Lea Valley Line to increase capacity to Stansted;
- Reduction of or lowering the rate of airport passenger duty (APD).

The latter two options were not included in the template assessment.

Scenario 2: maximum resilience

This scenario considered the following measures over and above those included in the core package of short term measures designed to enhance resilience in the short-term, specifically at Heathrow:

- Introduction of mixed mode operations for Heathrow runways for resilience purposes while maintaining the movement cap at 480,000 ATMs per year;
- Reducing capacity declaration at major airports to manage down congestion over time (or prevent airports reaching full capacity);
- Banning business and general aviation from Heathrow and Gatwick;
- Maintaining the current night flight regime.

Scenario 3: maximum mitigation

This scenario considered the following measures over and above those included in the core package of short term measures designed to reduce the impact of airports on their neighbours:

- Reduction or ban on night flights at Heathrow;
- Lowering capacity declaration at major airports;
- Displaced thresholds resulting in aircraft being higher above the ground at a specific distance from touchdown, with a resultant reduction in noise contours;
- Restricting new development within noise contours and supporting the development of clear guidance on the planning, policy and compensatory action;
- Developing a comprehensive noise compensation regime;
- Developing higher night time landing charges at Heathrow;
- Banning general aviation and business aviation from Heathrow and Gatwick;
- Establishing an independent noise regulator;
- Incorporating the Quota Count (QC) system into full day operations at all major airports.

Scenario 4: more night flights but no more flights overall

This scenario considered the following measures over and above those included in the core package of short term measures designed to allow the optimisation of schedules and operations into the night period:

- Raising or eliminating night flights cap at Heathrow and re-arrange other movements within the cap;
- Lowering capacity declaration at major airports to manage down congestion;
- Displaced thresholds resulting in aircraft being higher above the ground at a specific distance from touchdown, with a resultant reduction in noise contours;
- Banning general aviation and business aviation from Heathrow and Gatwick;
- Incorporating or diluting the QC system into full day operations at all major airports.

Scenario 5: extra Heathrow capacity with offsets

This scenario considered the following measures over and above those included in the core package of short term measures to allow additional flights at Heathrow with no major change in infrastructure or operational procedures:

- Raising the annual Heathrow ATM cap to 550,000 ATMS per year;
- Applying enhanced TEAM and TED to improve overall efficiency as circumstance allow;
- No increase in the night flights cap;
- Displaced thresholds resulting in aircraft being higher above the ground at a specific distance from touchdown, with a resultant reduction in noise contours;
- Increase incentives for quieter aircraft;
- Incorporate the QC system into full day operations at all major airports;
- Establish an independent noise regulator.

2. OPERATIONAL IMPACT ASSESSMENT

Introduction

This section describes the approach taken to assessing the operational impact of the measures that were quantifiable. Full descriptions of the measures are provided in the relevant measures templates.

Calculating the impacts of arrivals queue management

NATS estimates that arrivals queue management is capable of transferring up to three minutes delay per flight from the stacks to the en route phase of flight. This formed the basis of the impact assessment.

The approach to calculation of the fuel and CO_2 benefits from arrival queue management was based on the work performed jointly by NATS and CAA.[4] The process applied was as follows:

- the average impact of applying arrival queue management was assessed by averaging the reduction in stack holding to individual flights on a flight-by-flight basis, using operational records, and averaging over summer and winter seasons separately. This was achieved by subtracting for each flight the three minutes absorbed in the en route phase of flight, transferred from the stack hold (setting the hold to zero for flights held less than the time absorbed en route) to calculate a new average stack hold per flight. Sensitivity of the results to the amount of time that can be absorbed en route was also tested by varying the assumption that three minutes could be absorbed en route from one minute to five minutes. Examination of the savings in average stack holding, as a proportion of the average was tested for 2008, 2010 and 2012 (years for which data are available) and found to be consistent year-on-year and summer to winter. The results are shown in the following figure, indicating that absorbing three minutes of stack holding in the en route phase of flight would reduce average stack holding by approximately 40%;

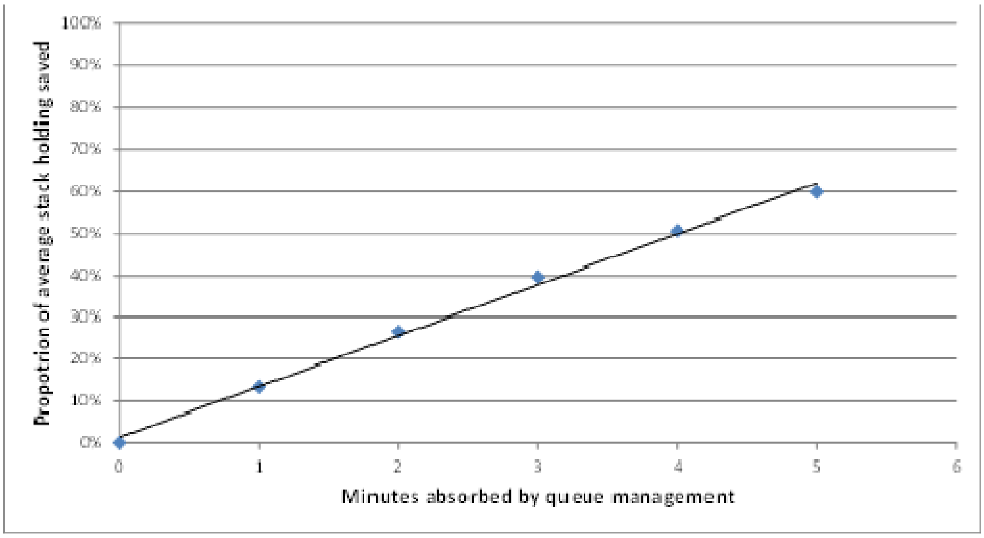

Figure 1:Proportion of stack holding reduced by queue management

- CO_2 emissions calculated for observed stack holding are scaled according to the ratios of the average stack holding delay (calculated in the queue management scenario) to the observed stack holding delay. This assumes that queue management has a uniform impact across all flights, which is reasonable given that all of the calculations are based on broad averages;
- the saving in CO_2 is the difference between the emissions from the observed stack holding and the stack holding reduced by queue management. This assumes that the reduced emissions from flying more slowly compensates for the increased time in the en route phase of flight. The work performed by NATS and CAA indicates that this is a reasonable assumption and probably represents an

4 Feasibility and options for reducing airborne holding for Heathrow arrivals, Helios report produced under Framework Agreement 1387 Service Order Number 20, 30 June 2011

underestimate in savings. Averaged over winter and summer seasons, the calculations indicate that queue management would save just over 100,000 tonnes of CO_2 per year, based on 2008 traffic;

- fuel savings are calculated from reduced emissions at the ratio of 3.149 tonnes of CO_2 equates to one tonne of fuel, indicating that queue management would save approximately 33,000 tonnes of fuel; and
- fuel is assumed to cost $1000 or £667 per tonne[5], indicating that queue management that absorbed three minutes of stack holding per flight would result in an annual saving, compared to 2008, of approximately £22M per year.

The impacts of queue management were scaled for Gatwick using the results for Heathrow. Scaling factors of 16% in summer and 9% in winter were used based on the relative magnitudes of stack holding at Heathrow and Gatwick described in the CAA runway resilience report.

Calculating the impacts of changes in capacity and demand

Introduction

A number of the proposed measures are based on changing the ratio of runway demand to runway capacity. However, the measures as proposed are often not defined fully or explicitly and required gaps to be filled in order for impacts to be estimated. Our interpretation of these measures is as follows:

- the principle of **time-based separations** is to mitigate the reduction in runway capacity during periods of strong headwinds. This does not provide additional capacity;
- **early morning smoothing** on a single runway re-distributes the demand in the early morning. It has been assumed that this smoothing occurs in the first three hours of the day and distributes the demand evenly over those three hours, effectively increasing demand between 05:00 and 06:00 but reducing demand in the following two hours;
- **independent parallel approaches** increases capacity when both runways are being used for arrivals because the two traffic streams no longer have to be coordinated with each other;
- **reduced spacing on SIDs** (standard instrument departure routes) increases departure capacity by up to 15%;
- both **TEAM** and **TED** allow both runways (at Heathrow) to be used simultaneously for arrivals or departures respectively. TEAM therefore increases arrival capacity, but reduces departure capacity and, conversely, TED increases departure capacity but decreases arrivals capacity;
- **mixed mode** allows both runways to be used for both arrivals and departures at the same time providing a general increase in capacity without the penalties associated with separate application of TEAM or TED in segregated mode operations. Some of the mixed mode scenarios investigated also include a relaxation of the movement cap and, hence, allowing an increase in demand, as well as increased capacity for existing flights.

Some of the measures are mutually exclusive or combination of their impacts would be double counting. This has been taken into account when combining the individual impacts into scenario impacts as follows:

- mixed mode supersedes the impacts of operational freedoms, TEAM and TED, time based separations and reduced separation between SIDs;
- smoothing early morning arrivals on a single runway precludes the application of mixed mode, TEAM or operational freedoms before 08:00.

5 Heathrow Airfield Operational Efficiency Programme Benefits Case, draft 14 April 2013

Approach to delay modelling

Changes in the ratio of demand to capacity are readily investigated using statistical techniques, based on and validated against a large sample of operational data. This methodology was developed and applied successfully in the CAA's 2008 runway resilience study and has been extended and re-applied in this analysis.

The same modelling process, based on a standard queuing approach, has been applied to all elements of holding. The general approach consists of six main steps, is summarised below with an overview being given in Figure 2.

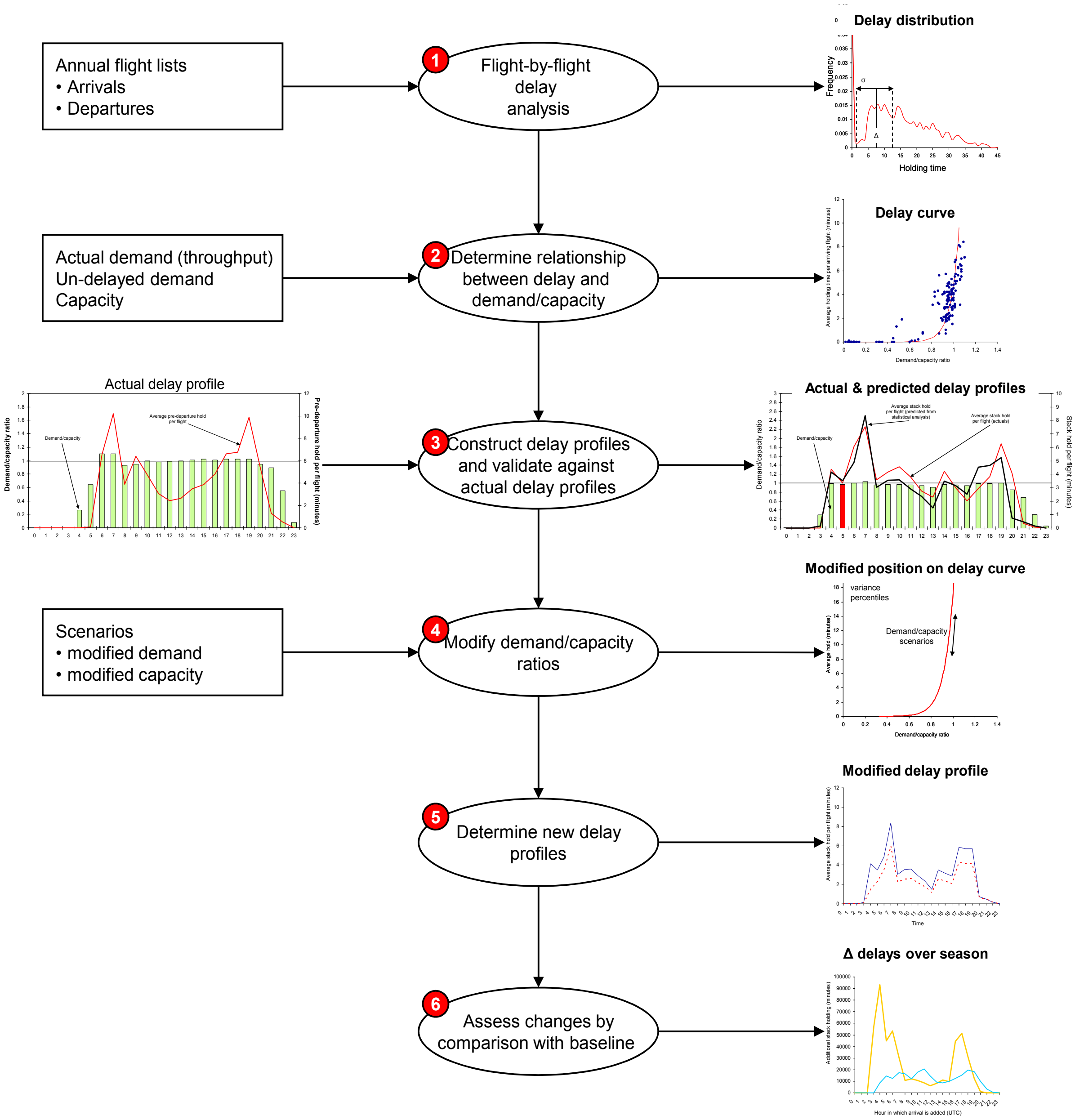

Figure 2:Overview of statistical analysis process

The basic steps in the modelling process were as follows:

- Step 1 in the analysis process comprised analysis of flight-by-flight data to determine delay distributions. These delay distributions were calculated for each hour of operation over the 2008 summer and winter seasons and characterised by the average and the 95th percentile representing the peak;

- Step 2 in the analysis process used the delay distributions and hourly un-delayed demand derived from the flight-by-flight data. It involved determining when the flight would have operated had it not been delayed, and capacity derived from the scheduling limits or flow regulations when these were in place, to determine the relationship between delay (average and 95th percentile) and the ratio of demand to capacity;
- Step 3 of the process used the delay, demand/capacity relationship to reconstruct the hourly delay profile and to compare this predicted profile with the one actually observed as a means of validating the approach. Hourly profiles were created for both average delays per flight and peak (95%ile) delays per flight and compared to the corresponding operational data. These modelled hourly delay profiles are defined as the baseline for comparison with the scenarios to be investigated;
- Step 4 modified the demand/capacity ratios based on the scenarios being assessed by modifying the capacity and demand profiles appropriate for the scenario being considered. The new delay for the scenario was predicted from the position on the delay curve of the modified demand/capacity ratio;
- Step 5 constructed the hourly delay profiles for the scenario from the new delays derived in Step 4. Rollover effects from hour-to-hour were incorporated by adding the requisite number of additional flights to the subsequent hour if the modified demand/capacity ratio was greater than unity;
- Step 6 compared the scenario delay profile with the baseline and calculated the new total delays for the day accounting for changes in traffic caused by the addition or subtraction of demand.

The outputs of the scenario modelling process were:

- baseline hourly average and peak delay profiles for Air Traffic Flow Management (ATFM) and stack holding for arrivals, and taxi delays (excess taxi time) for departures;
- modified hourly average and peak delay profiles for the scenario being investigated;
- change in hourly delay profiles for average and peak delays compared to the baseline (defined as the modelled delay profile rather than the actual delay profile to avoid systematic errors);
- change in total daily delays for the scenario compared to the baseline.

Time-based separations

The first step in the calculation of the benefits of time-based separations (TBS) was to determine the proportion of time that Heathrow operations are subject to high winds. This was done using data collected by Heathrow Airport during its Operational Freedoms Trial and the assumption that arrivals flows are prejudiced when the headwind at 3000ft exceeds 20 knots.[6] The basis of this is that it was one of the trigger conditions agreed for the application of operational freedoms. The proportion of the time affected by high winds was 20% of days during the summer season and 36% of days during the winter season. It was assumed that these proportions are typical of all years, not just 2012-13.

Based on discussions with NATS, TBS is expected to increase flow rates by up to five arrivals per hour during windy conditions. The assumption made for this analysis was that the increase in flow rate due to TBS is, on average, three arrivals per hour. This increase in flow rates mitigates the negative impact of wind, but does not result in an overall increase in capacity. Averaged over the season, weighted by the number of days on which windy conditions occur, this results in increases in flow rates of approximately 1.5% in summer and 2.6% in winter. The statistical delay models, described above, include the impact of high winds. Therefore, it is possible to apply these increases in capacity estimated for time-based separation to the models to estimate the reduction in delays that would be expected. Following this approach, the estimate of reductions in average stack holding delays is 1.3 minutes per flight in summer and 2.6 minutes per flight in winter, based on 2008 traffic and performance.

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6 This can be derived from the Operational Freedoms Trial monthly reports published at http://www.heathrowairport.com/noise/noise-in-your-area/operational-freedoms-trial/phase-2

This translates to (see section on economic assessment) a saving of £12M per year to airlines and a saving of £5M per year to passengers.

Early morning smoothing

The impact of early morning smoothing on arrivals delays was estimated by using the statistical delay model with a modified demand profile. The demand profile was modified by redistributing the demand evenly over the first three hours of the day, from 05:00 to 08:00, as illustrated in Figure 3 below. This figure shows that the net effect is to reduce demand in the 06:00 and 07:00 hours but increase demand in the 05:00 hour.

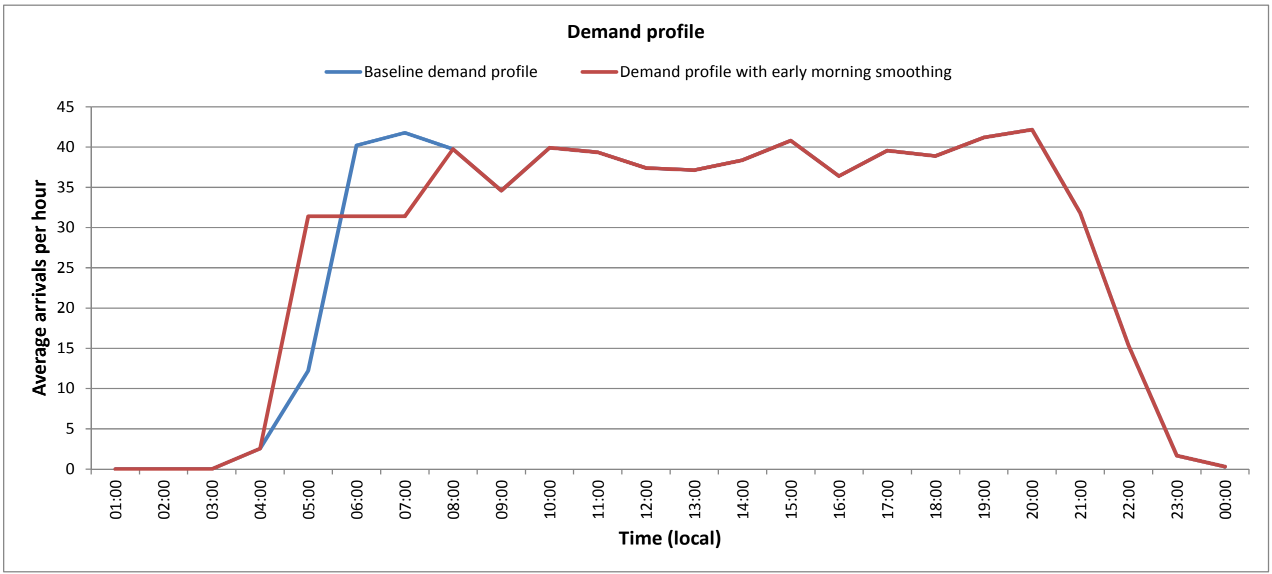

Figure 3:Redistribution of early morning demand

The modified demand profile results in a modified average stack holding delay profile as illustrated in Figure 4 for the summer season using 2008 as the baseline.

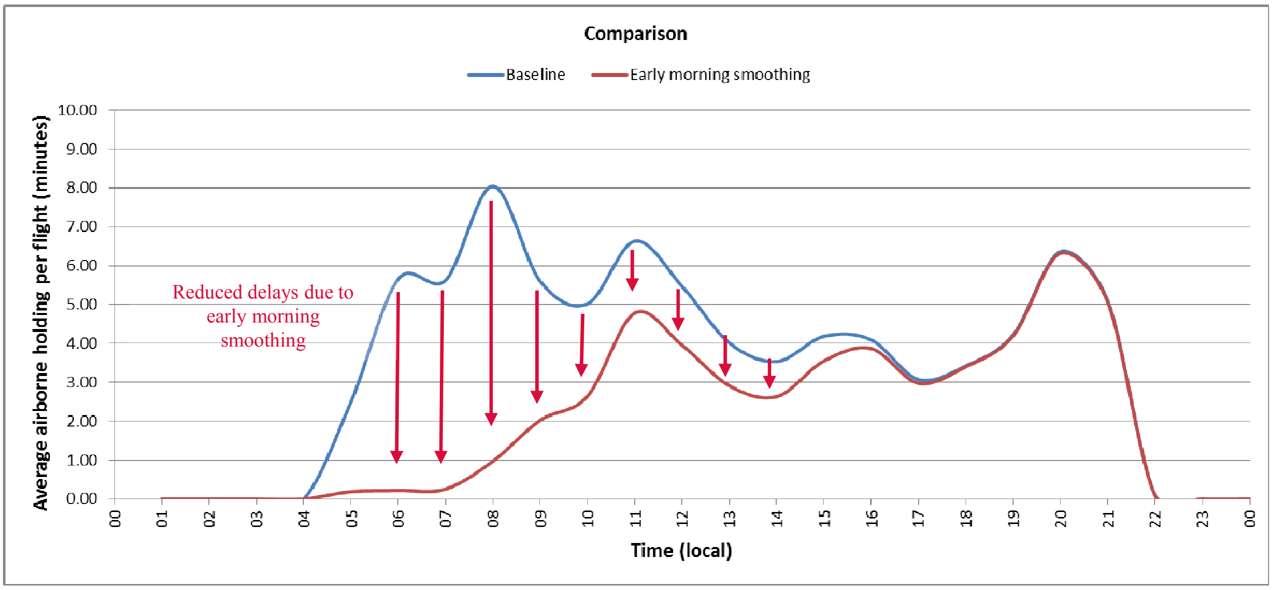

Figure 4:Illustration of the impact of early morning smoothing on stack holding

The figure shows that the measure reduces delay to very low levels when it is applied, as would be expected as demand is reduced to approximately 30 arrivals per hour compared to a capacity of approximately 40 arrivals per hour. The figure also shows that, because of knock-on effects, the impact of the early morning smoothing extends through the day to late afternoon, long after the application of the measure has ceased.

The saving or reduction in holding predicted for early morning smoothing is predicted to be approximately 1.7 minutes per flight during the summer season and 0.9 minutes per flight during the winter season. This equates to a cost saving of approximately **£12M per year** for airlines and **£6M per year** for passengers against a 2008 baseline.

Independent parallel approaches

Independent parallel approaches are an enabler of benefits when both runways are being used for arrivals simultaneously, specifically for measures such as TEAM. Under current operations, independent parallel approaches would only deliver substantial benefits in the 06:00 hour when both runways are used equally for arrivals, approximately 21 to 22 arrivals per hour on each runway with substantial stack holding. Under the assumption that independent parallel approaches would increase the capacity of each runway to approximately 30 arrivals per hour, independent parallel arrivals would deliver an average delay saving of approximately 1.1 minutes per flight in summer and 0.5 minutes per flight in winter. These averages are taken over all flights because of knock-on effects as observed in early morning smoothing.

However, in scenarios where early morning smoothing is used, independent parallel approaches would not deliver any *specific* benefits because:

- TEAM would not be applied at 06:00 in the way that it is now as only a single runway would be used for arrivals in the early morning;
- independent parallel approaches are implicitly assumed in the scenarios including TEAM and mixed mode operations.

Independent parallel approaches have, therefore, been treated as an enabler rather than delivering explicit benefits in their own right.

Reduction in separation of SIDs

The principal assumption, based on estimates from NATS, in the assessment of the impact of reduced separation of SIDs at Heathrow is that the likely gain in departure capacity is approximately 15%. The results of applying this capacity increase to the statistical delay models described above are illustrated in Figure 5 for departure delays, assuming that all aircraft have the required capabilities.

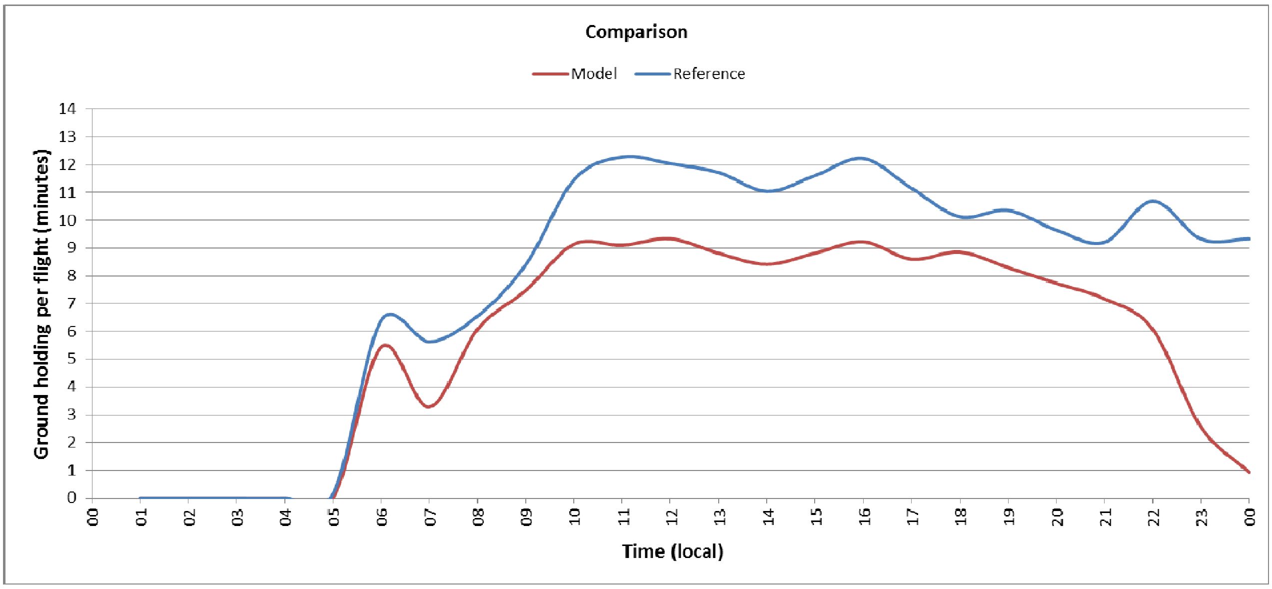

Figure 5:Illustration of the impact of reduced SID separation on departure delays

The figure shows that there is a reduction in departure delay across the entire day but that the greatest benefits in terms of reduced delays are delivered from late morning onwards. Quantitatively, the model results indicate that a 10 to 15% increase in departure capacity due to a reduction in separation of SIDs would reduce average departure delays by 2.0 to 2.8 minutes per flight in summer and 2.2 to 2.9 minutes per flight in winter compared to a 2008 baseline. This translates into a cost saving of approximately £15M to 20M per year for airlines and £10M to £14M for passengers.

Results for Gatwick were obtained by scaling the Heathrow results in proportion to the relative traffic volumes assuming similar levels of departure delay at Heathrow and Gatwick as described in the CAA's Runway Resilience study.

TEAM and TED

Tactically Enhanced Arrivals Management (TEAM) and Tactically Enhanced Departures (TED) are not designed to be applied together and so do not represent mixed mode.

As TEAM is currently applied, no additional benefits have been assumed for TEAM in most scenarios. The exception to this is considered in scenario 5 where the movement cap is lifted from 480k to 500k air transport movements (ATMs) per year. In this case, TEAM has been applied when the statistical model predicts average arrival delays of 20 minutes or more, as illustrated in the following figure, Figure 6. This figure includes the effects of early morning smoothing.

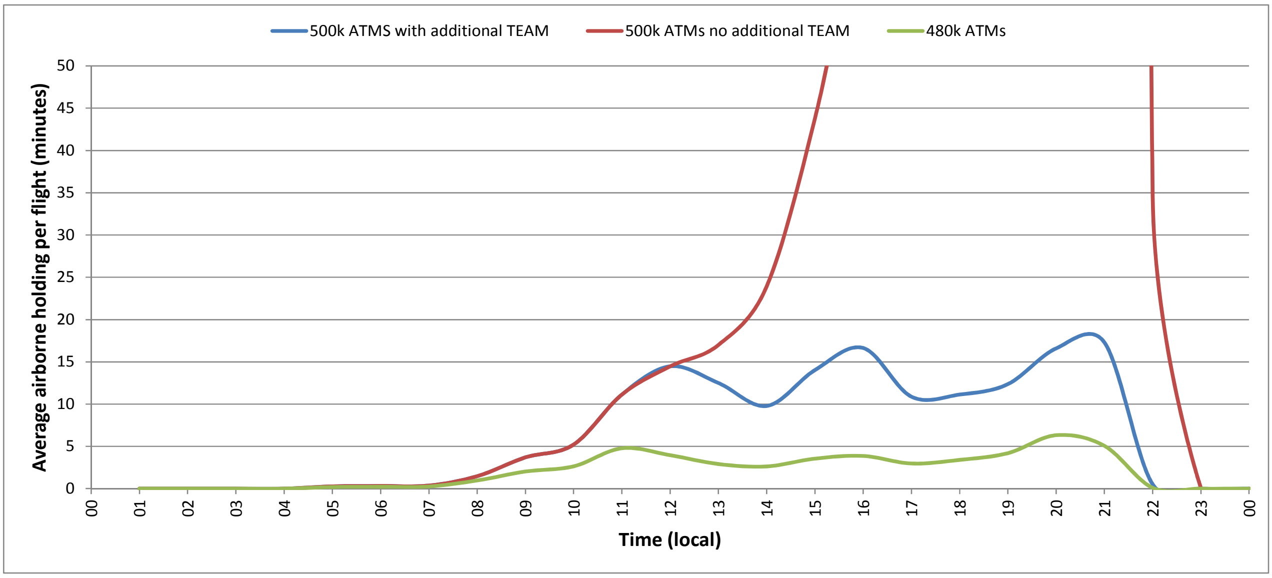

Figure 6:Illustration of the impact of additional TEAM on a 500k ATM scenario at Heathrow

The figure shows that with 500,000 ATMs without additional TEAM arrival delays escalate very quickly after the effects of early morning smoothing have worn off. The delays (red curve) are off the scale of the chart and are indicative that the arrivals queue has become unstable as demand is consistently exceeding capacity and there is no safety valve. The figure also shows the impact of applying TEAM, with an assumed increase in capacity of 5% in hours when the delay approaches or exceeds 20 minutes. This brings delays (blue curve) back to manageable proportions, although they are still considerably higher than the 480,000 ATM cap scenario (green curve). Average delays per flight in the 500,000 ATM scenario are estimated to be 9.8 minutes per flight in the summer and 9.3 minutes per flight in the winter compared to the 2008 baseline of 4.8 minutes per flight and 6.3 minutes per flight respectively.

In addition to the increased delays, caused by the additional demand, increased application of TEAM will increase the number of de-alternated flights, i.e. the number of arrivals using the designated departure runway. The modelling results indicate approximately 15 additional de-alternated flights per day, on top of the average of 15 to 23 per day normally experienced[7].

[7] Operational freedoms trial report

The situation concerning departures is complex. It is assumed that the TED benefits are coupled to the benefits delivered by reduced separation of the SIDS to deliver the full 15% capacity increase estimated by NATS. However, departure capacity is decreased by the need to apply TEAM for large parts of the day. Heathrow Airport's trial of operational freedoms[8] indicated that a loss of departure capacity of three movements per hour when TEAM is applied, i.e. a reduction in departure capacity of around 7%. Applying the statistical delay models to these scenarios for departures indicates average departure delays of 8.6 and 7.5 minutes per flight in summer and winter compared to the 2008 baseline of 9.9 and 9.8 minutes per fight respectively in the 2008 baseline. In this case, the departure delays are reduced compared to the baseline because the 15% capacity increase from reduced separation between SIDs coupled with TED outweighs the combined impact of the increase demand (approximately 5%) and the capacity decrease due to TEAM (7% decreased in departure runway capacity when TEAM is applied).

Mixed mode

Mixed mode operations would enable both runways to be used for arrivals and departures within the same time period during the day. Depending on its implementation, previous work by NATS indicates that mixed mode could deliver 5%, 10% or 15% additional capacity. In this work, it is assumed that mixed mode delivers an additional 10% in arrival capacity. When coupled with reduced separation of SIDs (which is one of mixed mode's principal enablers) mixed mode is assumed to deliver a 15% capacity increase for departures, subsuming the capacity increase due to reduced separation of SIDs. It is assumed that mixed mode operations, whether applied for resilience or capacity purposes, commence in 2019 and, when they are applied, they subsume the benefits generated by reduced separation of SIDs, TEAM and TED and operational freedoms.

Mixed mode has been investigated in several scenarios:

- as a resilience measure alone, with no additional flights, i.e. 480k movements per year;
- combined with variations on relaxation of the movement cap to:
    - 500,000 movements per year;
    - 515,000 movements per year; and
    - 520,000 movements per year.

Table 1 shows the results generated by the statistical delay model for each of these scenarios.

Scenario	Average delays in minutes per flight					
	Summer		Winter		Combined	
	Arr	Dep	Arr	Dep	Arr	Dep
2008 baseline	4.8	9.9	6.3	9.8	5.4	9.8
Mixed mode, 480k ATMs	0.9	7.2	2.1	6.8	1.4	7.0
Mixed mode, 500k ATMs	1.3	7.9	3.0	7.5	2.0	7.7
Mixed mode, 515k ATMs	1.9	8.4	4.1	8.1	2.8	8.3
Mixed mode, 520k ATMs	2.2	8.6	4.6	8.3	3.2	8.5

Table 1: Average delays estimated for mixed mode scenarios

Operational freedoms

Heathrow Airport's operational freedoms[9] trial did not show any substantial savings in terms of reduced delays arising from TEAM, TED or early vectoring. Therefore, in this analysis no delay savings have been assumed. However, the application of operational freedoms has been assumed to mitigate delays that

[8] http://www.heathrowairport.com/static/Heathrow_Noise/Downloads/PDF/Operational-Freedoms-Final-Report-Heathrow.pdf

[9] http://www.heathrowairport.com/static/Heathrow_Noise/Downloads/PDF/Operational-Freedoms-Final-Report-Heathrow.pdf

are likely to result from ever-increasing proportions of A380 aircraft in the traffic mix, which was only tested with a low proportion of A380s during the trial period.

Simple calculations based on the separation between aircraft indicate the capacity reductions that would be expected as the proportion of A380s in the traffic mix increases. These reductions are due to the spacing between the A380 and the following aircraft being greater than for other combinations of aircraft. This capacity loss as a function the proportion of A380s in the traffic mix is shown in Figure 7.

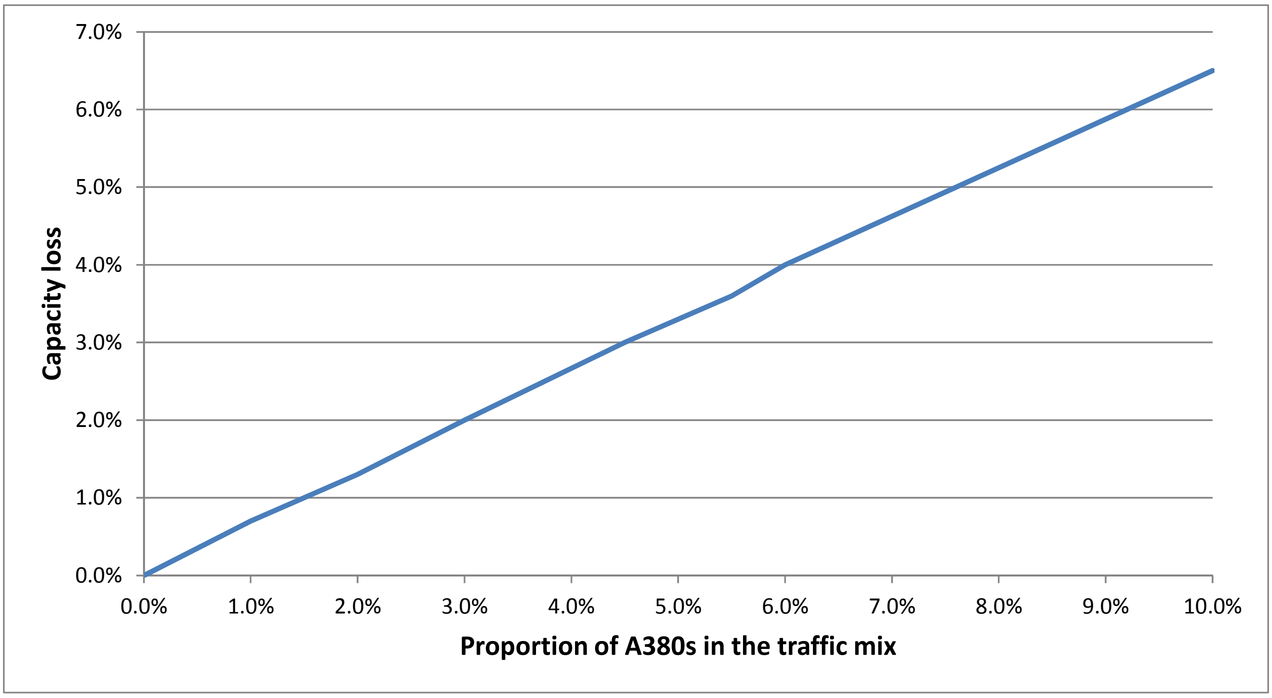

Figure 7:Capacity loss as a function of the proportion of A380s in the Heathrow fleet

The proportions of A380s assumed for the calculations are: 3.0% (20 arrivals per day) in 2014, 4.5% in 2019 (30 arrivals per day) and 9.0% in 2030 (60 arrivals per day).

The arrival delay associated with capacity loss due to A380s was calculated using the statistical delay models assuming that TEAM would be applied (and hence a 5% arrival capacity increase and associated departure capacity decrease) when the arrivals delays were approaching 20 minutes. The benefit of operational freedoms was then taken as the difference between the delays without the A380 capacity penalty (assuming that operational freedoms allows the A380s to be taken out of the arrival stream) and the delays calculated with A380s in the arrival stream. The departure delay associated with landing A380s on the departure runway was assumed to be negligible but the number of resulting de-alternated flights was estimated.

The results are shown in the following table:

% of A380s in the mix	Arrival benefit (average delay minutes saved per arrival)		Departure penalty (average delay minutes increase per departure)		Additional daily de-alternated flights (approximate)
	Summer	Winter	Summer	Winter	
3.0	6.9	1.4	0.6	0.4	21
4.5	7.1	2.4	0.6	0.6	30
9.0	6.8	3.1	0.7	0.7	90

Table 2: A380 related impacts of tactical de-segregation.

Calculating the impacts of reduced block times

To minimise the impact of increased congestion punctuality, airlines extend their planned block times with further costs incurred. This applies to both network carriers where punctuality is important to ensure that connections work at hub airports and for low cost carriers where punctuality is very important to optimise the utilisation of the aircraft and to ensure that it is in the right place at the end of the day. The CAA runway resilience study illustrated the increase in block times on the Paris CDG – Heathrow route in the following figure.

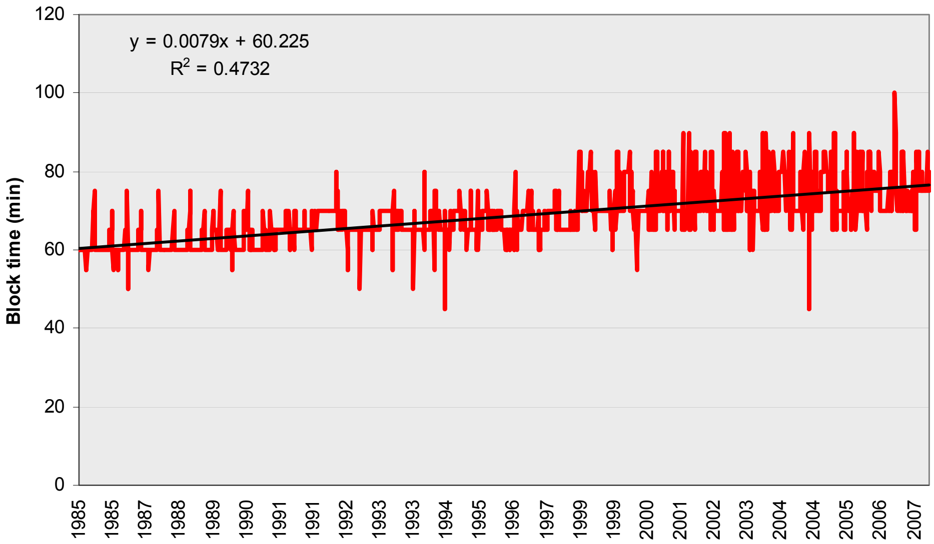

Figure 8:Increase over time in block times on the Paris CDG –Heathrow route

The underlying trend is clear and the block time has increased by circa 18 minutes over approximately 20 years.

As an approximation of the benefits in terms of the potential reduction of block times, it has been assumed that a reduction of half the increase observed for the Paris route (i.e. 9 minutes) could be achieved over a period of ten years starting in 2020, when airlines have sufficient confidence in increased resilience to factor this into their schedules. It is further assumed that this benefit is restricted to Heathrow and that it only applies to 60% of Heathrow inbound flights, representing short- and medium-haul routes that are likely to have block time buffers.

Other impacts of Heathrow's airfield operational efficiency programme

Other components of Heathrow's airfield operational efficiency (AOE) programme are likely to deliver quantifiable benefits. These have been addressed by Heathrow Airport and are simply summarised here.

- A-CDM is estimated to reduce ground delays by 1.5 minute per departure through improved processes and controls. This equated to approximately £9.0M per year;
- A-CDM is estimated to enable a reduction in 130 short-haul and 70 long-haul cancellations per year through improved processes in adverse conditions, saving approximately £6.3M per year;
- enhanced low visibility procedures are estimated to reduce overall cancellations (arrival plus knock-on departures) by 600 per year. At a ratio of 92% short-haul and 8% long haul cancellations (the overall ratio used for cancellations in the AOE business case), this gives a saving of approximately £11M per year.

3. ENVIRONMENTAL IMPACT ASSESSMENT

Introduction

In the initial sift assessment, we considered a wide range of environmental aspects aligned closely with the sift criteria identified in the Airports Commission Guidance Document 2, Long Term Capacity Options: Sift Criteria published in May 2013. Our review of proposed measures included within the short term options scenarios suggested that the most relevant areas of environmental concern are those where proposed measures might directly impact (noise, air quality and climate change), and that other environmental issues (e.g. habitat impacts, water quality) were less relevant and so no assessment could be made.

In the use of three key categories for environmental concern, the assessment considered both local and global impacts. The local impacts considered were noise (sound levels, number and location of people exposed) and air quality (from changes to emissions of oxides of nitrogen – NOx). Global impacts were limited to climate change considerations (from changes to carbon dioxide – CO_2 – emissions reduction).

Table 3 shows the measures for which approximate impacts have been quantified using a series of assumptions that were applied consistently across the packages of measures. In other measures, meaningful quantitative assessment was not possible due to limitations in data availability for the measure concerned. In all cases, the assessment and data are caveated because the impacts are derived from calculations, models and simulations that by their nature are subject to limitations (and inaccuracies) in data provided by the manufacturers, airlines or airports dependent on the nature of the issue under consideration. However, the impacts are considered as informed estimates, are applied consistently across proposed measures, and are broadly indicative for a valid comparison between the packages and their components. Key references and sources are identified in the relevant sections below. Qualitative assessment was informed by the requirement to address perceived as well as actual environmental impacts. This was particularly significant for noise.

Measure	Environmental and social assessment
Queue management	CO_2 and NOx quantified; Noise not quantified
Network A-CDM	CO_2 and NOx quantified; Noise not quantified
Local A-CDM	CO_2 and NOx quantified; Noise not quantified
Reduced engine taxi	CO_2 and NOx quantified; Noise not quantified
Time-based separations	CO_2 and NOx quantified; Noise not quantified
Steeper approaches	CO_2 Quantified and no benefit found; NOx benefits similar to CO_2; Noise not quantified.
Reduction in separation between SIDS	CO_2 and NOx quantified; Noise not quantified
Operational freedoms	CO_2 and NOx quantified; Noise not quantified other than through increase in the number of de-alternated flights
Removal of westerly preference	CO_2 and NOx quantified; Noise part quantified from ERCD 0705
Early morning smoothing on a single runway	CO_2 and NOx quantified; Noise not quantified

Table 3: Measures for which environmental impacts have been quantified

Noise

Initial assessment of the noise impact of the packages was broadly qualitative, due to the nature of the information supplied to the Airport Commission during the early stages of the process. However, from existing studies and known impacts, it was considered that a number of the measures would not have a significant noise effect – such as application of time based separations, for example – so commentary has been based on best understanding of the impacts of the measures.

For the core package and each of the five scenarios a qualitative assessment was undertaken:

- the actual change in noise around Heathrow;
- the perceived change in noise around Heathrow;
- the actual change in noise elsewhere;
- the perceived change in noise elsewhere.

For each of these elements, the measures included within a package were assessed, and a value given. These values were judgment-based on a 1 to 5 rating scale, ranging from very positive impact to very negative impact.

The individual ratings for each element were combined to give an overall value for the change in noise around Heathrow, and separately the change in noise elsewhere. These two values were combined to give an overall value, and consequently an overall rating. When combining the values, greater weight was applied to those relating to the strongest ratings, so for example one highly negative entry (5) was more significant than two positive entries (2 x 2).

The key reference used in the qualitative noise assessment was the CAA Environmental Research and Consultancy (ERCD) Report 0705, *Revised Future Aircraft Noise Exposure Estimates for Heathrow Airport*, dating from 2007. The assumptions made in the qualitative analysis regarding aircraft types, fleet mix, aircraft noise and performance and airspace were based on ERCD 0705, but were adjusted to reflect the situation post 2010. The general assumption in the assessment of the short term packages noise impact from aviation is linked to the changes to fleet mix, aligned with the continued reduction in noise from engine and airframe efficiency improvements. Modern aircraft already within the fleet (such as the Airbus A380, Boeing 737-NG[10] and Boeing 787 Dreamliner) have delivered significantly reduced noise footprints (along with other operational efficiencies) compared to earlier aircraft. Aircraft scheduled to enter service in the next decade (such as the Airbus A350 XWB[11], Airbus A320-family neo[12] and Boeing 777X) will continue this trend, and retrofit of modern engine technology will reduce the impact of those older aircraft that remain within the fleet mix.[13]

Subsequently, more quantitative noise assessment was performed by ERCD. This analysis calculated noise contours for Heathrow for the measures that were identified as likely to have a noise impact. The methodology and results are reported in detail in a separate report.

Emissions

Climate change impacts

There has been a significant amount written about aviation and climate change. The assessment of the short term options has not attempted to address the bigger picture in this regard, and reference should be made to the Airports Commission Discussion Paper 03 – Climate Change, and the reference list contained therein. In this assessment, non-CO_2 impacts (such as radiative forcing from flights at altitude) were not considered, both because the science remains uncertain and these effects will not be addressed by the short term measures. Therefore, the short term climate change assessment has concentrated on the assumed reductions/increases in CO_2 emissions from fuel burn associated with reduced delays, reduced taxi times or increased ATMs.

The principal environmental impact of delays is to increase aircraft emissions above and beyond those for the un-delayed flight because of the additional running time of the engines associated with the delay. Delays for the different scenarios and measures were calculated using the statistical approach as

10 Next Generation – 737-600, 737-700, 737-800 and 737-900, progressively introduced since 1996.
11 Extra Wide Body
12 New Engine Option
13 http://www.sustainableaviation.co.uk/wp-content/uploads/SA-Noise-Roadmap-Publication-version1.pdf

described above. A simple but standard methodology, described below, has been used to determine the additional emissions associated with delays.

For the purposes of modelling, operations are divided into two flight phases (above and below 3000ft), corresponding roughly to cruise and the landing-take-off (LTO) cycle requiring different calculations. Emissions calculations have been performed on a flight-by-flight basis, following the same approach as for delays with the results being shown as daily averages per hour with the averaging being performed over the 2008 summer and winter seasons.

Taxi-related emissions: The ICAO Aircraft Engine Emissions Databank[14] was used as the basis of the calculation of fuel flow rates on the ground for departures. Fuel flow for each flight was based on a generic engine type (the most commonly used) for each aircraft type on a flight by flight basis and the fuel burn associated with ground holding delay calculated. This was then turned into CO_2 emissions for departure delay using the simple relationship of 1 tonne of fuel burn = 3.149 tonnes of CO_2. This was further extended to NO_x emissions using the relationship that one tonne of fuel burn equates to 12.8kg of NO_x.

Stack holding: Calculations of emissions associated with stack holding have used the BADA[15] (Base of Aircraft Data) to calculate the fuel burn associated with stack holding alone above 3000ft where the main assumption is that the fuel burn can be approximated to the nominal cruise flow data from BADA.

Differences in fuel consumption between holding areas have been assumed to be insignificant. However, fuel burn is altitude dependent. Therefore fuel burn in the stack has been calculated as a simple range:

- minimum - fuel burn for the minimum altitude (7,000 feet)
- maximum - fuel burn for the maximum altitude (overall 16,000 feet)

Again, CO_2 emissions were related to fuel burn by a factor of 3.149.

Fleet mix evolution has not been modelled to the same degree of detail as undertaken within ERCD 0705. Therefore, due to uncertainties regarding future aircraft/engine fuel efficiency improvements, no general assumption has been made about reduced emissions in this regard, and savings/increases are presented in 2008 terms. Actual savings will vary, therefore, as the overall flight CO_2 impact would reduce through aircraft efficiency improvements, resulting in smaller proportional benefits of savings from reduced delays, etc. However, the same approach has been applied to all measures and packages, and thus the results may be considered indicative.

The carbon cost benefits were calculated using DECC[16] methodology for valuation of Green House Gases (GHG) emissions for policy analysis, and published forecasts of traded carbon prices (2012 update: the 2013 issue has since reduced the projected traded carbon values). This is aligned with Government Green Book Appraisal methods. Traded prices were used due to the commitment to include aviation within the EU-ETS, notwithstanding the current moratorium and legal challenges. Values would differ if non-traded, or costed according to recent Committee on Climate Change Values for the full effects of GHG emissions. The cost benefits are therefore conservative, although traded values are currently (end 2013) lower than is anticipated by 2030. Application of the DECC methodology allowed a monetisation of the benefits from reduced CO_2 emissions at low, central and high value scenarios, and for these to be converted into Net Present Value (NPV) calculations. This was applied to all estimated CO_2 reduction opportunities reductions.

The results of the analysis are presented in detail in the scenario templates.

[14] ICAO (2009). ICAO Aircraft Engine Emissions Databank

[15] http://www.eurocontrol.int/services/bada

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

Reduced engine taxi

For reduced engine taxi (RET), CO_2 emissions were estimated from published figures on airport on ground movement component of Landing and Take Off (LTO) cycle emissions and CAA published figures on ATMs at airports. An average emission per ground movement was thus established. This is known to be a limitation, as emissions vary hugely by aircraft type and by airport size and fleet make-up, but has been developed as an approximation of benefits from system wide improvement available from implementation of reduced engine taxi best practice.

From CAA figures, for 2008, the ATMs for the top five UK airports were 1,221,252, for the top 10 airports were 1,702,245, and total UK ATMS were 2,534,315. In their 2012 CO_2 Road Map[17], Sustainable Aviation have noted "that there remain some uncertainties surrounding the potential impact on taxiway capacity arising from significant deployment of reduced engine taxiing" (p.8). That Road Map therefore chose not to associate any savings from RET. However, for indicative purposes of the ST assessment, benefits were estimated to be delivered by a conservative 500,000 ATM employing reduced engine taxi, which is approximately 40% of the ATMs at the top 5 UK airports, or 20% of the UK entire ATMs. To avoid overplaying the benefits, assuming RET opportunities are available, a conservative approach was also taken to calculating emissions benefits available, which was set at the lowest reported ground movement fuel burn benefit identified in RET trials.

To identify the potential benefit from RET, reference was made to published papers on studies into trials at various airports. In particular, evidence from the BMI trial at Heathrow[18] suggested reduced CO_2 in taxi-in of between 19-36% and 7-35% in taxi-out. Sustainable Aviation's Aircraft on the Ground[19] CO_2 emissions programme indicated 20-45% reduced fuel burn from reduced engine taxi, and 20% savings at Heathrow from RET and APU avoidance. Use of 500,000 ATMs and 7% of emissions from ground movements resulted in an estimated saving of 46,500 tonnes of CO_2/year. However, for Short Term scenarios where capacity was increased, the savings volume was reduced by 50% because of assumed capacity constraints, in line with the concerns flagged within the Sustainable Aviation report. For reasons noted above, should taxiway capacity issues be addressed, savings could be much greater than the 7% of ground emissions from 500,000 ATMs assumed, but equally benefits cannot be guaranteed.

Local air quality

In terms of local environmental impacts, the effect of airports on local air quality is less obvious than their effect on noise, but can still be significant. Emissions from aircraft are only one of the factors determining local air quality, and surface transport related emissions are of greater significance, although aviation emissions can be significant close to the airport boundary. The Environmental Guidance Manual for Airports (2006) notes that emissions from aircraft above 200 metre have only a minor influence on local air quality, but that ground based aircraft emissions can have significant effects on local air quality close to the airport boundary. Environmental Protection UK (EPUK) notes that aircraft engines generally combust fuel efficiently and that jet exhausts have very low smoke emissions. Improvements in engine technology already noted in the noise section have similarly affected the emissions performance of aircraft engines.

For the short term assessment, the impacts have been measured by estimating impacts from ground movements only, based on emissions of oxides of nitrogen. The main pollutant of concern around airports is nitrogen dioxide (NO_2). Emissions of fine particulate matter (PM2.5) are also of concern, since particulate emissions from jet exhausts are almost all in this fine fraction. NO_2 is formed by nitrogen oxide (NOx) emissions from aircraft but also surface traffic and airport operations (such as static boiler combustion). This assessment has not attempted to estimate impacts from surface transport or fixed

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17 http://www.sustainableaviation.co.uk/wp-content/uploads/SA-CO2-Road-Map-full-report-280212.pdf
18 http://www.heathrowairport.com/about-us/community-and-environment/sustainability/case-studies/taxiing-the-way-to-lower-emissions
19 http://www.sustainableaviation.co.uk/wp-content/uploads/aircraft-on-the-ground-best-practice-guidance-june-2010.pdf

assets due to limited availability of data, and lack of clarity regarding emissions associated with airport traffic compared to non-airport traffic on local roads. The assessment also does not attempt to estimate in flight emissions (either above or below 200m). NOx benefits are calculated from reduced engine taxi (RET) benefits. These have been calculated from a typical combustion ratio of CO2 and NOx emissions, based on fuel burn. RET benefits have been estimated from the same source data used to inform the CO_2 benefits.

According to Heathrow's Air Quality Strategy, direct airport NOx (oxides of nitrogen) emissions for 2008/09 were estimated to be in the region of 5800 tonnes. Ground level emissions, which make the most impact to local air quality, were less than half of these – approximately 2,600 tonnes. There is insufficient data to extrapolate for all short term options, so benefits of reductions in NOx from RET have been estimated only for Heathrow. RET was assumed to be less available where increased capacity was included within the package, due to the concerns raised by Sustainable Aviation regarding the viability of RET in congested taxiway situations.

4. ECONOMIC IMPACT ASSESSMENT

Introduction

There are broadly two main types of economic impacts that arise from the proposed measures to improve the operational rules and regulatory framework around aviation in the UK:

- economic efficiency benefits: For airlines these are savings in operating costs for airlines due to reduced delays such as reduced fuel consumption and labour costs, and also savings from reduced cancellations reducing the costs involved in managing cancellations (labour costs and costs to manage and compensate passengers, and loss of revenue). For airline passengers these are travel time savings.
- consumer surplus benefits arising from additional flights: The economic benefits arising from allowing additional flights where there is unmet demand.

It may be argued that there are also wider economic benefits that arise from induced and catalytic economic activity that would not otherwise occur, particularly if there are increases in capacity and enhanced factors that contribute towards agglomeration. These can be said to occur with significant increases in capacity (e.g. in this case if mixed mode was permitted to increase flights by 10-15%), but have not been assessed and so wider economic benefits have not been included here.

It is important to emphasise that the economic impact assessment here is a high-level strategic assessment of a wide range of measures which are not necessarily comparable. The primary intention behind that assessment has been to provide guidance as to the overall effectiveness of measures in contributing towards either a more efficient aviation sector, or to produce benefits from more capacity. It is not a full benefit/cost assessment, and should not be treated as such, but rather a framework to inform strategic decisions on the value of proceeding with specific measures.

Economic impacts of improve efficiency and resilience

Introduction

The key economic impacts of measures to improve the efficiency and resilience of airport operations come from:

- Airline operating cost savings (from reduced fuel consumption, reduced staff costs, improved aircraft utilisation);
- Passenger cost savings (travel time savings from reduced delays and with more fundamental improvements in travel time reliability, reduced scheduled travel times);
- Airline cancellation cost savings (avoiding the labour costs and loss of revenue arising from cancellation of flights because of incidents).

Given that most of the delay and resilience issues with UK airports arise from Heathrow (see for example the series of Eurocontrol Performance Review Reports), in almost all cases the worthwhile economic impacts of the measures contained in the various packages analysed come from application to Heathrow Airport. In a few cases there may also be benefits from application at other airports (e.g. Gatwick given it operates at capacity at certain times of day), but unless specified otherwise, only the benefits at Heathrow have been calculated.

The results of the operational impact assessments reported above are used as the basis to calculate monetary values for operational benefits as far as possible. This has been done based on standard, industry-accepted values based on Eurocontrol standard values for economic impact assessment[20] adapted to be representative of Heathrow and values provided by Heathrow Airport. These values at 2010 levels are consistent with those that have been used in the delay analysis for the long term options and are as follows:

[20] These are published here http://www.eurocontrol.int/ecosoc/public/standard_page/documents.html

- an average aircraft delay cost per minute for the Heathrow fleet mix of £30.70
- a passenger opportunity cost of £20.98 per minute per flight for the Heathrow fleet and passenger mix;
- a cancellation cost of £13,700 per short-haul cancellation and £64,100 per long-haul cancellation for the Heathrow fleet and passenger mix;
- a fuel cost of $1,000 or approximately £666 per tonne.

Benefit and cost impact of operational improvements

Local A-CDM: As described above, the benefits of A-CDM have been estimated from the associated operational improvements assuming that A-CDM at Heathrow is in full operation from 2014, and would result in 130 fewer short-haul flight cancellations, and 70 fewer long-haul flight cancellations. The annual benefit for passengers is calculated as around £6m; for airlines operating cost savings of £11m per annum, and cancellation savings of around £6m per annum. The costs of A-CDM at Heathrow are assumed to be sunk.[21]

Network A-CDM: In 2005, Eurocontrol published a report that outlined the average annual cumulative benefits from introducing A-CDM across seven airports in Europe. Whilst, this represents benefits of local implementation across multiple airports, it has been used by Eurocontrol to provide a strategic economic assessment of the value of A-CDM across Europe. Although it limited its total results to seven airports, this has been assumed to represent the network benefits for Europe as being at least at this level, and to assess the UK share of this as a proportion of the total European air traffic. The Eurocontrol report on A-CDM made a wide range of assumptions and calculations, contained in Annexes H and I of the report.

It is clear that the Network A-CDM benefits that would accrue to the UK would only arise if there was substantial pan-European implementation of A-CDM across the Eurocontrol area. As such, to consider the value of benefits from seven airports alone would be expected to be a conservative assessment of the network wide level of benefits, which would accrue not just to airlines and passengers at Heathrow, but to other UK airports. The total value of the benefits for the seven European airports from A-CDM is taken as a broad proxy for a low end estimate of European wide benefits of A-CDM implementation, and was multiplied by 14.5% to represent the UK's share of European air traffic (sourced from Eurocontrol NM Monthly Network Operations Report June 2013). It is assumed that the network benefits from A-CDM would be realised from 2020. The annual benefit for airlines and passengers in the UK from network A-CDM is estimated at around £20.7m per annum.

Arrival queue management: Assessment of the operational benefits of queue management is described above. These have been translated into economic terms using standard values. It is estimated that airlines will gain £22m per annum in fuel savings from queue management from 2019 onwards. The cost of queue management is estimated by NATS to be £6M.

Improved low visibility procedures: The benefit from improved low visibility procedures is based on reduced cancellations using standard values and is estimated to be £11M per year starting in 2014.

Time based separations: The delay savings due to time based separations translate into benefits of reduced costs to airlines of £12M per annum, primarily from reduced fuel consumption. Passengers will benefit from around £5M per annum from travel time savings. These benefits are assumed to commence in 2019.

Early morning smoothing on a single runway: Based on the operational impact assessment and standard monetary values, it is estimated that airlines would gain a £12M per annum savings in fuel, and passengers a £6M per annum in saved time. It is assumed that this benefit starts in 2015. Costs are unknown.

[21] Costs that have already been incurred and cannot be recovered.

Reduction in separation of SIDs: Again based on the results of the operational impact assessment and standard monetary values, airlines are expected to save around £18m per annum in fuel from the introduction of this measure, with passengers benefiting by around £12m per annum in reduced delays. This measure is assumed to commence in 2016. Costs to the airport and NATS, which will be passed on to airlines and passengers through the charges system, are not well known but are likely to be several £Ms although significantly lower than the benefits.

Operational freedoms: Benefits are based on the delay savings associated with the application of operational freedoms to ameliorate the negative impact of increasing proportions of A380s in the Heathrow fleet mix. Airlines are estimated to benefit by £44M per annum from 2014, rising to £49M per annum by 2017. Passengers are estimated to benefit by £19M per annum from 2014, rising to £21M p.a. by 2016.

Block-time reduction: Benefits are based on a potential reduction of nine minutes in the block-time of Heathrow's short- and medium-haul arrivals (60% of traffic). As such, the benefits due to reduced block-times because of more reliable performance are estimated to be £2M per year in 2020 rising to £6M per year in 2030.

Mixed mode for resilience: Benefits are based on the operational analysis results for the various mixed mode scenarios and the standard values for delay benefits. Mixed mode for resilience is expected to deliver:

- £74M to airlines and £43M to passengers at a 480k ATM capacity cap
- £53M to airlines and £28M to passengers at a 500k ATM capacity cap
- £38M to airlines and £21M to passengers at a 515k ATM capacity cap
- £32M to airlines and £18M to passengers at a 520k ATM capacity cap

These benefits are in addition to the benefits of additional passengers enabled by raising the capacity cap, as described below.

Other quantified benefits

Reliever airport concept: The reliever airport concept is assumed here to be a measure to promote business and general aviation flights using airports other than Heathrow and Gatwick. By encouraging the use of alternative airports (e.g. Northolt, Biggin Hill and Farnborough) for such services, the incremental capacity released could produce benefits from increased reliability and resilience for flights at Heathrow and Gatwick. Given that such capacity usage is typically ad-hoc (often based on notified cancellations of services by airlines that possess slots), it is not seen as being able to offer a meaningful capacity benefit beyond this. The value of this reduction in flights at both airports was estimated with reference to the average resilience benefits from removing incremental flights from operation at Heathrow and Gatwick. The benefits derived from reducing those movements by on average two a day come from the "UK CAA Runway Resilience Study – Final Report".[22] It stated that the benefit in reduced delays achieved by removing one flight pair at Heathrow per hour was £4.3 million per annum (2007 values) averaged over the year. This comes from time savings per annum of between 5,000 and 65,000 minutes, depending on the time of day that flights are withdrawn. It has been assumed that a similar removal of a flight pair at Gatwick would generate 10% of the benefits seen at Heathrow. The total benefits could be around £0.5 million per annum.

Prohibition on Business and General Aviation at LHR and LGW: This takes the reliever airport concept and effectively mandates that business and general aviation not operate at Heathrow and Gatwick. By doing this, it is expected that the existing usage of those airports for such purposes ceases, providing incremental improvements in reliability, albeit at times of day that will vary according to demand. A similar approach was used to assess the resilience/delay reduction benefits as applied to the reliever airport concept. As with the reliever airports concept, the benefits are derived from the "UK CAA

[22] Helios, XPX Consulting & SH&E Limited, December 2008.

Runway Resilience Study". Given this would result in removal of more flights than the reliever airports concept, the benefits are estimated to be proportionally higher (approximately £1.4 million per annum). However, the costs to those users of Heathrow and Gatwick have not been calculated.

Reduced capacity cap at LHR: A reduction in the capacity cap at Heathrow would mean that when an airline with an existing slot chooses to stop using that slot (and has not passed it onto another airline), that slot would disappear, reducing the overall capacity at Heathrow. Given that this scenario is most likely in the event of bankruptcy or commercial error (as slots at Heathrow can readily be traded), this is unlikely to be frequent or to have a significant impact. However, it is assumed that if it were implemented, it would create incremental benefits from reduced delays, and these have been assessed as an incremental reduction in average delays. The "UK CAA Runway Resilience Study" valued one flight per day at Heathrow as £1.09 million per annum (in terms of capacity), but £0.3 million per annum benefit in reduced delays. As such, the benefits arise from the possible time savings per annum of between 5,000 and 65,000 minutes depending on the time of day that flights are withdrawn.

Consumer surplus impacts

Introduction

Allowing more flights, either by changing existing operating rules (e.g. allowing mixed mode or more night flights) or removing bilateral air services agreement restrictions on service provision, might increase consumer surpluses by allowing airlines to offer more capacity. In turn this benefits consumers from lower average prices (as airlines lower prices on new services to attract customers, or face higher competitive pressure on existing services), or lower generalised travel costs, by reducing overall travel times (with more direct flights and higher serviced frequencies).

Given considerable operational constraints on airlines meeting demand, particularly for flights from Heathrow Airport, provision of more capacity would be expected to adapt more dynamically to meet market demand, and increase the numbers of consumers able to access lower fares, and timetabled services that best meet their demand.

The analysis of options to increase airport capacity in the short-to-medium term identified two major options to allow for increases in services:

- Greater liberalisation of bilateral/multilateral air services agreements to allow for more 5th freedom services between the UK and third countries;
- Introduction of mixed mode operation at Heathrow Airport to enable more flights to operate to and from the airport.

Mixed mode for capacity at Heathrow

The "UK CAA Runway Resilience Study – Final Report"[23] provides values for the benefits of additional flights, which were based on benefits to existing users (reduced fares and travel time penalties, including increased convenience), benefits to generated users (users that would not otherwise have travelled, because of lower fares and increased convenience) and producer benefits (revenue to airlines and airports). The values derived from the CAA report have two other limitations. Firstly, they take a purely linear view of the value of additional flights. Four additional hourly flights are presumed to each have the same value as one additional flight.

Yet as capacity is added, the values of each additional flight incrementally diminish (at that point in time), as airlines are most likely to introduce new services on routes where passengers are most likely to be willing to pay the highest yielding fares (and so perceive the highest benefits from the new flights). Capacity is not allocated by auction, but on a first-come-first-use basis, this may not necessarily result in the most efficient utilisation of capacity. However, as a general rule, it is fair to assume that the net economic benefit of additional flights diminishes as new capacity meets less commercially valuable demand. Secondly, it is likely that additional flights will have different values according to time of day.

[23] Helios, XPX Consulting & SH&E Limited, December 2008.

Additional landing slots at 06.00 are likely to have a far higher value than that of 15:00, based on the value of slots that have exchanged in recent year.[24] Based on observation of publicly available information, the value of a single daily slot pair traded has averaged at around £9.7 million, indicating that an airline will need to recover that cost (effectively a variant of capital cost) over several years, on top of the capital and operating costs of a flight including ground handling and landing fees. That £9.7 million average is the price that scarcity of slots at Heathrow imposes on the market, although it would appear it could be as low as £5.3 million in some cases[25], or over £15 million in others.

A measure of the indicative value of additional flights may be deduced from the market price for these slots. Since this market is not fully transparent and involves airlines exchanging such rights which only exist based on a "use or lose" rule, these prices can only be obtained by observing some airline behaviour and what gets published directly or indirectly about these transactions. However, such values are only of use in indicating what the likely relative benefit variations will be by time of day. In this case, it means that there may be as much as a factor of three between the benefits of flights with early morning arrivals compared to late evening arrivals.[26] The actual economic benefit from slot utilisation will vary considerably, depending on capacity provided, the destination, the travel alternatives, and the quality of service offered. Regardless of these limitations, the values of additional slots have been taken as an average. It is expected that over the medium term, these values are likely to be fairly conservative, as the total amount of additional capacity that could be made available from mixed mode is estimated by NATS as part of the work done around 2006/7 on options for increasing Heathrow capacity, to be around a maximum 15% uplift on existing flights. Even if this was all made available (which would be likely to see only small benefits in improved resilience), it is unlikely to meet the unconstrained demand for capacity at Heathrow beyond 2030.

The primary assumption used was to take the existing user benefits, generated user benefits and producer benefits from an additional flight per hour to establish the economic benefits of allowing an additional flight per hour to operate at Heathrow (take-off and landing). The APD revenue generated was not included as this is not a benefit to the economy, but a financial transfer from consumers to the state.

Based on the CAA study, it has been assumed that one additional flight per day would have an average economic benefit of around £1.09 million in 2010 values.[27] Based on the value airlines place on different slot pair timings[28], this value could range from nearly £2 million from an early morning flight, to less than £0.66 million for an early evening flight. Based on the scenarios developed, allowing mixed mode at Heathrow for new capacity would mean:

- £60 million in annual benefits from allowing 500,000 flights per annum;
- £104 million in annual benefits from allowing 515,000 flights per annum;
- £119 million in annual benefits from allowing 520,000 flights per annum;

[24] http://centreforaviation.com/analysis/heathrow-airports-slot-machine-hitting-the-jackpot-again-108646

[25] BA Annual Report 2012, as the average value of each additional slot pair acquired from BMI.

[26] Based on analysis by the Centre for Aviation (http://centreforaviation.com/analysis/heathrow-airports-slot-machine-hitting-the-jackpot-again-108646)

[27] This was calculated using the analysis in the Helios CAA Runway Resilience study updated to 2010 values. It includes producer (airport) benefits (based on additional revenue from flights and passengers), benefits for existing consumers (based on time savings from increased frequency of services) and benefits for generated consumers (based on utility from flights due to lower fares). It excludes revenue generated for Treasury from additional APD (as this is considered to be a transfer), airline revenue, or any wider economic benefits arising from additional flights such as the provision of connectivity for business travel, tourism or cargo. It also excludes the cost of CO_2 from additional flights and the lessening of benefits from delay reduction that would arise from mixed mode operations (this is considered separately). It also excludes the effects of capacity on the Heathrow Shadow Cost which is utilised in the DfT National Air Passenger Demand Model.

[28] Without taking into account that slot pairs, especially for long haul flights, may not necessarily be within a few hours of each other. e.g. Qantas's twice daily services have over a 12 hour gap between arrival and departure.

- £179 million in annual benefits from allowing 540,000 flights per annum.

These are annual benefits, and are based on all of the additional capacity being utilised in any one year. Clearly, the more capacity that is introduced, the longer the period until such capacity is fully utilised (and the capacity benefits realised).

5th freedom liberalisation

The UK already has a comparatively liberal environment for foreign airlines to provide air services. However, the provision of 5th freedom services tends to be more restricted.[29] Such passenger services exist at present as follows:

- Air New Zealand (Heathrow to Los Angeles);
- EVA (Heathrow to Bangkok);
- Kuwait Airways (Heathrow to New York JFK);
- Pakistan International Airlines (Manchester to New York JFK);
- Qantas (Heathrow to Dubai);
- Royal Brunei Airlines (Heathrow to Dubai);
- Singapore Airlines (Manchester to Munich).

In most cases, such services exist as an operational factor arising from airlines needing a refuelling stop en-route between their own hub and the end point of a route. However, in some cases it enables an airline to economically service two destinations when separate services may not be commercially viable. Some other such services have terminated more recently as new aircraft have enabled new non-stop services to be provided (e.g. Air India has dropped Heathrow-New York JFK services). The benefits of all of these services are to increase competition on routes that already have existing airline services (between one and four airlines operate services already on these routes), but not to introduce new routes.

In 2005, the CAA published a report titled "An Economic Assessment of the Impacts of Granting Fifth Freedom Rights to Passenger Services from UK Regional Airports".[30] It was prepared to consider whether more fifth freedom services from airports outside London, could add to connectivity and generate net economic benefits for the UK.

That report considered seven case studies of possible such services, to assess the economic benefits that they could offer. This took into account the extent to which such services could generate new demand, and transfer demand from existing services. That report indicated that removing barriers to such services could catalyse interest from some airlines to provide new services, particularly to regional (non-London) UK airports. This would generate consumer benefits by reducing the fare and time cost to fly to such destinations, and generate producer benefits by attracting tourist and business travel to those cities.

Out of the seven case studies presented in the CAA report, the three of "highest economic benefit" have been assumed to proceed. As the remainder had low or net negative benefits, they have been discounted as being unlikely either to be commercially viable or get regulatory approval. The three case study examples themselves were:

- Dubai-Manchester-Houston (Emirates)
- Bangkok-Delhi-Manchester (Thai Airways)
- Toronto-Birmingham-"India" (Air Canada).

[29] This excludes operations by airlines from other EU Member States, which under the EU's open skies policy, allows any EU airlines to provide services between any two EU Member States.

[30] http://www.caa.co.uk/docs/589/Regionalfifths_report.pdf

However, the actual routes of the services found to be of highest benefit in the 2005 study, are of less importance today than at the time of the study. This is because the airline industry has continued to evolve rapidly, making it less certain that these services are the most likely to be either commercially viable or likely to gain regulatory approval from the other countries as necessary. However, these examples have been taken forward on the assumption that other such fifth freedom services are likely, because the rise of new hubs such as Abu Dhabi, Doha and Istanbul may give rise to new opportunities. Of the 5th freedom services that currently operate, four did not exist at the time of the 2005 report (although some others did and have since discontinued).

It has been assumed that additional services would arise only if they were commercially viable and had approval from all relevant countries (e.g. US approval would be needed for a Manchester-Houston service if it were to be operated by say Emirates), and so it was considered prudent to assume that only three new such services would operate, on average, at any time. The value of these services was taken to be that of the three "highest benefit" case study examples, uplifted to 2010 values.

It is concluded that there could be around £34 million a year in economic benefits arising from new 5th freedom airline services (assumed to be three new daily routes that did not previously exist between the UK airport and a third airport). These benefits primarily accrue to UK consumers, from being able to access more convenient services with moderately lower fares, and UK airports from the increase in revenue due to increased flights. For a regulatory change in itself, these benefits are considerable. As such, it would appear worthwhile to consider negotiating revised air services agreements with those countries that are most likely to be the end point destinations of such services, as well as the home countries of the airlines likely to be most interested in such services.

Changes to numbers of night flights

Proposals to increase the number of night flights at Heathrow are seen as being likely to generate considerable economic benefits. This is partially reflected in the paucity of slot trading at such times, as airlines regard the slots they hold to be too commercially valuable to trade.

To establish the value of night flights, the value of an additional incremental flight at Heathrow was taken and adjusted based on a weighting using the scale of price variations for slot pairs at Heathrow. This weighting provided a proxy for the greater benefit seen in night flights purely based on the commercial attractiveness of flying at those times, using the assumption that this would also be reflected in higher economic benefits (as consumers can reasonably be expected to perceive this higher benefit as well, given fares at such times tend to reflect the scarcity of capacity on those flights).

The "UK CAA Runway Resilience Study – Final Report" was used as a source for the value of allowing additional flights, which (in 2010 values) means that the economic benefit of one additional flight pair per day averages at £1.09 million per annum. Observations by the Centre of Aviation of the range of prices for slots at Heathrow indicated that early morning slots may be at least 60% more expensive than the average across the day. It has been assumed that by applying this markup, the annual value of an additional night flight per day could be £1.77 million.

Given that 17 flights operate in the pre-06:20 period at Heathrow, the current direct value of such flights could be at least £30 million per annum.

However, there are a range of estimates of the value of these flights, reflecting different methodologies and assumptions. Oxford Economics in a separate study[31] estimated that the direct economic benefits of night flights were £158 million per annum in the 2330-0600 Night Quota Period, with higher estimates for indirect and induced benefits. This would indicate that any increases in the number of night flights, particularly in the 0430-0600 early morning arrivals period, is likely to have a positive economic benefit that could range from around £1.8 million to over £8 million per flight per annum Conversely, measures

[31] Economic Value of Night Flights at Heathrow, Oxford Economics, December 2011. This report was commissioned by British Airways and BAA Limited

to reduce or restrict such flying further would create economic losses which are likely to be of a similar order.[32]

It would appear that of all of the flights operated at Heathrow, the ones operating (arriving) under the Night Quota Period appear to be valued, on average, more highly than those at other times. Given the high demand immediately after that period for landing and take-off slots, it would indicate that airlines and concurrently passengers and cargo customers of airlines regard these flights to have a highly positive value, indicating that benefits are likely to be substantially positive.

32 By contrast, CE Delft (*Ban on night flights at Heathrow Airport: A quick scan Social Cost Benefit Analysis, January 2011*) estimated that the direct economic benefits of night flights could range from £35 million to disbenefits of £860 million per annum, because of a monetisation of noise disbenefits. This report was commissioned by HACAN.

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