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Aviation Strategy: Noise Forecast and Analyses

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Executive Summary

The Department for Transport is developing a new Aviation Strategy and, in support of the strategy, commissioned the CAA to undertake analyses of airport noise forecasts and consideration of how airport noise may be limited. This report presents a feasibility study of implementing airport noise limits nationally and locally, including consideration of the pros and cons that noise limits may create. To inform the consideration of noise limits, it uses DfT aviation growth forecasts to estimate the level of aircraft noise in the shorter/medium term (2025) and in 2030, 2040 and 2050. The report also includes two sensitivity analyses to understand what the effect would be if older aircraft were replaced at a faster rate and also if the rate of technology improvement was accelerated.

A review of suitable noise metrics, targets and limits relating to aircraft noise exposure and their associated effects on limiting noise emission, exposure and health impact was undertaken. The limits review considered ways to limit noise emission at source, the area exposed around an airport, the population exposed within that area, and their associated health impacts, from which a reduced set of metrics was selected for detailed analysis.

The noise around an airport varies over time, primarily depending on aviation growth rates, and the introduction of quieter aircraft. Over the last 30 years there has been a significant reduction in noise exposure around virtually all UK airports. However, after the recession of 2009, which was followed by sustained growth, noise exposure has grown over the past five years at several airports. In order to inform a consideration of noise metrics and potential targets and limits, noise analysis was undertaken for eight airports (Birmingham, Edinburgh, Glasgow, London Gatwick, London Heathrow, Luton, Manchester and Stansted), for two historical years (2006 and 2016) and the following forecast years: 2025, 2030, 2040 and 2050. The forecast analysis takes into account the adoption of the Airports National Policy Statement (NPS) and assumes a third North West Runway (NWR) at Heathrow is built by 2030.

The analysis of the 2006 and 2016 noise performance was undertaken to review the application of different limits and to understand the implications of changing noise emission (quota), contour area, population exposure, and noise impacts over the past ten years.

The forecast analysis for 2025, 2030, 2040 and 2050 was undertaken to identify the effect of different limits in relation to modelled traffic growth, in order to understand the implications and opportunities for reducing noise generation, population exposed and noise impacts. Central and high scenarios were used in the analysis based on the latest UK Aviation Forecasts. A summary of the high scenario analysis covering the total for all airports is presented in Table (a). The results presented use a population growth per CACI forecast data.

Table a: Summary of noise metric results with population growth including a third NWR runway at Heathrow, Scenario: HIGH

			Year						
Metric	**Period**	**Level**	**2006**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Traffic (ATMs)	Average summer day 16h*	-	4349.5	4295.3	4497.8	5322.5	5655.9	5984.3	+39.3%
	Average summer night 8h*	-	454.3	522.0	549.4	616.2	656.4	700.2	+34.1%
Noise emission (Quota Count)	Average summer day 16h* QC	-	2696.7	2470.5	2453.1	2614.0	1966.3	1922.9	-22.2%
	Average summer night 8h* QC	-	301.3	299.6	261.8	266.6	202.2	207.7	-30.7%
Area exposure (Km^2)	Average summer day LAeq16h*	>54 dB	530.4	490.2	497.1	523.2	440.6	440.5	-10.1%
	Average summer night LAeq8h*	>48 dB	419.6	473.0	462.6	473.2	409.7	420.1	-11.2%
	Average annual 24h Lden	>55 dB	615.6	575.1	583.7	610.8	520.3	524.5	-8.8%
	Average annual 8h* Lnight	>50 dB	268.0	256.7	245.6	256.4	216.9	223.2	-13.0%
Population exposure (Numbers exposed to noise level)	Average summer day LAeq16h*	>54 dB	825,400	782,300	802,700	846,000	771,000	796,000	+1.8%
	Average summer night LAeq8h*	>48 dB	521,700	655,500	605,300	589,600	557,800	604,100	-7.8%
	Average annual 24h Lden	>55 dB	997,300	950,000	963,400	1,007,200	920,700	953,200	+0.3%
	Average annual 8h* Lnight	>50 dB	304,600	323,600	288,100	310,100	299,900	329,300	+1.8%
	Average summer night 8h* N60	>10 events	1,215,900	1,473,400	1,457,100	1,622,500	1,580,900	1,645,200	+11.7%
	Average summer day 16h* N65	>10 events	2,449,500	1,965,000	2,124,000	2,145,000	1,946,000	1,955,000	-0.5%
	Average summer day 16h* N70	>10 events	974,600	838,700	880,100	794,400	675,500	658,500	-21.5%
	Average Individual Exposure (70)	>10 events	61.8	79.5	80.8	84.6	88.6	95.4	+20.0%
	Person Events Index (70)	>10 events	64,098,100	69,457,300	75,795,300	83,375,000	75,469,400	80,896,600	+16.5%
Noise impact (Numbers exposed to noise level)	Highly sleep-disturbed average annual 8h* Lnight	>45 dB Lnight	73,800	78,900	74,800	76,600	72,100	76,300	-3.3%
	Highly annoyed (daytime) average annual 24h Lden	>54 dB Lden	180,500	173,200	174,100	183,100	168,500	174,000	+0.5%

*16h: 0700-2300 and 8h: 2300-0700

The results show that from 2006 to 2016, noise emission (QC) and noise contour areas have decreased. Population exposure has, in some cases, not followed the same trend due to the growth in population within the noise contours between the two years.

For the forecast years, the results show that noise emission and noise contour areas are expected to reduce, however the population exposure, the number of Highly annoyed people and the number of Highly sleep-disturbed people are forecast to increase, when accounting for the forecast growth in population from 2016 onwards. Some differences are seen between different noise exposure indicators, for example N70 decreases, whilst PEI(70) and AIE(70) increase, reflecting the growth in movements by quieter aircraft. Care must, however, be used when interpreting AIE results – the 20% increase in AIE reflects the decreasing population within N70 contours over time and therefore does not represent an average resident's number of events above 70dB L_{Amax}.

When a static population was considered from 2016 onwards, the population exposed decreased in line with noise contour area reductions. Impacts are also forecast to reduce, with the number of Highly annoyed people decreasing by 18.5% and the number of Highly sleep-disturbed people decreasing by 24.3%, assuming no population influx into the noise contour areas.

In order to recommend appropriate noise limits, an analysis was undertaken to determine the correlation between all metrics and their ability to limit the amount of noise emitted, the area exposure or ability to control the number of people Highly annoyed or Highly sleep-disturbed.

In order to address the Aviation Policy Framework objective to "limit and where possible reduce the number of people in the UK significantly affected by aircraft noise" and take into account the latest UK airspace policy noise objectives to "limit and, where possible reduce the number of people significantly affected by the adverse impacts from aircraft noise", the proposed limit scheme would contain the following:

1) A nationally set absolute Quota Count limit or noise contour area limit at a particular noise level for both day and night, aggregated across all major airports;
2) A locally set absolute Quota Count or noise contour area limit at a particular noise level for both day and night for each airport;
3) Local monitoring of the number of highly annoyed and highly sleep disturbed people; and
4) Reporting requirements.

A sensitivity analysis on two of the forecast noise technology assumptions was also undertaken to assess the impact of a faster substitution of quieter aircraft into the forecast fleets and of a faster rate of technology improvement.

Chapter 1

Introduction

The Department for Transport is developing a new Aviation Strategy and commissioned the CAA to undertake four analyses in support of the strategy: airport noise forecasts, a consideration of how airport noise may be limited, the effect of emerging aviation technologies on future noise exposure and to investigate the potential role that ambient (background) noise plays in attitudes to aircraft noise. This report covers the first two items and presents a feasibility study of implementing airport noise limits nationally and locally, including consideration of the pros and cons that noise limits may create. To inform the consideration of noise limits, it uses DfT aviation growth forecasts to estimate the level of aircraft noise in the shorter/medium term (2025) and in 2030, 2040 and 2050. The report also includes two sensitivity analyses to understand what the effect would be if older aircraft were replaced at a faster rate and also if the rate of technology improvement was accelerated.

Aviation noise has been a major global issue for decades and ICAO's balanced approach to noise management[1] sets four pillars for noise reduction: 1) reduction of noise at source through technological improvements to aircraft; 2) land use planning; 3) better operational practices; and 4) operating restrictions on aircraft. There is evidence that public sensitivity to noise has increased[2], and this should be considered.

Globally, there has been a shift towards implementing noise limits at airports in order to reduce noise. These limits are usually aimed at reducing either noise generation (e.g. quota count at Madrid Airport), noise exposure (e.g. contour area limits at Heathrow and Stansted; noise level in Paris; Person Event Index at Sydney Kingsford Smith Airport) or noise impacts (e.g. contour shape and Number of People Annoyed at Amsterdam Schiphol).

The UK Government has set out in the Aviation Policy Framework[3] its overall objective on noise, which is to "limit and where possible reduce the number of people in UK significantly affected by aircraft noise" and the new UK airspace policy[4] noise objective to "limit and, where possible reduce the number of people significantly affected by the adverse impacts from aircraft noise". Aircraft are getting quieter, but growth in movements can

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1 ICAO Doc. 9829, "Guidance on the Balanced Approach to Aircraft Noise Management", Second Edition, ICAO, 2008.

2 "Survey of noise attitudes 2014: Aircraft, CAP 1506, CAA, February 2017.

3 Aviation Policy Framework, Cm 8584, Department for Transport, ISBN: 978-0-10185-842-7, March 2013.

4 "Consultation Response on UK Airspace Policy: A Framework for balanced decisions on the design and use of airspace", Department for Transport, October 2017.

counterbalance these improvements in terms of the population exposed to noise and in terms of noise impacts. There is an expectation that airports make particular efforts to mitigate noise where changes are planned, as presented in the Airports Commission final report[5] and Airports National Policy Statement[6] where a consultation took place on how to address the noise impacts. The Independent Commission on Civil Aircraft Noise (ICCAN)[7] is being created and DfT encourages the use of ICAO's balanced approach to aircraft noise management.

A new Aviation Strategy to look at aviation's challenges, with the aim "to achieve a safe, secure and sustainable aviation sector that meets the needs of consumers and of a global, outward-looking Britain" is being developed by DfT and will set out the long-term direction for aviation policy making to 2050. As part of the preparation for the Aviation Strategy consultations[8], DfT has requested that CAA undertakes the noise analysis for this work.

The objective of this report is to undertake an assessment of the feasibility of implementing noise limits nationally and locally in UK.

The main tasks carried out are:

1. Review of suitable KPIs, targets and limits related to aircraft noise, including the pros and cons, risks and perverse incentives of each option (Chapter 2);
2. Selection of the three most suitable KPIs for limiting the adverse impacts of aircraft noise (Chapter 3);
3. Gathering of 2006 and 2016 information for major national airports (Chapter 4);
4. Analysis of 2006 and 2016 information for major national airports for proposed KPIs; identify historic trends in noise emission at source, noise exposure and health impacts (Chapter 5);
5. Analysis of four forecast years and two fleet growth scenarios for the proposed KPIs; identify forecast trends in noise emission at the source, noise exposure, population exposure and population health impacts (Chapter 6);
6. Draft a proposed noise limit or target methodology (Chapter 7); and
7. Undertake a sensitivity analysis using the limits selected (Chapter 8).

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5 Final Report, Airports Commission, ISBN: 978-1-84864-158-7, July 2015.

6 Airports National Policy Statement: new runway capacity and infrastructure at airports in the South East of England, Department for Transport, ISBN: 978-1-5286-0441-3, June 2018.

7 Consultation Response on UK Airspace Policy: A framework for balanced decisions on the design and use of airspace, CM 9520, Department for Transport, ISBN: 978-1-5286-0087-3, October 2017.

8 "Beyond the horizon. The furure of UK aviation. Next Stepst towards an Aviation Strategy", HM Government, April 2018.

Chapter 2

Review of suitable metrics and limits

This section reviews suitable KPIs, and how they help to devise targets or limits in order to control aircraft noise emission, noise exposure and their associated health impacts, including the pros and cons of each option. In a previous CAA report[9], noise limits were presented as 'noise envelopes' and different metrics were presented. In this report, noise limits are a scheme to manage the excess noise and to avoid noise recurrence. A penalty system is used to enforce compliance and to penalise in cases where the limits are exceeded. The objective of introducing a noise limit is to consider ways to:

- Limit source noise emission;
- Limit the area exposed to certain levels of noise;
- Limit the number of people exposed to certain levels of noise; and
- Limit the health impacts associated with exposure to aircraft noise.

A noise limit scheme needs to take into account:

- The management of aviation growth: to what extent it should allow for sector growth and also factoring in forecast reductions in noise at source;
- The noise objective: identify whether the priority should be on limiting the aggregated adverse health impacts or the number of people exposed and identify the scope for a limit to reduce over time; and
- Fair competition within the UK airports: allowing for different airports to account for historical conditions and/or future developments.

The key considerations being used for this review of noise limits are:

- **National and local requirements:** assessing whether noise limits should be national or local or a combination of both given that national and local requirements may be different. National limits would allow for comparability amongst airports both in terms of competition matters, noise efficiency and can make visible the total number of people impacted by noise in the country. However, using absolute national limits may restrict aviation grown in certain areas. Local limits would allow for local authorities to balance noise issues against land use planning and economic issues. If absolute noise limits are used locally and selected appropriately, they can protect the population impacted by aircraft noise.

9 "Noise Envelopes", CAP 1129, Civil Aviation Authority, December 2013.

- **Reducing or mitigating noise levels:** assessing if noise limit schemes should minimise noise emission, noise exposure, noise impacts or a combination of these.
- **Reduction of severity of health impact and/or on number of people exposed:** assessing if the noise limit scheme should reduce the severity of health impacts (e.g. through estimation of numbers of people highly annoyed or monetisation of the overall impacts using DfT's WebTAG).
- **Use of absolute or relative targets:** assessing which noise limit metrics can be used on an absolute basis (no links to traffic volume) and relative basis (linked to a traffic volume) and the advantages and disadvantages of each. An absolute limit at the national level (for a set number of airports) would set an absolute limit on noise emission, exposure or impact, whereas a relative limit, linked to a traffic volume, may allow for better functioning of the internal market. At a local level, an absolute limit would give more certainty to local residents, whereas a relative target would prioritise the noise efficiency of an airport.
- **How to monitor compliance:** assessing if the best way of monitoring compliance would be through analysis of performance over a defined period, continuous checking or a combination of both.
- **Who should monitor compliance and who should enforce limits:** assessing who should monitor and enforce the noise limit scheme.
- **Preliminary findings from the CAA's Noise Impacts survey:** CAA undertook a noise survey in 2017[10] exploring issues that people wanted CAA to tackle, butthe results have not been published yet. The top six issues raised were: 1) Aircraft numbers increasing without being able to have a say; 2) Aircraft flying lower than they should; 3) Flights early in the morning; 4) Flights late at night; 5) My local airport isn't doing enough to manage noise; and 6) Aircraft flying where they shouldn't be flying. Issue 1 is considered as part of this assessment whereas issues 2 to 6 are being taken into consideration in other CAA work streams.

In order to assess the noise limits that could be used in the UK, this report uses a noise limit scheme that has been previously defined[11] and consists of four aspects covered in more detail in the following sections:

- A noise metric (section 2.1);
- A method for taking into consideration traffic volume of an airport (section 2.2);
- A monitoring mechanism for noise limits compliance (section 2.3);
- Enforcement procedures for noise limits (section 2.4);

[10] https://consultations.caa.co.uk/policy-development/aviation-noise-impacts/

[11] "Sound noise limits: Options for a uniform noise limiting scheme for EU airports", CE Delft, 2005.

Noise limits is then covered in section 2.5 and a review of limits used at UK and international airports is presented in section 2.6. The selection of specific aspects to be included in this analysis is undertaken in Chapter 3.

2.1 Noise metric

Aircraft noise varies in magnitude, time, sound frequency and the number of discrete noise events that occur. A noise metric is a defined way to monitor noise that captures some of or all of the factors into a single indicator. Aircraft noise can be classified into the groups of metrics below:

- Emission metrics: covering metrics that measure the sound energy emitted by aircraft (e.g. ICAO certification noise levels and quota counts);
- Exposure metrics: covering metrics that measure noise on the ground. They include:
  - Single event metrics: used to describe the noise occurring during one noise event, such as an aircraft overflight;
  - Multi event metrics: used to provide a description of the type of noise exposure experienced over a given period that have a link to human reactions; and
  - Supplementary metrics: used in conjunction with the above, to provide a more meaningful depiction of the noise exposure.
- Impact metrics: metrics that are related to the health impact of aircraft noise on the exposed population.

Table 2.1 presents a summary of these metrics. Further information regarding each metric is provided in ERCD Report 0904[12]. The selection of noise metrics for this study is considered in section 3.1.

[12] K. Jones, R. Cadoux; "ERCD Report 0904 Metrics for Aircraft Noise", Environmental Research and Consultancy Department, CAA, 2009.

Table 2.1 Different types of noise metrics and their advantages and disadvantages:

Metric Group	Type	Examples	Advantages	Disadvantages
Emissions metrics	Noise emissions: Energy emitted by aircraft.	Certificated noise levels, quota counts, etc.	Noise can be determined relatively easily.	It does not relate to the noise exposure experienced on the ground.
Exposure metrics	Single event metrics: Noise on the ground used to describe one noise event.	Lmax, SEL, PNL, EPNL, etc.	It is easier to measure and often much simpler for the public to understand.	It requires calculation or local noise measurements.
	Exposure over a period metrics: Noise on the ground used to describe noise exposure over a given period.	NNI, LAeq, variations of LAeq (Lnight, Ldn, Lden, hourly LAeq around shoulder hours)	It contains the same sound energy as the actual variable sound.	It requires calculation or ground measurements. Not helpful for the general public.
	Supplementary metrics: Measurements often used in conjunction with other metrics.	L90, L10, N70, PEI, AIE.	It can supplement information from other metrics.	It requires calculation or ground measurements. It treats noise at different levels in the same way.
Impact metrics	Noise annoyance: Measurements related to the impact of noise on the exposed population during the daytime	Number of highly annoyed people.	It limits noise nuisance.	It requires calculation or ground measurements. It is limited by the subjective nature of annoyance.
	Sleep Disturbance: Measurements related to the impact of noise on the exposed population at night.	Number of people sleep disturbed.	Limit sleep disturbance.	It requires calculation or ground measurements. It is limited by subjective nature of sleep disturbance.

2.2 Methods for taking into consideration traffic volume of an airport

When considering setting limits for an airport, a method for taking into consideration traffic volume is required if the performance of an airport is to be considered on a relative basis. Table 2.2 presents a summary of these methods including the advantages and disadvantages. The selection of methods to take into account the traffic volume of an airport is considered in Section 3.2.

Table 2.2 Methods for taking into consideration traffic volume of an airport:

Type	Definition	Advantages	Disadvantages
ATMs	Number of air traffic movements by airport	Enables limits at different sized airports according to the numbers of aircraft movements they handle.	It does not take into consideration freight load or distance flown.
Passenger throughput	Number of passengers transported by airport	Enables limits at different sized airports according to passenger throughput. Number of passengers can be used to calculate total weight by applying an average weight per passenger.	It does not take into consideration freight load or distance flown.
MTOW	Maximum takeoff weight (MTOW) transported by airport	Enables limits at different sized airports taking into consideration both passengers and freight flights.	It does not take into consideration distance flown.
Passenger - kilometre	Number of passengers x km travelled by airport	Enables limits at different sized airports taking into consideration total passengers and distance flown.	It does not take into consideration freight load or distance flown.
Tonnes of freight	Number of freight tonnes transported by airport	Enables limits at different sized airports taking into consideration total freight transported.	It does not take into consideration passenger load or distance flown.
Tonnes-kilometre of freight	Number of freight tonnes x km travelled by airport	Enables limits at different sized airports taking into consideration total freight travelled.	It does not take into consideration passenger load.
Revenue Tonne-Kilometres	Number of passengers by a notional weight (which includes their baggage) and adding it to the cargo traffic before making the distance calculation	Enable equitable exposure or impact-based limits to be set at different sized airports according to the different economic benefit they generate.	It does not take into consideration the weight of the aeroplane.
Passenger Unit	One passenger unit is equivalent to either one passenger or 90 kilograms of freight and mail.	Used for Eurostat[13] and considers actual loading (of passengers or freight) on aircraft.	It does not take into consideration mileage.
MTOW/50 x distance	Weight factor (MTOW/50) x distance factor	Used for Eurocontrol charges, just looks at the size of the aircraft.	Takes no account of the load factor.

[13] https://ec.europa.eu/eurostat/

2.3 Monitoring mechanisms for noise limits compliance

A noise limit scheme monitors compliance of implemented measures either continuously or over a defined period.

Monitoring compliance over a specified period of time can vary from simple checks such as annual air traffic movements to noise contours showing exposed areas and the population within. A check of compliance against the limit would be required at the end of the monitoring period and enforcement action could be taken in the event of a breach. Local authorities or other national bodies are best placed to monitor compliance over a defined period.

Continuous monitoring of compliance requires a more operational approach and would be undertaken as part of an airport's noise management strategy. If a regular review indicates that a breach may be likely, the airport can take early preventative action to avoid the breach. Certain parameters will be better suited for continuously monitoring compliance than others. Parameters such as air traffic movement numbers can be predicted in advance through the airport's standard scheduling processes, and then closely monitored (potentially daily, as is done currently for administration of the London airports' night-time Quota Count system).

Any monitoring mechanisms should anticipate the differences between monitoring performance using modelled or measured information. The use of modelled information allows for monitoring current performance but also allows for different past, present and future scenarios to be analysed. On the other hand, measured information is used for monitoring performance around airports, to validate models and to give assurance to residents of the noise levels in different locations. Local measurements may be prone to uncertainty, cost, suitability, coverage issues and adverse weather.

Table 2.3 presents a summary of the monitoring mechanisms including advantages and disadvantages. Section 3.3 covers "Selection of noise limit schemes"..

Table 2.3 Monitoring mechanisms for noise limits compliance of an airport:

Monitoring mechanism	Definition	Advantages	Disadvantages
Defined monitoring compliance	Uses an agreed monitoring period to evaluate the parameters.	Does not disturb regular operation of the airport Can use models to calculate the limits. Analysis on a wide range of locations. Analysis of future scenarios.	Can only enforce compliance after the period is complete. Depends on availability of data for that period. Depend on precision of the acquired data or modelling used.
Continuous monitoring compliance	Using continuous monitoring to evaluate compliance.	Captures information at the time it happens and at specific locations. Well perceived by local communities.	Availability of measurement points. Can potentially impact on airport operations.

2.4 Enforcement procedures

To maintain public confidence in the planning system it is important that limits are enforced effectively. Any enforcement measures should be agreed during the design of the noise limit controls.

This plan should be established with stakeholder agreement and published. This should set out how authorities will monitor the implementation, investigate alleged cases of unauthorised actions and act where it is appropriate to do so. The plan should highlight how this is to be undertaken proactively and in a manner that is appropriate to the circumstances.

This noise plan requires an organisational body to oversee enforcement procedures.

Table 2.4 presents a summary of enforcement procedures including advantages and disadvantages.

Table 2.4 Enforcement procedures for noise limits compliance of an airport:

Enforcement procedure	How	Examples	Advantages	Disadvantages
Monetary penalty for exceedance	Compliance checked at the end of the monitoring period	Schiphol Airport	Allows for improvement of relationship with community if fines invested in a community fund	Lack of ability to enforce compliance during monitoring period
Loss of future capacity in the next control period	Compliance checked at the end of the monitoring period	Luton night contours	Creates commercial incentive for compliance	Lack of ability to enforce compliance during monitoring period.
No ability to exceed limits	Regular monitoring of the parameters	Sydney noise curfew	Creates behaviour change and commercial incentive for compliance	Monitoring is costlier
Loss of right to operate	Noise levels measured per aircraft type	John Wayne Airport	Creates commercial incentive for compliance	Can have financial implications for airlines

2.5 Noise Limits Schemes

In this analysis, the noise limit schemes are considered under the following categories:

- Restricting noise emissions;
- Restricting noise exposure; and
- Restricting noise impact.

2.5.1 Restricting noise emissions

There are many factors which affect the amount of noise that is produced at an airport. Some of these have a very noticeable effect, whereas others are more subtle.

In general terms, a busy airport tends to make more noise than one which is less busy. For example, a high passenger throughput requires accordingly high numbers of aircraft movements. Even where fewer operations by large aircraft carry the same numbers of people as more movements by smaller aircraft, the larger aircraft typically produce more noise.

It is therefore possible to use relevant inputs as a proxy for the noise created. Possible input limits are described below and could be applied to define an envelope.

Aircraft movements

The number of aircraft ‘movements’ (total number of arrivals and departures) which occur at the airport over a given period can be set at an agreed amount based on an equivalent level of noise exposure that is not to be exceeded. There is, however, no precise relationship between the number of movements and amount of noise produced as larger aircraft produce more noise than smaller ones at the same technology level.

Passenger throughput

The number of passengers (total number of arrival and departure passengers) that can use an airport over a given period. Whilst passenger throughout better captures aircraft size and to a certain extent the number of movements, it does not reflect distance flown – aircraft flying longer distances generate more noise than ones flying shorter distances.

Noise quota

Each aircraft type is assigned a noise classification[14] according to its certificated noise performance: the noisier the aircraft, the greater the noise classification. The numbers of movements of each aircraft type, over a given period, are multiplied by the corresponding noise factor (classification), and these ‘noise factored movements’ are counted against an overall noise quota for an airport. Noise quota can be set separately for winter and summer seasons. They may be sub-divided between arrivals and departures, or between types of services in other ways, depending on the degree of flexibility required within the permitted limits. The noisier the aircraft used, the higher its noise factor and the greater the amount of the quota budget each movement uses up, thereby providing an incentive for airlines to use quieter aircraft types. Noise quota budget may be set to permit a limited amount of growth, i.e. to share the benefits of improving aircraft technology.

[14] “London Heathrow, London Gatwick and London Stansted Airports Noise Restrictions Notice (No.2) 2018”, AIP SUPPLEMENT 049/2018, DfT, 2018.

2.5.2 Restricting noise exposure

This section focuses on the noise exposure experienced by people on the ground and the limits, that could be used to restrict it.

Noise contour area

A clear and concise way of describing the noise exposure around airports is to calculate the area enclosed by the noise contour of a noise metric and level. Being a single numerical value, it is straightforward to set a limit on this area value to restrict aircraft noise exposure near an airport. Limits could be applied to the area of a contour of any agreed metric and at any agreed level. In some cases, it may be appropriate to use a noise metric which has a precedent for use in noise control or the assessment of noise impact.

Noise contour shape

Many of the principles of using the area of a noise contour apply to a greater or lesser degree to using the actual shape of the contour as a limit. However, this criterion goes beyond the remit of the area limit by being explicit on how much noise each neighbouring community can expect to be exposed to. In doing so, it leaves little scope for redistribution of noise geographically within a reporting period without breaching the limit.

Noise level limits

Noise level limit use noise measurement and prediction to establish noise exposure at specified locations in the geographical area near an airport. The noise levels from each noise monitor are integrated over a period and compared with an agreed limit value. A breach would occur if the measured level at any of the noise monitors exceeds the limit.

Population/dwellings exposed to noise

As well as calculating the area enclosed within a noise contour, it is also straightforward to count the population and number of dwellings enclosed. Being single numerical values, they lend themselves to use as envelope limits. However, the population within a given noise contour will change over time, as the population distribution changes, both through the addition of new housing and also due to the change of use of existing housing that may alter the population density within existing housing. Both of these factors are outside the aviation industry's control and therefore limit the value of using population-based indicators for restricting noise exposure.

Person-Events Index (PEI)

Person-Events Index (PEI) is the number of noise events each resident is exposed to above a certain threshold level, say 70 dB LAmax, summed to give a single figure that represents the total noise load or burden the airport places on the surrounding population[15]. The more noise is concentrated on fewer people, the lower the value of PEI will be. It also assists in the interpretation of noise exposure distributions when considering different operating arrangements at an airport. The index enables a relatively quick assessment to be made of noise exposure information and reveals a somewhat different picture to initial conclusions based solely on the populations exposed.

Average Individual Exposure (AIE)

PEI gives an indication of total noise load on the surrounding population, but not how it has been distributed across the population. Dividing the PEI by the total exposed population gives the average number of noise events per person, more commonly known as the Average Individual Exposure (AIE).

2.5.3 Restricting noise impact

The two most common impacts of aircraft noise are daytime annoyance and night-time sleep disturbance.

Number of people annoyed (daytime)

Noise affects different people by different amounts. Research in the field of noise attitudes has developed exposure-annoyance relationships, including the percentage of people who might be expected to be highly annoyed during the daytime at different noise exposure levels based on average community response. This relationship can be used to estimate the total number of people who might be expected to be highly annoyed by aircraft noise at a given airport.

This limit relies on the exposure-annoyance relationships, which are subject to change reflecting advances in research. This introduces an element of uncertainty, which would need careful management. One approach might be to review existing limits whenever the dose-response relationship is revised. Like population counts, estimates of the number of people highly annoyed are also subject to changing population distributions that are outside the control of the aviation industry.

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[15] "Expanding Ways to Describe and Assess Aircraft Noise", discussion paper, Department of Transport and Regional Services, Australia, ISBN 0 642 42262 1, March 2000.

Number of people sleep-disturbed (night-time)

Whereas noise from aircraft operations during the daytime results in annoyance, noise from night operations tends to disturb people's sleep. This metric is almost identical to the number of people annoyed, but requires a different exposure-response relationship and different noise exposure indicator as input, namely the percentage of people who are highly sleep-disturbed by night-time aircraft noise at different night LAeq8h levels. Like the number of people highly annoyed it also suffers from being affected by changing dose-response relationships for sleep disturbance and changing population distributions.

Summary

Table 2.5 presents a summary of the noise limit methods including advantages and disadvantages. The selection of noise metrics for this study is considered in Section 3.3.

Table 2.5 Noise limits scheme options for an airport

Type of Limit	Metric	Example of prior use	Advantages	Disadvantages
Limit noise emissions	Number of movements	Stansted, London City, Belfast City and Heathrow	Simple and easy to implement. Addresses people's growing sensitivity to the frequency of aircraft noise events	Does not take account of the noisiness of aircraft and therefore does not incentivise the use of quieter aircraft
	Seats for sale	Belfast City	Limits both ATMs and aircraft size	Administratively more complex and onerous. Potential enforcement challenges.
	Passenger throughput	Belfast City and Stansted	Provides more operational flexibility than a simple movement cap	Does not directly take account of the noisiness of aircraft or the number of operations
	Noise quota - night	Heathrow, Gatwick, Stansted, Manchester, East Midlands, Birmingham, Southampton, Bristol, Leeds, Amsterdam, Frankfurt, Madrid	Depending on the application places limits on the maximum noise quota for a single movement and the total nightly quota, based on the certificated noise levels for each aircraft operated. Reflects that larger aircraft tend to have higher QC values	Administratively more complex to administer so aircraft types can have differing noise quota classifications depending on variant or engine type
	Runway use restriction		Directly limits noise exposure in specific areas close to a runway. Where used a runway rotation control directly facilitates noise sharing.	

Type of Limit	Metric	Example of prior use	Advantages	Disadvantages
Limit noise exposure	Noise contour area	Heathrow, Gatwick, Stansted, Manchester, East Midlands	LAeq noise contours, by definition, represent long-term noise exposure, A contour area, expressed as a single numerical value, is easy to understand and apply as a criterion.	The LAeq indicator does not necessarily reflect all aspects of the perception of aircraft noise.
	Noise contour shape	Amsterdam Schiphol	Provides a very tight noise control and the potential to offer a comprehensive deal to residents. Maintains adherence to a noise sharing arrangement.	Significantly restricts operational flexibility. Could limit ability to alter noise sharing regime.
	Population/dwellings exposed to noise		Reflects the number of people exposed to noise. Incentivises concentration of noise in less populated areas.	Provides limited means to differentiate between people acutely or mildly exposed.
	Noise level limit	Paris Charles de Gaulle	Uses measured levels, therefore simple and transparent. Best suited to airports with simple departure route structures	Measurements are subject to extraneous noise and equipment precision. Aircraft can be operated in ways which optimise low noise over the monitors, potentially resulting in higher noise elsewhere
	Person-Events Index (PEI)	Sydney Kingsford Smith	Reflects the number of people affected by noise. Reflects the number of events each person is exposed to	Controls only take effect after the noise ‘breach’ has occurred. Population encroachment will impact on the value of PEI
	Average Individual Exposure (AIE)	Sydney Kingsford Smith Airport	Reflects the average number of noise events each person is exposed to and is a linear metric	Controls only take effect after a noise breach has occurred. Population encroachment will impact on the value

Limit noise impact	Number of people annoyed (daytime)	Amsterdam Schiphol	Considers the increased risk of being annoyed by aircraft noise at higher exposure levels	Changing understanding of exposure-annoyance relationship may introduce long-term planning uncertainty and risk
	Number of people sleep-disturbed (night-time)	Amsterdam Schiphol	Considers the increased risk of sleep disturbance at higher noise exposure levels	Complicated to calculate. Changing understanding of exposure-annoyance relationship may introduce long-term planning uncertainty and risks
	Monetised health impacts (WebTAG)		Considers the overall monetised risk of diseases associated with high noise levels	Complexity of calculation and needs to have two comparative scenarios for evaluation as set up in WebTAG.

2.6 Review of limits used at UK and international airports

2.6.1 UK Airports

A review of the implementation of noise limits at UK airports has been undertaken, to assess the extent that limits have been implemented. A summary of this assessment is presented in Table 2.6. The results show that most of the airports implement noise quota limits at night, but there is limited implementation of other noise emission restrictions during the day. In relation to limiting noise exposure, half of the airports use noise contour areas to limit noise exposure. In terms of limiting noise impact on people, most of the airports are monitoring their own impacts, but the results show that to date none of the airports have adopted limits based on noise impact on the surrounding population.

2.6.2 International Airports

The assessment of international airports is intended to highlight examples of different implementations of noise restriction limits and therefore is not a comprehensive review. Table 2.7 presents a summary of the findings, indicating that different airports focus on different ways of limiting noise. Further details will be brought to this assessment where relevant. Section 2.6.3 presents how limits are implemented at Schiphol Airport, where a wide interest on its noise control shape limits has been raised in UK in recent years.

Table 2.6: Noise limit schemes implemented in the top 10 busiest UK airports (by number of passengers)

Metric Type	Metric	Heathrow	Gatwick	Manchester	Stansted	Luton	Edinburgh	Birmingham	Glasgow	Bristol	Belfast Intl
Limit noise emission	Aircraft (per type) movement cap										
	No of movements	✓			✓					✓	
	Runway use restrictions										
	Seats for sale										
	Passenger throughput				✓						✓
	Noise quota - day					✓					
	Noise quota - night	✓	✓	✓	✓	✓		✓		✓	
Limit noise exposure	Noise contour area	✓	✓	✓	✓	✓					✓
	Noise contour shape										
	Noise level limit										
	Population exposed										
	Person-Events Index (PEI)										
	Average Individual Exposure (AIE)										
Limit noise impact	Number of people annoyed (daytime)										
	Number of people sleep-disturbed										
	WebTAG										

Table 2.7: Noise limit schemes implemented in selected international airports.

		Amsterdam	Paris CDG	Frankfurt	Sydney
Restrict noise emission	Aircraft (per type) movement cap				
	No of movements				
	Seats for sale				
	Passenger throughput				
	Noise quota - day				
	Noise quota - night			✓	
	Runway use restrictions				
Restrict noise exposure	Noise contour area				
	Noise contour shape	✓			
	Noise level limit	✓	✓		
	Population exposed				
Restrict noise impact	Number of people annoyed (daytime)	✓			
	Number of people sleep-disturbed				
	Person-Events Index (PEI)				✓
	Average Individual Exposure (AIE)				✓

2.6.3 Overview of Schiphol limits

Noise contour shape goes beyond the remit of the noise contour area by being explicit on how much noise each neighbouring community can expect to be exposed to and then placing a limit on it. This type of limiting scheme leaves little opportunity for redistribution of noise, geographically, within a reporting period without breaching the limit.

One disadvantage of a noise contour shape limit is that the airport becomes constrained to operate in a particular way despite factors that may be beyond the airport’s control. On the other hand, it has the advantage of offering clearer commitment to residents.

Schiphol airport utilises noise contour shape to limit noise exposure levels at specific locations around the airport’s perimeter and thereby controls the shape of the noise contour.

The system is rather complex, particularly in terms of calculating the limits and also in terms of planning runway operating modes to avoid breaches. Some allowance for weather variations is incorporated into the limit values, so when limits are breached, investigations are carried out to analyse whether it was due to atypical weather or other reasons. When maintenance work is undertaken that restricts access to a runway, adjustments to the limit values need to be consulted on and agreed.

The system is particularly relevant to an airport like Schiphol with five runways that may be used in a variety of different operating modes, to enforce distribution of noise and avoid concentration on a few preferred runways, and in setting clear expectations for residents.

At Amsterdam Schiphol airport a sequence of runway preferences has been defined that determines the preferred operating runways, weather permitting. To control the runway preference system, a noise budget restriction system was developed and implemented to set limits on noise exposure at specific locations and is applied through enforcement of maximum noise exposure limits at many locations near the airport. Each enforcement point has its own limiting noise exposure value, which may not be exceeded at the end of the year.

The noise contribution of an aircraft operation at each enforcement point is determined through noise calculations that consider the aircraft type, type of operation, runway, flight path and time of day. Noise load at each enforcement point is tracked on a daily and two-weekly basis.

A review of this scheme is being considered because of extensive negotiations with local and national government, the aviation sector and community representatives.

At an airport with fewer runways enforced distribution of noise would be much more dependent on distributing flights across different flight paths, which may not be possible to the same extent as that achieved using different runways, and it could lead to sub-optimal use of flight paths, additional track miles flown, leading to increased carbon emissions or even a loss of airspace capacity.

Chapter 3

Selection of suitable metrics for health impacts and noise limit schemes

To choose the noise limits that could be used in the UK, a selection of the appropriate aspects covered in Chapter 2 is considered:

- Selection of noise metric (section 3.1);
- Selection of method for taking into consideration traffic volume of an airport (section 3.2);
- Selection of noise limit schemes (section 3.3).

3.1 Selection of noise metric

Table 3.1 summarises the noise metrics selected to represent the different approaches for restricting noise, and to bring a range of options for reviewing how to limit noise impacts.

3.2 Selection of method to take into account the traffic volume of an airport

Several methods can be used to take into consideration the traffic volume at an airport and provide a relative measure for a noise limit. If a relative method is to be introduced in the UK it should be set to account for different sized airports according to the different economic benefits they generate.

A method that accounts for weight (maximum payload) and distance travelled would be recommended to enable impact-based limits as it would take into consideration both freight and passenger weight as well as distance travelled over a period.

Table 3.1: Selection of noise metrics for limiting noise

Limit Type	Metric Type	Metric Group	Recommended metrics for selection
Source Emissions	Noise emissions	Energy emitted by aircraft.	Quota count
Exposure	Single event metrics	Area or number of people exposed to specified numbers of noise events above a specified Lmax level	N65, N70 (daytime), N60 (night-time)
		The sum of the number of events above a specified Lmax level that the surrounding population is exposed to.	Person Event Index (PEI), PEI(70)
		The sum of the number of events above a specified Lmax level that the surrounding population is exposed to divided by the number of people exposed	Average Individual Exposure (AIE), AIE(70)
	Exposure metrics	Noise on the ground used to describe noise exposure over a given period. Area or number of people exposed to certain noise levels.	LAeq, Lden
Impact	Noise annoyance	Measurements related to the impact of noise on exposed population.	Number of (highly) annoyed people
	Sleep disturbance	Measurements related to the impact of noise on exposed population at night.	Number of people (highly) sleep disturbed.
	Monetised impact	Monetary estimate of the adverse health impacts associated with the noise exposure	WebTAG monetary estimate of health impact

3.3 Selection of noise limit schemes

The selection of noise limit schemes should take into consideration the direct ability to limit:

- Noise emission;
- Area exposed;
- Population exposed; and
- Health impact.

Table 3.2 presents the summary of the schemes and their ability to fulfil the objectives above. The results of this table are used to decide on which schemes to take forward for analysis.

Table 3.2: Limit schemes review

		Limit scheme objective		Use of limit	
Limit Type	Metric Type	**Limit area impact**	**Limit population impact**	**Absolute Limit**	**Relative limit**
Limit noise emissions	Aircraft (per type) Movement Cap	✗	✗	✓	✓
	No of movements	✗	✗	✓	✓
	Seats for sale		✗		✓
	Passenger throughput	✗	✗	✓	✓
	Noise quota - day	Y	✓	✓	✓
	Noise quota - night	✗	✗	✓	✓
Limit noise exposure	Noise contour area	✓	✓	✓	✓
	Noise contour shape	✓	✓	✓	✗
	Noise level limit (to control shape of contour)	✓	✓		✗
	Population/dwellings exposed to noise	✗	✓	✓	✓
	Runway use restrictions	P	✗	✓	✓
	Person-Events Index	✗	✗	✓	✓
	Average Individual Exposure	✗	✗	✓	✓
Limit noise impact	Number of people annoyed (daytime)	✗	✓	✓	✓
	Number of people sleep-disturbed (night-time)	✗	✗	✓	✓
	WebTAG	✗	✓	✓	✓

In respect of the other considerations covered in section 2.5, the following will be used in the analysis:

- National and local requirements: both national and local requirements will be taken into consideration in the analysis;
- Limit noise exposure or adverse health impacts: all limits that directly achieve the objective will be taken into consideration;
- Use of absolute or relative targets: it is proposed that absolute limits are set at a local level in order to limit overall noise emission, exposure or impact. At the national level, it is proposed that both absolute and relative targets are considered to take into consideration the growth forecasts for the country;
- Population or spatial limits: it is proposed that a spatial limit is considered given the limitations the aviation sector has in limiting the population within a certain area;
- Preliminary findings from CAA 2017 Noise Survey: preliminary results show that the top issues people want the CAA to tackle is "Aircraft numbers increasing without being able to have a say", therefore this will be included in the analysis;
- How should compliance be monitored (measurements or calculations): a review of options is presented as part of the analysis;
- Who should monitor compliance and who shoud enforce limits: a review of options is presented as part of the analysis.

A summary of the analysis undertaken for the selection of the noise limit scheme is given in Table 3.3.

Table 3.3: Limit schemes selected for further investigation

Limit Type	Metric Type	Absolute Limit for population exposed	Relative Limit for population exposed	Absolute Limit for area exposed	Relative Limit for area exposed
Limit noise emissions	Noise quota - day	✓	✓	✓	✓
	Noise quota - night	✓	✓	✓	✓
Limit noise exposure	Noise contour area	✓	✓	✓	✓
	Noise contour shape	✓	✗	✓	✗
	Noise level limit (to control shape of contour)	✓	✗	✓	✗
	Population/dwellings exposed to noise	✓	✓	✗	✗
	Person-Events Index	Possibly	Possibly	Possibly	Possibly
	Average Individual Exposure	Possibly	Possibly	Possibly	Possibly
Limit noise impact	Number of people annoyed (daytime) Lden	✓	✓	✗	✗
	Number of people sleep-disturbed	✓	✓	✗	✗
	Respite	Possibly	Possibly	Possibly	Possibly
	webTAG	✓	✓	✗	✗

In summary, following from previous analysis, the approaches recommended for further consideration in the next chapters include:

For limiting noise emissions:

From the analysis presented in this chapter daytime and night-time noise quota limits were selected as the metrics to assess forecast noise and consider as noise emission limits.

For limiting noise exposure:

From the analysis presented in this chapter, the following limits were selected as the metrics to assess forecast noise and consider as noise exposure limits:

- National L_{Aeq} or L_{den} limit on the area exposed to at least 51 or 54 dB;
- National night-time limit on the area exposed (L_{Aeq8h} or L_{night}) to at least 45 or 48 dB;
- National L_{Aeq} or L_{den} limit on the area exposed to at least 51 or 54 dB normalised by transport volume (ATMs);
- National night-time limit on the area exposed (L_{Aeq8h} or L_{night}) to at least 45 or 48 dB normalised by traffic volume (ATMs);
- National N_{Ax} limit on the area exposed to at least 5 or 10 events per average summer day above 65 or 70 dB L_{Amax} or 60 dB L_{Amax} per average summer night;
- National limit based on average summer daytime total number of person-events above 70dB L_{Amax}, PEI(70) 10 events;
- National limit based on summer daytime Average individual exposure of events above 70 dB L_{Amax}, AIE(70) 10 events;
- Local daytime (L_{Aeq} or L_{den}), (54 or 51) dB contour area limit;
- Local night time (L_{Aeq8h} or L_{night}), (48 or 45) dB contour area limit;
- Local N_{Ax} limit on the area exposed to at least 5 or 10 events per average summer day above 65 or 70 dB L_{Amax} or 60 dB L_{Amax} per average summer night.

It was recommended that the number of people within the area should be a reported figure, but this should not be a limit imposed on the aviation sector as the control of the local population at a given location is outside the control of the aviation sector.

For limiting health impact

Nationally, it is recommended that limits to annoyance and sleep disturbance should be included using criteria from the WHO Europe Burden of disease report[16] or the UK Survey of Noise Attitudes 2014[3]. Whilst SoNA 2014 presented an updated dose-response function based on L_{Aeq16h}, a complementary night-time dose-response function has not been published. Thus, it was decided for consistency purposes to use the EU dose-response functions[17]. The annoyance function was limited to noise exposure above 51 dB L_{den} and 54 dB L_{den} to avoid uncertainty issues with estimating noise exposure at low noise levels[18]. Similarly, for night-time, the highly sleep-disturbed dose-response function was limited to noise above 45 dB L_{night} and 48 dB L_{night}.

Although, it was initially planned to use DfT's web-based Transport Appraisal Guidance, WebTAG, to provide a monetary value for the health impacts, this was not possible. WebTAG was conceived and implemented to assess the relative health impacts of future road, rail or aviation transport infrastructure proposals as part of an options appraisal and compare the health impacts of options against a do-nothing scenario in their opening year and over the standard 60-year life assessed for transport infrastructure. In this report, noise exposure and impacts are being compared over time and not against a do-nothing scenario, and thus WebTAG cannot be applied to such situations.

Locally, it is recommended that limits on annoyance and sleep disturbance should also be calculated using the same functions and lower thresholds.

16 Burden of disease from environmental noise: Quantification of healthy life years lost in Europe, WHO Europe, ISBN: 978 92 890 0229 5, 2011.

17 Good practice guide on noise exposure and potential health effects, EEA Technical Report No. 11/2010, ISBN 978 92 9213 140 1, European Environment Agency, 2010.

18 Measurement and Modelling of Aircraft Noise at Low Levels, ERCD Report 1006, CAA, October 2010.

Chapter 4

Modelling methodology and data acquisition

This chapter gives an overview of the methodology and data utilised as part of this work, including the modelling methodology, modelling tool and input data. Chapters 5 and 6 present the results of this analysis.

Modelling methodology and modelling tool:

The calculations presented in this study were performed using CAA ANCON version 2.4, in line with ECAC-CEAC Doc 29 4th edition. An overview of ANCON and ECAC-CEAC Doc 29 4th edition is given in Appendix B.

Airports utilised:

This study's objective is to estimate future airport noise exposure and examine the feasibility of implementing noise limits in UK with the intention of limiting and where possible reducing noise emission, noise exposure and noise impacts at UK airports. In order to capture the overall population exposure, it was decided to use the top 10 airports by size of population exposed within the 2016 55dB L_{den} contour based on data reported to Defra for the Environmental Noise Directive (END). Data to enable forecast noise calculations for London City Airport and Leeds-Bradford Airport were not available to enable their inclusions as part of this assessment. Therefore, the eight airports utilised in this analysis are: Birmingham (BHX), Edinburgh (EDI), Glasgow (GLA), London Gatwick (LGW), London Heathrow (LHR), Luton (LTN), Manchester (MAN) and Stansted (STN).

Airport expansion:

The only airport expansion included in this report is a third North West Runway at Heathrow (LHR NWR) as it is the selected expansion option in the Government's Airport National Policy Statement[19].

19 "Airports National Policy Statement: new runway capacity and infrastructure at airports in the South East of England", Department for Transport, June 2018.

Historic traffic data:

Traffic data were provided by each airport (Birmingham, Edinburgh, Glasgow, Gatwick, Heathrow, Luton, Manchester and Stansted) for 2006 and 2016. Table 4.1 presents the number of movements for the baseline years and shows that the number of movements for an average summer day 16h has decreased by 1.2%, whilst the number of movements for an average summer day 24hr has increased by 0.3%. The decreased in daytime movements is dominated by Stansted airport, which has yet to return to movement levels seen prior to the 2009-10 recession. The increase in night time movements is likely due to growth of airlines wishing to maximise revenue and therefore operating more in the shoulder hours of 23:00 to 23:30 and of 06:00 to 07:00, but further analysis would be required to confirm this.

Table 4.1 Baseline average summer day and night movements for all airports assessed:

	Scenario: Baseline No. movements		
Time Period	**2006**	**2016**	**% change 2006-2016**
Average summer day 16h	4,350	4,295	-1.2%
Average summer night 8h	454	522	+14.9%
Average summer 24h	4,804	4,817	+0.3%

Forecast traffic data:

Traffic forecasts provided by DfT for each airport were based on the 2017 UK Aviation Forecasts[20] for two scenarios: Central and High demand. The High scenario is described as having a higher passenger demand from all world regions, lower operating costs and a global emissions trading scheme. These scenarios are described in more detail in reference 17. The forecasts provided a breakdown of the annual forecast ATMs by aircraft type.

The noise indicators considered required that the data was broken down by average summer day (0700-2300) and night (2300-0700) periods, reflecting the summer seasonal peaks present at most UK airports, and for the annual L_{den} metric, broken down into annual average day (0700-1900), evening (1900-2300) and night (2300-0700) periods. Data on the proportions of movements in the different time periods from the Airports Commission, itself based on 2011 data, was found to differ from historical 2016 data and thus in the

[20] DfT 2017 UK Aviation Forecasts, October 2017.

absence of better data, information from 2016 was used determine the proportions of operations in each time period by aircraft type, runway and flight path.

Table 4.2 (a) and (b) presents the number of movements for the forecast years for both High and Central scenarios. Table 4.2 (a) shows that the number of movements in the High scenario for an average summer day is forecasted to increase by 39.3% and that for an average summer night is forecasted to increase by 34.1% between 2016 and 2050. For the Central scenario, Table 4.2 (b) shows that the number of movements for an average summer day is forecasted to increase by 37.5% and that for an average summer night it will increase by 26.8%.

Table 4.2 (a) Forecasted ATMs for all airports assessed – High Scenario

	Scenario: High	No. movements				
Time Period	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
High - average summer day 16h	4,295	4,498	5,323	5,656	5,984	+39.3%
High - average summer night 8h	522	549	616	656	700	+34.1%
High - average summer 24h	4,817	5,047	5,939	6,312	6,685	+38.8%

Table 4.2 (b) Forecast ATMs for all airports assessed – Central Scenario

	Scenario: Central	No. movements				
Time Period	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Central - average summer 16h	4,295	4,395	5,230	5,602	5,906	+37.5%
Central - average summer night 8h	522	511	573	623	662	+26.8%
Central - average summer 24h	4,817	4,906	5,804	6,225	6,568	+36.3%
%Variation Central-High (24h)	-	-2.8%	-2.3%	-1.4%	-1.7%	

Aircraft noise performance:

For current aircraft types, the noise performance for 2006 and 2016 was based on radar data and noise measurements provided by Heathrow Airport, Gatwick Airport and Stansted Airport for 2006 and 2016. In all other cases the aircraft noise performance was based on Gatwick Airport data, except for the most dominant aircraft types operating at Birmingham and Manchester airports respectively, where local data is used. The use of Gatwick data strikes a balance between a lack of available and/or robust data available for some airports, and proportionality, recognising that airline standard operating procedures result in similar noise performance across different airports for the same airline operating to similar destinations – and with the exception of Heathrow airport, for the remaining seven airports assessed, noise is dominated by the same airlines and aircraft types.

For future aircraft types, the noise performance is based on noise certification data if the aircraft is already certified. For the longer term (beyond 2030) the aircraft noise performance is based on the ICAO long-term technology improvement trend of 0.1dB/year improvement[21].

Fleet retirement:

The fleet retirement rate used for 2006 to 2016 was based on actual data provided by the airports. The rate used for the forecast scenarios was given by UK Aviation Forecasts 2017[16].

Population data:

The population data used for exposure and impact assessment was provided by CACI Limited[22]. Data for 2006 was based on a CACI 2006 update of the 2001 Census and data for 2016, a 2016 update of the 2011 Census. CACI forecast data was used for 2030, 2040 and 2050. For 2025, the data was interpolated between 2016 and 2030.

21 ICAO (2014), Report by the Second CAEP Noise Technology Independent Expert Panel, ICAO Doc. 10017, ISBN 978-92-9249-401-8, ICAO, 2014.

22 www.caci.co.uk

Chapter 5

2006 and 2016 Performance Analysis

Chapter 3 presented the selection of the most suitable metrics for limiting noise exposure and health impacts and Chapter 4 presented the methodology and data used for the calculations. This chapter presents the results of the noise metric assessment for 2006 and 2016 using the noise limit schemes selected in Chapter 3 and methodology and data presented in Chapter 4.

The purpose of the 2006 and 2016 performance analysis is to review the application of different metrics and to understand the implications on the noise contour area, population exposed and health impacts.

The metrics used for this analysis are those presented in Table 3.3 including limits for restricting noise emissions, noise exposure and noise health impacts. The results for the 2006 and 2016 analysis, presented in this chapter, are the combined results for all airports considered in Chapter 4. The results with the breakdown for each individual airport are presented in Appendix C.

For metrics that restrict noise emissions, quota count is the selected metric for evaluation and the results are presented in Table 5.1. The results show that there is a reduction in quota count for average summer day 16h. For summer night, the results show that there was a small reduction in quota count. This decrease is mainly due to a shift towards quieter aircraft, given that the ATMs increased.

Table 5.1: 2006 & 2016 Analysis - Quota Count

	Scenario: Baseline	Quota Count	
Metric	**2006**	**2016**	**% change**
QC - average summer day 16h	2,697	2,471	-8.4%
QC - average summer night 8h	301.3	299.6	-0.6%
QC - average summer 24h	2,998	2,770	-7.6%

For metrics that restrict noise exposure, Table 5.2 presents a summary of the results. The results show that the noise contour area for an average summer day and an average 24 hour day have reduced at the majority of noise contour levels. On the other hand, the noise contour areas for night noise have increased both for an average summer night and for an average annual night.

In terms of the population exposed to noise, the population exposed in an average summer day and in an average annual 24 hour day have reduced at the majority of noise contour levels. On the other hand, the populations exposed to night noise have increased both in the average summer night and in the average annual 24 hour day. The increase in population exposed can be related both by the increase in aircraft movements at night and by the increase in the average population growth for the period (presented in more detail later in this chapter).

Table 5.2 also presents the results for the Number Above metric. N60 is used for indicating the number of aircraft movements above 60 dB over an average summer night, whilst N65 and N70 are used to indicate the number of movements above 65 and 70 dB respectively during an average summer day. The results from 2006 to 2016 present a reduction in Number Above for the average summer day and an increase in Number Above for average summer nights.

The analysis of PEI (70) and AIE (70) (Table 5.2) indicates an increase in PEI (70), which is in line with the increase in number of movements and increase of population in the area. The analysis also looked at AIE, showing that AIE has increased, which indicates that the population exposed to 70 dB events is being subjected to more events due to the increase in ATMs for the period.

Table 5.2: 2006 & 2016 Analysis - Summary of noise exposure results for the selected metrics and contour levels

		Scenario: Baseline	Noise Exposure				
		Area (km²)			Population Exposure		
Metric	Level	2006	2016	% change 2006-2016	2006	2016	% change 2006-2016
Average summer day LAeq16h	>51	932.3	879.0	-5.7%	1,550,500	1,560,800	+0.7%
Average summer day LAeq16h	>54	530.4	490.2	-7.6%	825,400	782,300	-5.2%
Average summer night LAeq8h	>45	716.2	819.7	+14.4%	1,016,600	1,243,200	+22.3%
Average summer night LAeq8h	>48	419.6	473.0	+12.7%	521,700	655,500	+25.6%
Average annual 24h Lden	>50	1,590.0	1,455.2	-8.5%	2,629,900	2,474,500	-5.9%
Average annual 24h Lden	>55	615.6	575.1	-6.6%	997,300	950,000	-4.7%
Average annual 8h Lnight	>45	669.3	680.9	+1.7%	1,029,100	1,117,000	+8.5%
Average annual 8h Lnight	>50	268.0	256.7	-4.2%	304,600	323,600	+6.2%
Average summer night 8h N60	>5 events	1,563.9	1,728.2	+10.5%	1,800,700	2,155,400	+19.7%
Average summer night 8h N60	>10 events	843.6	1,071.6	+27.0%	1,215,900	1,473,400	+21.2%
Average summer day 16h N65	>5 events	2,877.6	2,096.5	-27.1%	3,645,400	2,608,800	-28.4%
Average summer day 16h N65	>10 events	2,011.0	1,561.1	-22.4%	2,449,500	1,965,000	-19.8%
Average summer day 16h N70	>5 events	1,070.8	758.4	-29.2%	1,379,300	1,061,800	-23.0%
Average summer day 16h N70	>10 events	777.9	592.1	-23.9%	974,600	838,700	-13.9%
AIE (70)	>5 events	-	-	-	47.0	65.9	+40.0%
AIE (70)	>10 events	-	-	-	61.8	79.5	+28.7%
PEI (70)	>5 events	-	-	-	66,754,500	71,053,600	+6.4%
PEI (70)	>10 events	-	-	-	64,098,100	69,457,300	+8.4%

Table 5.3 presents the 2006 and 2016 analysis results for noise impact. When analysing the noise impact results for 2006 and 2016, it is observed that the number of highly annoyed people during daytime has decreased in line with the annual average day 24h metric. The number of highly sleep-disturbed people has increased in lower noise bands and increased in higher noise bands.

Table 5.3: 2006 & 2016 analysis - summary of noise impact results

	Scenario: Baseline		
	2006	**2016**	**% change 2006-2016**
No. of people highly sleep-disturbed average annual 8h Lnight >45 dB	73,800	78,900	+6.9%
No. of people highly sleep-disturbed average annual 8h Lnight >50 dB	29,600	31,100	+4.8%
No. of people highly annoyed (daytime) average annual 24h Lden >51 dB	244,000	240,200	-1.6%
No. of people Highly annoyed (daytime) average annual 24h Lden >54 dB	180,500	173,200	-4.0%

Overall, the 2006 and 2016 analysis are presented in Table 5.4.

Table 5.4: Summary of results for 2006 and 2016 analysis

Metric	% change 2006-2016
ATM, average summer day 16h	-1.2%
ATM, average summer night 8h	+14.9%
Quota count, average summer day	-8.4%
Quota count, average summer night	-0.6%
Noise contour area, average summer day, >54 dB	-7.6%
Noise contour area, average summer night, >48 dB	+12.7%
Population exposed, average summer day, >54 dB	-5.2%
Population exposed, average summer night >48 dB	+25.6%
Number Above, average summer day, N65 >10	-19.8%
Number Above, average summer night, N60 >10	+21.2%
Number Above, average summer day, N70 >10	-13.9%
Average Person Exposure, >10	+28.7%
Person Events Index, >10	+8.4%
No. of people highly annoyed, >54 dB	-4.0%
No. of people highly sleep disturbed, >45 dB	+6.9%

CHAPTER 6

Analysis forecast scenarios for 2025, 2030, 2040 and 2050

This chapter presents the results of the analysis of noise metrics calculated for 2025, 2030, 2040 and 2050.

The purpose of the forecast scenarios analysis is to identify the relationship between the trends of different metrics that track noise emission, noise exposure and noise impact in relation to forecast traffic growth, to understand the implications and opportunities of setting limits. The year 2025 was included in the analysis as there was a gap between the baseline and 2030. It may also be used as a future baseline for the major expansion proposed at Heathrow. The year 2016 is used as the baseline for the forecast analysis. Traffic forecasts were provided by DfT for each airport, based on the 2017 UK Aviation Forecasts[17].

The results represented in this chapter are the combined results for all eight airports considered in Chapter 4 and take into consideration the Heathrow third runway (LHR NWR). The results for each individual airport are presented in Appendix C. The results excluding Heathrow Airport are summarised in Appendix D.

The traffic movements used for each year and each scenario are presented in Table 4.2 (a) and Table 4.2 (b) and show that the 24h traffic for High and Central scenarios increase in relation to the 2016 baseline by approximately 39% and 36% respectively.

For noise limiting schemes that restrict emissions, quota count was the selected metric for evaluation and the results are presented in Table 6.1(a) for the High scenario and Table 6.1(b) for the Central scenario. The forecast results for the High scenario show a decrease in quota count for an average summer day and a decrease in quota count for the average summer night. Given that the number of ATMs for the High scenario are forecast to increase during the period, the decrease in quota count is expected to come from improvements in noise certification. Results for the Central scenario present similar trends as the High scenario. However, the Central scenario experiences lower quota count reductions than the high scenario for daytime and higher quota count reductions.

Table 6.1 (a): Forecast analysis - Quota Count (including LHR NWR), Scenario: HIGH

	Scenario: HIGH Quota Count					
Metric	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
QC - average summer day 16h	2,471	2,453	2,614	1,966	1,923	-22.2%
QC - average summer night 8h	299.6	261.8	266.6	202.2	207.7	-30.7%
QC - average summer 24h	2,770	2,715	2,881	2,169	2,131	-23.1%

Table 6.1(b): Forecast analysis - Quota Count (including LHR NWR), Scenario: CENTRAL

	Scenario: Central Quota Count					
Metric	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
QC - average summer day 16h	2,471	2,356	2,526	1,881	1,808	-26.8%
QC - average summer night 8h	299.6	248.9	254.0	193.0	195.4	-34.8%
QC - average summer 24h	2,770	2,605	2,780	2,074	2,004	-27.7%

For metrics that could limit noise exposure, Table 6.2 (a) presents a summary of the results for noise contour areas and population exposed for the High scenario. The results show that the noise contour areas for all noise exposure metrics considered are forecast to reduce by 2050, and that it consistently peaks in 2030 due to traffic growth that is subsequently offset by quieter aircraft entering the fleet in 2040 and 2050.

In terms of the population exposed to noise (Table 6.2(b)), the results show that for the average summer day, there is a small decrease within the 51 dB L_{Aeq16h} contour, but a small increase is forecast within the 54 dB L_{Aeq16h} contour. On the other hand, the average summer night contours show a small increase in population within the 45 dB L_{Aeq8h} contour and a decrease within the 48 dB L_{Aeq8h} contour. The average annual 24h population exposed to noise is forecast to increase and the average annual night time population within the 45 dB L_{night} contour will decrease whilst the population within the 50 dB L_{night} contour is forecast to increase. All of these changes are heavily influenced by forecast population growth within the noise contours.

Overall, for the noise contour levels where the population decreases, the populations have not decreased at similar rates to the noise contour area reductions. This is due to the forecasted increase in population. The forecast growth in population over time will be discussed later in this chapter.

Table 6.2 (b) also presents the results for the secondary Number Above metric. For an average N65 and N70 are used to indicate the number of movements above 65 dB and 70 dB L_{Amax} and N60 is used for indicating the number of aircraft movements above 60 dB L_{Amax} for an average summer night. The results show that the N65 and N70 are forecast to decrease. The N60 is forecast to increase, despite reductions in night time

Quota Count and contour area due to changes in fleet mix leading to noise decreases close in and noise increases further out from the airport.

The results for PEI (70) (Table 6.2) show that it is forecast to increase, mostly due to population growth. The results also show that AIE is forecast to increase, partly due to population growth, but also to increasing ATMs, which, where events are well above 70 dB L_{max} close to the airport, are not fully offset by quieter aircraft.

Table 6.2 (a): Forecast analysis - summary of noise contour area (including LHR NWR), Scenario: HIGH

		Scenario: High		Area (km²) results		
Metric	**Level**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Average summer day L_{Aeq16h}	>51	879.0	895.9	940.5	807.7	804.6	-8.5%
Average summer day L_{Aeq16h}	>54	490.2	497.1	523.2	440.6	440.5	-10.1%
Average summer night L_{Aeq8h}	>45	819.7	798.8	826.5	726.3	745.0	-9.1%
Average summer night L_{Aeq8h}	>48	473.0	462.6	473.2	409.7	420.1	-11.2%
Average annual 24h L_{den}	>50	1,455.2	1,498.2	1,565.2	1,346.6	1,348.3	-7.3%
Average annual 24h L_{den}	>55	575.1	583.7	610.8	520.3	524.5	-8.8%
Average annual 8h L_{night}	>45	680.9	677.6	699.4	609.1	621.9	-8.7%
Average annual 8h L_{night}	>50	256.7	245.6	256.4	216.9	223.2	-13.0%

Table 6.2 (b): Forecast analysis - summary of population exposure (including LHR NWR), Scenario: HIGH

	Scenario: High	Population Exposure					
Metric	**Level**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Average summer day LAeq16h	>51	1,560,800	1,622,600	1,636,200	1,527,300	1,552,800	-0.5%
Average summer day LAeq16h	>54	782,300	802,700	846,000	771,000	796,000	+1.8%
Average summer night LAeq8h	>45	1,243,200	1,222,300	1,261,900	1,197,000	1,255,000	+0.9%
Average summer night LAeq8h	>48	655,500	605,300	589,600	557,800	604,100	-7.8%
Average annual 24h Lden	>50	2,474,500	2,587,700	2,893,500	2,668,100	2,743,200	+10.9%
Average annual 24h Lden	>55	950,000	963,400	1,007,200	920,700	953,200	+0.3%
Average annual 8h Lnight	>45	1,117,000	1,093,700	1,112,300	1,051,900	1,101,000	-1.4%
Average annual 8h Lnight	>50	323,600	288,100	310,100	299,900	329,300	+1.8%
Average summer night 8h N60	>5 events	2,155,400	2,139,800	2,318,800	2,227,300	2,335,000	+8.3%
Average summer night 8h N60	>10 events	1,473,400	1,457,100	1,622,500	1,580,900	1,645,200	+11.7%
Average summer day 16h N65	>5 events	2,608,800	2,725,500	2,664,300	2,503,900	2,359,600	-9.6%
Average summer day 16h N65	>10 events	1,965,000	2,124,000	2,145,000	1,946,000	1,955,000	-0.5%
Average summer day 16h N70	>5 events	1,061,800	1,116,100	996,300	861,000	817,300	-23.0%
Average summer day 16h N70	>10 events	838,700	880,100	794,400	675,500	658,500	-21.5%
AIE(70)	> 5 events	65.9	66.0	69.4	71.7	76.8	+16.6%
AIE(70)	> 10 events	79.5	80.8	84.6	88.6	95.4	+20.0%
PEI(70)	> 5 events	71,053,600	77,502,800	84,877,700	76,820,800	82,038,300	+15.5%
PEI(70)	> 10 events	69,457,300	75,795,300	83,375,000	75,469,400	80,896,600	+16.5%

Table 6.3 (a) shows the contour area noise exposure results for the Central scenario. The results show that all contour areas are expected to reduce and that the calculated area percentage reductions are bigger than in the High case. Table 6.3 (b) present the results for population exposed for the Central scenario. The results show that the population exposed to average summer day and average summer night noise will reduce. For the average annual 24h contour, the population exposed will increase at the lower noise contours and reduce at the higher noise contours. For the average annual night contours, the population exposed will decrease. The N-contours for the Central scenario follow the same trend presented for the High scenario, whereby N65 and N70 reduce and N60 increases with lower percentages than the Central case. PEI and AIE are also forecast to increase in the Central scenario.

Table 6.3 (a): Forecast analysis - summary of noise contour areas (including LHR NWR), Scenario: CENTRAL

		Scenario: Central AREA (km²) results					
Metric	**Level**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Average summer day LAeq16h	>51	879.0	865.2	910.2	782.1	770.4	-12.4%
Average summer day LAeq16h	>54	490.2	479.5	507.2	426.4	421.3	-14.0%
Average summer night LAeq8h	>45	819.7	771.3	792.5	702.4	710.4	-13.3%
Average summer night LAeq8h	>48	473.0	447.0	456.2	397.3	402.1	-15.0%
Average annual 24h Lden	>50	1,455.2	1,446.1	1,504.1	1,304.5	1,295.6	-11.0%
Average annual 24h Lden	>55	575.1	561.5	591.5	504.6	502.3	-12.7%
Average annual 8h Lnight	>45	680.9	650.4	674.1	589.9	596.4	-12.4%
Average annual 8h Lnight	>50	256.7	234.7	247.8	210.7	213.9	-16.7%

Table 6.3 (b): Forecast analysis - summary of population exposure results (including LHR NWR), Scenario: CENTRAL

		Scenario: Central Population Exposure results					
Metric	**Level**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Average summer day LAeq16h	>51	1,560,800	1,606,900	1,627,800	1,500,400	1,508,400	-3.4%
Average summer day LAeq16h	>54	782,300	791,600	835,400	743,400	757,000	-3.2%
Average summer night LAeq8h	>45	1,243,200	1,209,300	1,256,200	1,176,000	1,217,300	-2.1%
Average summer night LAeq8h	>48	655,500	597,000	581,000	541,800	576,000	-12.1%
Average annual 24h Lden	>50	2,474,500	2,573,700	2,889,900	2,622,400	2,650,300	+7.1%
Average annual 24h Lden	>55	950,000	948,100	992,800	890,900	909,700	-4.2%
Average annual 8h Lnight	>45	1,117,000	1,074,800	1,094,600	1,027,200	1,058,200	-5.3%
Average annual 8h Lnight	>50	323,600	282,400	303,600	290,400	306,700	-5.2%
Average summer night 8h N60	>5 events	2,155,400	2,109,200	2,296,500	2,194,100	2,278,400	+5.7%
Average summer night 8h N60	>10 events	1,473,400	1,446,500	1,612,600	1,555,400	1,621,200	+10.0%
Average summer day 16h N65	>5 events	2,608,800	2,697,700	2,638,100	2,463,300	2,291,300	-12.2%
Average summer day 16h N65	>10 events	1,965,000	2,093,500	2,115,800	1,914,400	1,889,600	-3.8%
Average summer day 16h N70	>5 events	1,061,800	1,092,100	957,300	836,400	755,900	-28.8%
Average summer day 16h N70	>10 events	838,700	864,800	768,500	656,100	619,100	-26.2%
AIE(70)	>5 events	65.9	64.6	70.0	69.9	79.2	+20.2%
AIE(70)	>10 events	79.5	79.5	88.8	91.4	102.4	+28.8%
PEI(70)	>5 events	71,053,600	75,831,100	84,265,200	73,877,700	77,360,800	+8.9%
PEI(70)	>10 events	69,457,300	74,164,700	82,813,200	72,588,800	76,321,000	+9.9%

Analysing the results for noise health impacts, the results show that the number of people highly annoyed is forecast to slightly increase and that the number of people highly sleep-disturbed is forecast to have a small decrease for the High scenario. For the Central scenarios, the number of people highly annoyed and highly sleep-disturbed will present a small reduction by 2050. Although the number of highly annoyed people and highly-sleep disturbed people will reduce by 2050, the forecast results show that the number of highly annoyed people and highly sleep disturbed will be at its highest in 2030.

Table 6.4 (a): Forecast analysis - summary of noise impact results (number of people highly annoyed and number of people highly sleep disturbed) (including LHR NWR), Scenario: HIGH

	Scenario: High Top 8 airports combined results					
	2016	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
No. of people highly sleep-disturbed Average annual 8h Lnight >45 dB	78,900	74,800	76,600	72,100	76,300	-3.3%
No. of people highly sleep-disturbed Average annual 8h Lnight >50 dB	31,100	26,700	28,800	27,500	30,300	-2.4%
No. of people highly annoyed (daytime) Average annual 24h Lden >51 dB	240,200	245,500	257,600	236,600	243,500	+1.4%
No. of people highly annoyed (daytime) Average annual 24h Lden >54 dB	173,200	174,100	183,100	168,500	174,000	+0.5%

Table 6.4 (b): Forecast analysis - summary of noise impact results (number of people highly annoyed and number of people highly sleep disturbed) (including LHR NWR), Scenario: CENTRAL

	Scenario: Central Top 8 airports combined results					
	2016	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
No. of people highly sleep-disturbed Average annual 8h Lnight >45 dB	78,900	73,400	75,300	70,200	72,800	-7.7%
No. of people highly sleep-disturbed Average annual 8h Lnight >50 dB	31,100	26,100	28,200	26,600	28,100	-9.6%
No. of people highly annoyed (daytime) Average annual 24h Lden >51 dB	240,200	242,300	255,900	230,900	233,800	-2.7%
No. of people highly annoyed (daytime) Average annual 24h Lden >54 dB	173,200	171,300	181,000	163,800	166,500	-3.9%

Table 6.5 presents the noise impact results assuming the population has not grown since 2016. The results show that the population exposed to noise would be reduced for all exposure metrics apart from PEI and AIE. The number of people highly annoyed and the number of people highly sleep-disturbed would reduce by at least 15% (Table 6.6).

The population exposed results from this study are slightly higher than the population exposed results provided in the NPS work (20,000-30,000 people). This is due to differences in the ANCON noise model database, allocation of DfT forecast and sensitivity to contour shape. These are explained in the next paragraphs.

ANCON noise model databases are updated year on year. Whilst the NPS work relied on the 2016 noise database, the Aviation Strategy forecasts used the 2017 database. It is a long-standing principle to use the latest available data. Normally CAA reviews the top ten noise dominant aircraft each year, but in 2017 a major review was untaken of calculated noise levels across all aircraft types, against noise measurements. Many remain the same, some are adjusted upwards, some downwards. For some aircraft newly introduced into service, e.g. A320neo and B737MAX, CAA obtained its first measurements and replaced industry certification data or estimates dating back to the time of the Airports Commission assessment.

As part of the noise modelling, there is a need to allocate the DfT aviation forecast ATMs across the day and night time periods, add a summer uplift (the core noise indicator LAeq16h, represents an average summer day) and distribute the ATMs across different airport departure routes. The NPS work relied on distributions to routes and across time periods based on third party advice to the Airports Commission work, and based on data from 2011-12. For the Aviation Strategy work, this data was updated to data from the 2016 Environmental Noise Directive noise mapping, done every 5 years. These changes subtly alter the uplift for a summer day, the split between day, evening and night periods and, most significantly, the split of ATMs across departure routes.

The third aspect that impacts population exposure is that the population within a contour is very sensitive to differences in contour shape. Contour area gives a much more reliable indicator of noise emission. Looking at LHR NWR 2050 as an example, the forecast area is 11% percent larger than for the NPS work, but the population is 9% smaller. The larger area indicates a higher noise emission. The fact the population decreases despite the area increase, is due to the contour shape changing. This is be due to the updated distribution of traffic across departure routes, reflecting the changes in markets since between 2012 and 2016, for example much higher growth on departure routes serving the Middle East for example.

It is also important to highlight that the nominal uncertainty of ANCON is ±1dB. It’s extremely unlikely that a contour would be in error by +1 or -1dB in every location, and comparisons with measurements demonstrate this is not the case, but ±1dB equates to ±70,000 people at Heathrow in 2050.

Table 6.5: Forecast analysis – summary of noise exposure results (including LHR NWR), Scenario: HIGH with 2016 Population

		Scenario: High with 2016_Pop Population Exposure results					
Metric	**Level**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Average summer day LAeq16h	>51	1,560,800	1,554,300	1,503,900	1,354,000	1,344,200	-13.9%
Average summer day LAeq16h	>54	782,300	768,700	778,600	683,700	689,800	-11.8%
Average summer night LAeq8h	>45	1,243,200	1,172,500	1,163,800	1,066,100	1,090,000	-12.3%
Average summer night LAeq8h	>48	655,500	579,600	543,800	493,800	521,300	-20.5%
Average annual 24h Lden	>50	2,474,500	2,468,900	2,663,900	2,363,300	2,370,300	-4.2%
Average annual 24h Lden	>55	950,000	924,500	928,400	817,600	827,200	-12.9%
Average annual 8h Lnight	>45	1,117,000	1,051,800	1,028,900	938,900	958,000	-14.2%
Average annual 8h Lnight	>50	323,600	273,900	284,600	264,600	283,300	-12.5%
Average summer night 8h N60	>5	2,155,400	2,045,300	2,137,200	1,979,800	2,029,300	-5.9%
Average summer night 8h N60	>10	1,473,400	1,394,400	1,494,200	1,405,400	1,425,800	-3.2%
Average summer day 16h N65	>5	2,608,800	2,614,700	2,464,800	2,206,200	2,062,600	-20.9%
Average summer day 16h N65	>10	1,965,000	2,034,700	1,986,100	1,701,600	1,705,900	-13.2%
Average summer day 16h N70	>5	1,061,800	1,067,400	918,100	765,400	710,500	-33.1%
Average summer day 16h N70	>10	838,700	842,900	731,900	600,100	572,300	-31.8%
AIE(70)	> 5 events	65.9	66.3	69.6	71.3	75.7	+15.0%
AIE(70)	>10 events	79.5	80.9	84.9	88.2	95.4	+19.9%
PEI(70)	> 5 events	71,053,600	73,917,200	79,134,900	69,048,800	72,034,600	+1.4%
PEI(70)	>10 events	69,457,300	72,262,500	77,758,200	67,846,700	71,023,400	+2.3%

Table 6.6: Forecast analysis - summary of noise impact results (number of people highly annoyed and number of people highly sleep disturbed) (including LHR NWR), Scenario: HIGH with 2016 Population

		Scenario: High with 2016 Pop Top 8 airports combined results					
Metric	Level	2016	2025	2030	2040	2050	% change 2016-2050
No. of people highly sleep disturbed average annual 8h Lnight 45dB	>45	78,900	71,800	71,000	64,400	59,700	-24.3%
No. of people highly sleep disturbed average annual 8h Lnight 50 dB	>50	31,100	25,300	26,600	24,400	26,400	-14.9%
No. of people highly annoyed (daytime) average annual 24h Lden 51dB	>51	240,200	234,600	243,200	210,100	203,500	-15.3%
No. of people highly annoyed (daytime) average annual 24h Lden 54 dB	>54	173,200	166,800	174,800	149,700	141,100	-18.5%

Overall in the forecast analysis for 2025, 2030, 2040 and 2050 considering population growth around airports, the results for the High scenario is presented in Table 6.7.

Table 6.7: Summary of forecast analyses results for 2025, 2030, 2040 and 2050

Metric	% change 2016-2050
ATM, average summer day 16h	+39.3%
ATM, average summer night 8h	+34.1%
Quota count, average summer day	-22.2%
Quota count, average summer night	-30.7%
Noise contour area, average summer day, >54 dB	-10.1%
Noise contour area, average summer night, >48 dB	-11.2%
Population exposed, average summer day, >54 dB	+1.8%
Population exposed, average summer night >48 dB	-7.8%
Number Above, average summer day, N65 >10 events	-0.5%
Number Above, average summer night, N60 >10 events	+11.7%
Number Above, average summer day, N70 >10 events	-21.5%
Average Person Exposure, >10 events	+20.0%
Person Events Index, >10 events	+16.5%
No. of people highly annoyed, >54 dB	+0.5%
No. of people highly sleep disturbed, >45 dB	-3.3%

When considering a static population from 2016 onwards, the populations exposed to noise reduce for all metrics taken into consideration. The number of people highly annoyed is forecast to decrease 18.5% and the number of highly sleep disturbed people is forecast to decrease by 24.3%.

CHAPTER 7

Proposed limits

As part of this analysis, it is considered that a limit scheme for each metric type for limiting noise would be selected to be monitored and that the selection of the limiting scheme would include noise metric selection, selection of a method to take into consideration the traffic volume of an airport, selection of a monitoring mechanism for assessing noise limit compliance and selection of enforcement procedures for noise limits.

7.1 Noise metrics

The methodology utilised to select the metrics took into consideration the pros and cons from Chapter 2, the suitability to achieve the objectives, presented in Chapter 3, and how well each metric correlated with the others. The comparison between each metric was undertaken in order to reduce the overall number of metrics under consideration. For this, the correlation between each metric was calculated using the Pearson's correlation coefficient[23]. The results for each metric pair are presented in Table 7.1 and values closer to 1 indicate a stronger correlation between the metrics; values closer to zero indicate a weaker correlation. The analysis has been undertaken using both a growing population and a static 2016 population. The results show higher levels of correlation between noise metrics when a static population is used, so a static population has been used for the metric selection analysis.

[23] https://www.spss-tutorials.com/pearson-correlation-coefficient/

Table 7.1: (a) Correlation between main metrics – High forecast scenario, 2016 static population (below 50% red, 50-70% yellow, above 70% green correlation)

	ATMs avg summer day	ATMs avg summer night	QC avg summer day	QC avg summer night	Area (km²) $L_{Aeq,16h}$ >54 dB	Area (km²) $LA_{eq,8h}$ >48 dB	Population $L_{Aeq,16h}$ >54 dB	Population $L_{Aeq,8h}$ >48 dB	Population N60 >10 events avg summer	Population N65 >10 events avg summer	Population N70 >10 events avg summer	No. of HSD	No. of HA
ATMs average summer day	1.00	0.91	0.62	0.82	0.49	0.22	0.02	0.01	0.63	0.28	0.83	0.43	0.69
ATMs average summer night	0.91	1.00	0.69	0.83	0.60	0.07	0.07	0.03	0.85	0.53	0.93	0.46	0.75
QC average summer day	0.62	0.69	1.00	0.85	0.98	0.33	0.48	0.01	0.41	0.57	0.81	0.31	0.97
QC average summer night	0.82	0.83	0.85	1.00	0.75	0.31	0.19	0.01	0.50	0.38	0.80	0.65	0.88
Area 54 dB L_{Aeq16h}	0.49	0.60	0.98	0.75	1.00	0.27	0.62	0.04	0.37	0.65	0.76	0.23	0.91
Area 48 dB L_{Aeq8h}	0.22	0.07	0.33	0.31	0.27	1.00	0.11	0.46	0.01	0.00	0.11	0.09	0.31
Population Exposed >54 dB L_{Aeq16h}	0.02	0.07	0.48	0.19	0.62	0.11	1.00	0.10	0.04	0.47	0.21	0.01	0.34
Population Exposed >48 dB L_{Aeq8h}	0.01	0.03	0.01	0.01	0.04	0.46	0.10	1.00	0.20	0.44	0.05	0.06	0.01
Population Exposed to N60 >10 events	0.63	0.85	0.41	0.50	0.37	0.01	0.04	0.20	1.00	0.66	0.78	0.30	0.44
Population Exposed N65 >10 events	0.28	0.53	0.57	0.38	0.65	0.00	0.47	0.44	0.66	1.00	0.68	0.10	0.50
Population Exposed N70 >10 events	0.83	0.93	0.81	0.80	0.76	0.11	0.21	0.05	0.78	0.68	1.00	0.32	0.79
No. of people highly sleep disturbed	0.43	0.46	0.31	0.65	0.23	0.09	0.01	0.06	0.30	0.10	0.32	1.00	0.37
No. of people highly annoyed	0.69	0.75	0.97	0.88	0.91	0.31	0.34	0.01	0.44	0.50	0.79	0.37	1.00

The total number of movements has the advantage of being easily calculated and the information is available at several airports, however the number of movements does not take into consideration the noise emissions from different aircraft, neither does it account for the different payload and distances travelled, which are important. The number of movements has good correlation with day noise quota count and night noise quota count, when broken down into the number of movements per day and night respectively. It shows reasonable correlation with day noise contour area, but it gives no mechanism to limit impact within a given area. It also does not have any correlation with people exposed, so it would be not be effective in controlling population noise exposure or in driving noise reduction. Overall, the number of movements is a metric that should be monitored to understand the growth of the aviation market, but it does not provide effective controls to limit noise generation, noise exposure nor noise impacts.

The metric considered in this study for restricting noise emissions is Quota Count. It has the advantage of being easily calculated, it is already used at several airports and can be used both at national and local level, as well as in an absolute sense or be normalised by the volume of traffic. On the other hand, noise Quota Counts are not that easy to administrate and this needs to be taken into consideration if applied to smaller airports. There is good correlation between the number of daytime movements and daytime Quota Count, and a good correlation between night-time movements and night-time Quota Count. The daytime Quota Count correlates relatively well with L_{Aeq16h} contour area; however, the correlation of night-time Quota Count with L_{Aeq8h} noise contour area is not that clear. More detailed investigation highlighted that the poorer than expected correlation between night-time contour area and Quota Count is isolated to Gatwick airport and night-time fleet changes between 2006 and 2016.

The results also showed that there is some correlation between daytime Quota Count and L_{Aeq16h} population exposed, however there is no clear correlation for night-time, this being due to the large differences in population density between the airports assessed. However, at a given airport, the correlation between day or night-time population is high. The Quota Count is considered effective at ensuring that the growth in number of movements is balanced out with the introduction of new technology. However, it is not an effective control for limiting noise within a given area with population growth as it offers no mechanism to directly limit the distribution of noise around an airport. Quota Count reductions can be associated with a reduction in noise impact, but only if the noise distribution and population remain constant, as it is not effective in controlling the influx of population into areas near the airport. Quota Count offers an easy way for airports to liaise with airlines on the management of their day to day noise emission and could play a role in linking a KPI more focused in addressing noise impacts and the operational requirements from airports.

In relation to metrics that restrict noise exposure, L_{Aeq16h}, L_{Aeq8h}, L_{den}, L_{night} were considered in the analysis. However, they require calculations and need to be supported with ongoing measurements. L_{Aeq16h} and $L_{Aeq,8h}$ have the advantage of already being routinely assessed and monitored at many UK airports, so limited change would be required for their use as a limit-based KPI. L_{den} is the metric specified for the environmental noise maps produced every five years under the European Noise Directive (Directive 2002/49/EC). Were it adopted as a KPI it would require assessment more frequently than is done currently, and whilst this would facilitate reporting to the EC, it would increase the assessment burden on airports. L_{den} also provides the opportunity to have a single metric to incorporate the noise levels for day, evening and night. However, when the impacts in different parts of the day are different, i.e. annoyance and sleep-disturbance, L_{den} does not address these. Given that some airports in the UK (Heathrow and Gatwick) already monitor L_{Aeq16h} at 54 dB (and above) and L_{Aeq8h} at 48 dB, it is proposed that these metrics together with their respective noise exposure areas are used as the basis for day and night noise exposure limits.

The average summer day L_{Aeq16h} contour area presents a relatively good correlation with population exposed and the average summer night L_{Aeq8h} noise contour area correlates relatively well with population exposed to night noise. The levels of correlation between the L_{Aeq16h} noise contour and the number of highly annoyed people are low due to the varying population density between different airports. At a given airport, the correlation between area and the number of people highly annoyed is high. Similar results are seen for the estimated number of highly sleep-disturbed people.

Other supplementary noise exposure metrics analysed to limit noise exposure are Number Above, PEI and AIE. These metrics can be applied to either summer or annual average time periods as well as for different periods of the day. In this report they have been analysed for the summer period. Number Above metrics are useful to understand how often a population is exposed to aircraft noise, but have the disadvantage that they treat noise at different levels in the same way, e.g. a noise event of 71 dB or 80 dB L_{Amax} is counted, but an event at 69 dB or 50 dB L_{max} is not. Nevertheless, Number Above presents a way of understanding the number of events above a certain noise level, but it does not directly relate to the level of exposure. Person Events Index (PEI) aggregates Number Above information at different quantities into a single indicator that can be considered the total noise load of an airport on the surrounding population. The Number Above metrics showed better correlation with the other metrics and therefore were selected for comparison in Table 7.1. Number Above provides a reasonable correlation with the number of ATMs and with Quota Count. Number Above has reasonable correlation with noise contour area and with population exposed during daytime. The correlation is not as clear for night-time. It shows some correlation with population exposed, but this was not strong enough to consider Number Above as an appropriate limit metric.

The analysis of noise impact took into consideration the number of highly annoyed people and the number of highly sleep-disturbed people. The advantage of these metrics is that they are directly related to the health impact associated with noise. On the other hand, they are limited by the dose-response relationships between noise exposure (L_{Aeq} or L_{den}) used to estimate the numbers of people likely to be highly annoyed or sleep disturbed, which are also subject to change over time. For this analysis, the estimates were based on L_{den} (annoyance) and L_{night} (sleep disturbance) respectively, so they are related to the annual noise exposure levels. Whilst an equivalent function is available for summer daytime, one is not available for the average summer night time, but it is recommended that similar functions are established in UK. Like for population exposure, it was found that the number of highly annoyed and highly sleep disturbed people did not correlate well with the other noise metrics when data were aggregated across airports because of the different population densities across airports, making the indicator unsuitable as a national indicator. However, it was found to correlate with noise exposure area and QC at a given airport, but like population it suffers from being affected by population growth.

Given that Number Above lacks an ability to restrict population exposure, it is not recommended as a main noise limit. However, Number Above are recognised as a useful supplementary noise metric and it is recommended as a KPI to be monitored at each airport.

Overall, Quota Count and average summer daytime and night-time noise contour area at a certain noise level are considered to represent the best correlation with other noise metrics and therefore to limit overall noise exposure.

7.2 Selection of method to take into consideration traffic volume of an airport

Several methods can be used to take into consideration the traffic volume at an airport and provide a relative measure for a noise limit. If a relative method is to be introduced in the UK it should be set to account for different sized airports according to the different economic benefit they generate.

For this study, only the number of movements for each airport was available. Figure 7.2 presents the results of normalising each metric by the number of average summer day movements. This was done by dividing each of the results by the number of average summer day movements. The results show that the normalisation does not give a consistent variation amongst most metrics and therefore may not be the most appropriate method for taking into consideration the traffic volume.

Figure 7.2: Metrics normalised by number of movements

Forecast	Metric	Level	2006	2016	2025	2030	2040	2050
High	No. Movements LAeq16h	-	1	1	1	1	1	1
High	No. Movements LAeq8h	-	0.1	0.1	0.1	0.1	0.1	0.1
High	QC - LAeq16h	-	0.6	0.6	0.5	0.5	0.3	0.3
High	QC - LAeq8h	-	0.1	0.1	0.1	0.1	0.0	0.0
High	Area (km²) LAeq16h	>54 dB	0.1	0.1	0.1	0.1	0.1	0.1
High	Area (km²) LAeq8h	>48 dB	0.1	0.1	0.1	0.1	0.1	0.1
High	Population exposed - LAeq16h	>54 dB	189.8	182.1	178.5	158.9	136.3	133.0
High	Population exposed - LAeq8h	>48 dB	119.9	152.6	134.6	110.8	98.6	100.9
High	Population exposed - N60	>10 events	279.5	343.0	324.0	304.8	279.5	274.9
High	Population exposed - N65	>10 events	563.2	457.5	472.2	403.0	344.1	326.7
High	Population exposed - N70	>10 events	224.1	195.3	195.7	149.3	119.4	110.0
High	No. of people highly sleep-disturbed Lnight 45dB	>45 dB	6.8	7.2	5.6	5.0	4.3	4.4
High	No. of people highly annoyed Lden 54 dB	>54 dB	41.5	40.3	37.1	32.8	26.5	23.6

Others studies[8] argue that a method that accounts for weight (maximum payload) and distance travelled would enable equitable exposure or impact-based limits as it would take into consideration both freight and passenger weight as well as distance travelled over a period. It is recommended that this method of taking into consideration traffic volume is tested and used as part of a noise limit. Eurocontrol Charges MTOW /50 uses a weight and a distance factor and therefore could be explored further as a metric to take into consideration traffic volume at an airport[24].

7.3 Selection of a monitoring mechanism for noise limits compliance

Chapter 2.3 presents the review of noise limits compliance limit. Following from section 7.1 the noise scheme derived would have metrics for noise emissions, noise exposure and noise impact and limits only for noise exposure, as it would be the best way of encouraging improvements in noise emissions and the reduction of noise impacts.

It is recommended that Quota Count and noise contour area are used to monitor noise exposure and that the number of highly annoyed people and number of highly sleep-disturbed people are monitored.

A wide range of options for compliance that could be used with these metrics is presented in Chapter 2. The selection presented here is based on keeping consistency as much as possible with what is already being used to monitor compliance.

For noise quota it is recommended that the London Airports' Quota Count system is expanded to other airports and applied to both day and night-time[25]. The monitoring of Quota Count would need to be undertaken on a continuous basis and reported annually. For noise contour area at a certain noise level, it is recommended that the selected airports would report their average summer L_{Aeq16h} and L_{Aeq8h} contour areas on an annual basis. The selection of airports could be aligned with the major airport definition in the Environmental Noise Directive, i.e. those with more than 50,000 ATMs per year or those within agglomerations, although it is recognised that this would require some airports to undertake annual assessments that do not currently.

The number of highly disturbed people and highly sleep disturbed people are currently derived from EEA functions[13] and calculated using noise exposure areas based on L_{den} and L_{night}. These metrics could be calculated as part of the Defra END five yearly reporting requirements. Alternatively, in the future, dose response functions could be derived from SoNA 2014, based on average summer day and night-time noise exposure and then be linked to the same metric for reporting noise exposure area.

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24 Central Route Charge Office, Customer Guide to Charges, Jan 16.

25 London Airports Noise Restrictions Notice (No. 2 2018)

7.4 Selection of enforcement procedures for noise limits

As presented in section 2.4, a noise limit scheme requires an enforcement procedure and an organisational body to oversee the enforcement process. Table 2.4 presents a summary of enforcement procedures including advantages and disadvantages.

Following on from the selection of noise metrics presented in section 7.1, it is recommended that Quota Count and average summer day and night noise contour areas are used to limit noise exposure and that the number of highly annoyed people and number of highly sleep-disturbed people are monitored.

If using a Quota Count based limit, it is recommended that the same approach as the London Airports Night Restrictions is used, and that any exceedance of the Quota Count results in a loss of future capacity in the next control period up to a certain proportion, beyond which a further penalty could be applied. The most appropriate control period would be the summer/winter scheduling periods, which would enable scheduling to be coordinated alongside the limit, as is done today at the London airports for the Night Quota Period.

If noise contour area at a specified contour level is used as the noise limit, a similar penalty system could be applied, but the period would need to be aligned with the noise metric, the average summer day or night.

7.5 Other factors

Unlike Quota Count, there are other factors that may alter the noise contour area for a particular airport and therefore need to be considered if an area limit is to be implemented. These factors include runway modal split, the airspace design and the distribution of flights across arrival and departure routes.

Runway modal split is dictated by wind direction and can alter contour area which could cause a breach through no fault of the airport. A change of airspace design, for instance, the introduction of different SIDs can change the contour shape and slightly alter the contour area. Where major airspace redesigns are considered, a contour area limit may need to be re-evaluated in light of the revised airspace design. Finally, a redistribution of flights between existing SIDs, e.g. due to a change in destination markets served, may also change contour shape and have a secondary effect on contour area for no increase in ATMs.

7.6 Selection of noise limit schemes

The selection of a suitable noise limit has taken into consideration the ability of the noise indicator to limit noise emission, limit area exposed to specific levels, the population exposed or health impacts. Other key considerations being used in this review, as introduced in Chapter 1, are the ability to fulfil national and local requirements, and to be related to factors within the aviation industry's control.

The analysis presented in section 7.1 to 7.5 shows that:

- Average summer day and night Quota Count represent relatively good correlations when compared with noise contour area, but little correlation with population exposed to noise when population remains constant at 2016 levels, due to differing population densities around the airports assessed. However, for a given airport, there is a good correlation between Quota Count and population exposure.
- Daytime L_{Aeq16h} contour area correlates well with population exposed to noise, when population growth is not considered. However, night-time L_{Aeq8h} contour area is not well correlated with population exposure, due to the wide range of population densities across airports, and night restrictions that result in night-time contours being similar in size across different airports, compared to daytime. $L_{Aeq,8h}$ contour area is, however, well correlated with population exposure for a given airport.
- Overall, Quota Count and noise contour area at a certain noise level present the best correlation with other noise metrics and are recommended to limit noise exposure.
- Because Quota Count and noise contour area at a certain noise level are unrelated to the population density around an airport, they are unable to control the population influx into areas exposed to noise around an airport.
- Unless the aviation industry is given much greater control over the population influx around an airport, it is not possible to recommend noise limits based on population exposure that are currently beyond the control of the aviation industry.
- Neither Quota Count nor noise contour area present very good correlations with the number of people estimated to be highly-annoyed or highly-sleep disturbed, again, due to the varying population densities across the airports assessed and therefore are not recommended as a national noise limit. There is, however, good correlation at a given airport and so there is merit in monitoring the number of people highly annoyed or highly sleep disturbed, but given that the surrounding population is allowed to grow, these metrics are outside an airport's control and no limits should be applied to them.

- The recommended methods of choice to take into consideration the traffic volume of an airport are weight (freight & passenger payload) and distance travelled. These two enable equitable exposure or impact-based. Existing airport statistics reporting Revenue Passenger Kilometres (RPK) and Revenue Tonne Kilometres (RTK) could be used as the basis of total airport productivity, however, this would add complexity and need further consideration.
- At a local level, the use of a relative limit linked to Quota Count or noise contour area would not necessarily limit noise exposure for the communities around airports. Therefore, an absolute limit is proposed to limit local noise. A locally set absolute Quota Count or noise contour area limit for each airport would allow for local authorities to balance noise limits with land use and economic issues. The local absolute limit will also ensure that airports are accountable for reducing the noise.
- At the national level, there may be wider opportunities for growth whereby a relative metric would be more suitable, however it would not necessarily limit noise exposure and would only give an indication of how efficient the airport is compared to others. A relative limit, e.g. QC per flight, would also need to be considered alongside other aviation environmental impacts such air quality and greenhouse gas emissions. The introduction of a nationally set absolute Quota Count limit or noise contour area limit would allow for comparison between airports to be made, to get a better understanding of the internal market and of the total number of people impacted by noise in the UK. If an area limit is selected, the national limit will also allow for comparison of noise contour area efficiency between airports. On the other hand, absolute national limits may restrict aviation grown in certain areas.
- In terms of noise monitoring mechanisms, it is recommended to keep in line with current reporting as much as possible in order to minimise any extra reporting burden. Therefore, for Noise Quota it is recommended that the London Airports Night Restrictions system be applied to other airports for the daytime and night-time periods across summer and winter seasons (aligned with airport scheduling changes). For noise contour area at a certain noise level, it is recommended that average summer day 54 dB L_{Aeq16h} and 45 dB L_{Aeq8h} contours are used.
- To monitor the number of people impacted, the number of highly annoyed and highly sleep-disturbed people should be used. These should be calculated using UK dose-response functions based on average summer day L_{Aeq16h} and night L_{Aeq8h} contours and thus related to noise contour area limits.

In summary, the proposed limit scheme consists of:

1) A nationally set absolute Quota Count limit or noise contour area limit at a particular noise level for both day and night, aggregated across all major airports;
2) A locally set absolute Quota Count or noise contour area limit at a particular noise level for both day and night for each airport;
3) Local monitoring of the number of highly annoyed and highly sleep-disturbed people;
4) Reporting requirements.

CHAPTER 8

Sensitivity analysis

Two sensitivity analyses were considered in order to understand what the impact would be if the older fleet was substituted at a faster rate and if the rate of technology improvement was accelerated.

In order to undertake a sensitivity analysis considering the impact of a faster rate of introduction of quieter aircraft into airport operations, this study considers that for all airports in 2025, each aircraft type is substituted with its newest equivalent type, maintaining size and range capability. The sensitivity analysis was undertaken on the average summer day L_{Aeq16h} and night L_{Aeq8h} noise contours to compare the variation between the fleet as per (DfT) forecast and a further acceleration of fleet replacement of 4% per year.

A 4% acceleration was selected by analysing the rate of change observed at the London airports in the last three summers (2015-2017) as per Figure 8.1, which shows that the average rate of fleet change per year is approximately 3%. Therefore, this sensitivity analysis considered how much the noise could be reduced if the rate of fleet change was doubled to 6% per year. The results presented in Table 8.1 show that the average summer day 54 dB L_{Aeq} contour area would reduce by a further 8% by 2025 if the rate of change towards new technology is doubled each year. The corresponding population reduction would be 6.7%. Slightly smaller improvements are seen for the night-time noise contours, due to the different fleet mix and the dominance of arrival operations.

Figure 8.1 Estimated percentages of traffic less than one year old

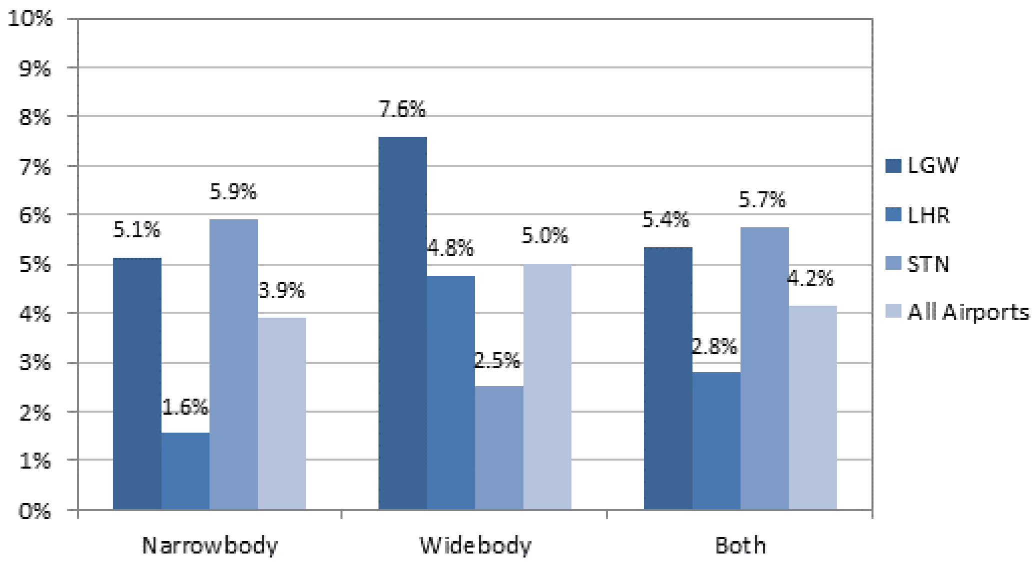


Table 8.1(a): Best in class results – 2025 noise contour area

		2025 contour area (km²)		
Metric	**Level**	**High**	**High best in class**	**% change**
Average summer day LAeq16h	>51	895.9	832.2	-7.1%
Average summer day LAeq16h	>54	497.1	457.5	-8.0%
Average summer night LAeq 8h	>45	798.8	745.5	-6.7%
Average summer night LAeq 8h	>48	462.6	431.2	-6.8%

Table 8.1(b): Best in Class results – 2025 Population Exposure

		2025 population exposed		
Metric	**Level**	**High**	**High best in Class**	**% change**
Average summer day LAeq16h	>51	1,622,600	1,547,700	-4.6%
Average summer day LAeq16h	>54	802,700	748,600	-6.7%
Average summer night LAeq 8h	>45	1,222,300	1,171,200	-4.2%
Average summer night LAeq 8h	>48	605,300	73,600	-5.2%

In order to understand the impact of different rates of technology improvement the main analysis (which used a 0.1dB/year improvement rate) was repeated using a 0.3 dB/year improvement rate and representing the upper bound of the ICAO Independent Expert Noise Technology Review[17] (0.1 dB/year being the lower bound). The analysis was undertaken for all airports in 2050 using the average summer day L_{Aeq16h} and night L_{Aeq8h} noise contours. Table 8.2 (a) presents the results, showing a further 8% reduction in average summer day L_{Aeq16h} contour area, and a further 5% reduction in average summer night L_{Aeq8h} contour area, if the rate of improvement of technology is accelerated from 0.1 dB per year to 0.3 dB per year.

Table 8.2(a): Rate of technology improvement results - noise contour area

		2050 contour area (km²)		
Metric	**Level**	**High**	**High with tech. improvement**	**% change**
Average summer day LAeq16h	>51	804.6	746.7	-7.2%
Average summer day LAeq16h	>54	440.5	406.3	-7.8%
Average summer night LAeq 8h	>45	745.0	706.6	-5.2%
Average summer night LAeq 8h	>48	420.1	398.4	-5.2%

Table 8.2(b): Rate of technology improvement results - population exposed

		2050 population exposed		
Metric	Level	High	High with Tech Improvement	% change
Average summer day LAeq16h	>51	1,552,800	1,434,200	-7.6%
Average summer day LAeq16h	>54	796,000	686,200	-13.8%
Average summer night LAeq 8h	>45	1,255,000	1,181,600	-5.8%
Average summer night LAeq 8h	>48	604,100	561,800	-7.0%

In the same manner, if there is a delay in introducing “best in class” aircraft or a delay in fleet replacement that reduces the noise improvement rate to less than 0.1 dB per year, the noise contour area and population exposure reductions estimated in the main analysis would be reduced.

CHAPTER 9
Conclusions

The Department for Transport is developing a new Aviation Strategy and commissioned the CAA to undertake four analyses in support of the strategy: airport noise forecasts, consideration of how airport noise may be limited, the effect of emerging aviation technologies on future noise exposure and to investigate the potential role that ambient (background) noise plays in attitudes to aircraft noise. This report covers the first two items and presents a feasibility study of implementing airport noise limits nationally and locally, including consideration of the pros and cons that noise limits may create. To inform the consideration of noise limits, it uses DfT aviation growth forecasts to estimate the level of aircraft noise in the shorter/medium term (2025) and in 2030, 2040 and 2050. The report also includes two sensitivity analyses to understand what the effect would be if older aircraft were replaced at a faster rate and also if the rate of technology improvement was accelerated.

A review of suitable noise metrics, targets and limits relating to aircraft noise exposure and their associated effects on noise limiting noise emission, exposure and health impact was undertaken. The limits review considered ways to limit noise emission at source, the area exposed around an airport, the population exposed within that area, and their associated health impacts, from which a reduced set of metrics was selected for detailed analysis.

The noise around an airport varies over time, primarily depending on aviation growth rates, and the introduction of quieter aircraft. Over the last 30 years there has been a significant reduction in noise exposure around virtually all UK airports. However, after the recession of 2009, which was followed by sustained growth, noise exposure has grown over the past five years at several airports. In order to inform a consideration of noise metrics and potential targets and limits, noise analysis was undertaken for eight airports (Birmingham, Edinburgh, Glasgow, London Gatwick, London Heathrow, Luton, Manchester and Stansted), for two historical years (2006 and 2016) and the following forecast years: 2025, 2030, 2040 and 2050. The forecast analysis takes into account the adoption of the Airports National Policy Statement (NPS) and assumes a third North West Runway (NWR) at Heathrow is built by 2030.

The analysis of the 2006 and 2016 noise performance was undertaken to review the application of different limits and to understand the implications of changing noise emission (quota), contour area, population exposure, and noise impacts over the past ten years.

The forecast analysis for 2025, 2030, 2040 and 2050 was undertaken to identify the effect of different limits in relation to modelled traffic growth, in order to understand the implications and opportunities for reducing noise generation, population exposed and noise impacts. Central and high scenarios were used in the analysis based on the latest

UK Aviation Forecasts. A summary of the high scenario analysis covering the total for all airports is presented in Table 9.1. The results presented use a population growth per CACI forecast data.

Table 9.1: Summary of noise metric results with population growth including a third runway (NWR) at Heathrow, Scenario: HIGH

Metric	Period	Level	Year 2006	2016	2025	2030	2040	2050	% change 2016-2050
Traffic (ATMs)	Average summer day 16h*	-	4349.5	4295.3	4497.8	5322.5	5655.9	5984.3	+39.3%
	Average summer night 8h*	-	454.3	522.0	549.4	616.2	656.4	700.2	+34.1%
Noise emission (Quota Count)	Average summer day 16h* QC	-	2696.7	2470.5	2453.1	2614.0	1966.3	1922.9	-22.2%
	Average summer night 8h* QC	-	301.3	299.6	261.8	266.6	202.2	207.7	-30.7%
Area exposure (Km^2)	Average summer day LAeq16h*	>54 dB	530.4	490.2	497.1	523.2	440.6	440.5	-10.1%
	Average summer night LAeq8h*	>48 dB	419.6	473.0	462.6	473.2	409.7	420.1	-11.2%
	Average annual 24h Lden	>55 dB	615.6	575.1	583.7	610.8	520.3	524.5	-8.8%
	Average annual 8h* Lnight	>50 dB	268.0	256.7	245.6	256.4	216.9	223.2	-13.0%
Population exposure (Numbers exposed to noise level)	Average summer day LAeq16h*	>54 dB	825,400	782,300	802,700	846,000	771,000	796,000	+1.8%
	Average summer night LAeq8h*	>48 dB	521,700	655,500	605,300	589,600	557,800	604,100	-7.8%
	Average annual 24h Lden	>55 dB	997,300	950,000	963,400	1,007,200	920,700	953,200	+0.3%
	Average annual 8h* Lnight	>50 dB	304,600	323,600	288,100	310,100	299,900	329,300	+1.8%
	Average summer night 8h* N60	>10 events	1,215,900	1,473,400	1,457,100	1,622,500	1,580,900	1,645,200	+11.7%
	Average summer day 16h* N65	>10 events	2,449,500	1,965,000	2,124,000	2,145,000	1,946,000	1,955,000	-0.5%
	Average summer day 16h* N70	>10 events	974,600	838,700	880,100	794,400	675,500	658,500	-21.5%
	Average Individual Exposure (70)	>10 events	61.8	79.5	80.8	84.6	88.6	95.4	+20.0%
	Person Events Index (70)	>10 events	64,098,100	69,457,300	75,795,300	83,375,000	75,469,400	80,896,600	+16.5%
Noise impact (Numbers exposed to noise level)	Highly sleep-disturbed average annual 8h* Lnight	>45 dB Lnight	73,800	78,900	74,800	76,600	72,100	76,300	-3.3%
	Highly annoyed (daytime) average annual 24h Lden	>54 dB Lden	180,500	173,200	174,100	183,100	168,500	174,000	+0.5%

*16h: 0700-2300 and 8h: 2300-0700.

The results show that from 2006 to 2016, source noise emission (Quota Count) has decreased by 8.4% for an average summer day and by 0.6% for an average summer night. Noise contour areas have decreased by 7.6% for an average summer day at 54 dB and by 12.7% for an average summer night at 48 dB. Population decreased by 5.2% for an average summer day and increased by 25.6% for an average summer night, due to the growth in population within the noise contours between the two years.

For the forecast years, the results show that source noise emission (Quota Count) is expected to reduce by 22.2% for an average summer day and reduce 30.7% for an average summer night. The noise contour areas are expected to reduce by 10.1% for an average summer day and by 11.2% for an average summer night. However, the population exposed is expected to increase by 1.8% for an average summer day at 54 dB and to decrease by 7.8% for an average summer night at 48 dB. The number of Highly Annoyed people is expected to increase by 0.5% at 54 dB and number of Highly Sleep Disturbed people is expected to decrease by -3.3% at 45 dB, when accounting for the forecast growth in population from 2016 onwards.

When a static population was considered from 2016 onwards, the population exposed decreased by 11.8% for an average summer day at 54 dB and by 20.5% for an average summer night at 48 dB, in line with noise contour area reductions. Impacts are also forecast to reduce, with the number of Highly Annoyed people decreasing by 18.5% at 54 dB for an average annual day and the number of Highly Sleep-Disturbed People decreasing by 24.3% at 45 dB for an average annual night, assuming no population influx into the noise contour.

In order to derive the proposed noise limits, an analysis was undertaken to determine the correlation between the metrics selected, to understand how well they relate to each other and their ability to limit the amount of noise emitted, the noise exposure (contour area) and the number of people highly annoyed or highly sleep-disturbed.

In order to address the Aviation Policy Framework objective to “limit and where possible reduce the number of people in the UK significantly affected by aircraft noise” and take into account the latest UK airspace policy noise objectives to avoid significant adverse impacts and mitigate and minimise adverse impacts, the proposed limit scheme would contain the following:

1) A nationally set absolute Quota Count limit or noise contour area limit at a particular noise level, for both day and night, aggregated across all major airports;
2) A locally set absolute Quota Count or noise contour area limit at a particular noise level, for both day and night, for each airport;
3) Local monitoring of the number of highly annoyed and highly sleep disturbed people;
4) Reporting requirements.

A sensitivity analysis on two of the forecast noise technology assumptions was also undertaken to assess the impact of a faster substitution of quieter aircraft into the forecast fleets and of a faster rate of technology improvement.

If the rate of substitution of aircraft to the best in class is doubled from 2016 to 2025 a further 8% reduction in noise contour areas would be achieved for an average summer day at 54 dB and a further 6.7% reduction in noise contour area would be achieved for an average summer night. In the same way, the population exposed would decrease by 6.7% for an average summer day at 54 dB and by 5.2% for an average summer night at 48 dB.

If the rate of technology improvement was increased from 0.1 dB to 0.3 dB per year from 2016 to 2050 the noise contour area would reduce by a further 7.8% for an average summer day at 54 dB and by 5.2% for an average summer night at 48 dB. The population exposed would reduce a further 13.8% for an average summer day at 54 dB and by 7% for an average summer night at 48 dB.

APPENDIX A

Glossary

A-weighting A frequency weighting that is applied to the electrical signal within a noise-measuring instrument as a way of simulating the way the human ear responds to a range of acoustic frequencies.

AIE Average Individual Exposure is the average number of noise events per exposed person above a certain level

ATM Air Traffic Movements

BHX Birmingham Airport

dBA Units of sound level on the A-weighted scale.

DNL See Ldn.

DfT Department for Transport (UK Government).

Eurostat European Statistical Office

EDI Edinburgh Airport.

EPNL Effective Perceived Noise Level. Its measurement involves analyses of the frequency spectra of noise events as well as the duration of the sound.

ERCD Environmental Research and Consultancy Department of the Civil Aviation Authority.

GLA Glasgow Airport.

ICAO International Civil Aviation Organization.

HA The number of people (highly) annoyed during the day according to EU WHO [4] or SoNA [5] definitions.

HSD The number of people (highly) sleep-disturbed according to EU WHO [4] or SoNA [5] definitions.

LA The A-weighted sound level (in dBA).

LAeq8h Equivalent sound level of aircraft noise in dBA for the 8 hour annual day. For conventional historical contours for a particular year this is based on the daily average movements that take place between 0700 and 2300 local time during the 92-day period 16 June to 15 September inclusive.

LAeq16h Equivalent sound level of aircraft noise in dBA for the 16 hour annual day. For conventional historical contours for a particular year this is based on the daily average movements that take place between 0700 and 2300 local time during the 92-day period 16 June to 15 September inclusive.

LAmax The maximum A-weighted sound level (in dBA) measured during an aircraft fly-by.

Lday Equivalent sound level of aircraft noise in dBA for the 12-hour annual day (0700-1900).

Lden Equivalent sound level of aircraft noise in dBA for the 24-hour annual day, evening, and night where the evening movements are weighted by 5 dB and night movements are weighted by 10 dB.

Ldn 24-hour Leq measure with an un-weighted 11-hour daytime period (0700-2200) and a 10 dB weighting for any noise events occurring during a 9-hour night- time period (2200-0700). This metric is commonly referred to as the Day-Night Level (DNL).

Leq Equivalent sound level of aircraft noise, often called equivalent continuous sound level. Leq is most often measured on the A-weighted scale, giving the abbreviation LAeq.

Levening Equivalent sound level of aircraft noise in dBA for the 4-hour annual evening (1900-2300).

LGW London Gatwick Airport.

LHR London Heathrow Airport.

LHR London Heathrow Airport.

Lnight Equivalent sound level of aircraft noise in dBA for the 8-hour annual night (2300-0700).

LTN Luton Airport.

MAN Manchester Airport.

N_XX Number Above is the number of aircraft events louder than XX dBA

Pearson's correlation coefficient is a number between -1 and 1 that indicates the extent to which two variables are linearly related.

PEI Person Event Index is the number of noise events all residents are exposed to above a certain threshold level and gives a figure that represents the total noise load or burden the airport places on the surrounding population

PNL/PNdB Perceived Noise Level, measured in PNdB. Its measurement involves analyses of the frequency spectra of noise events as well as the maximum level.

PNLT Tone-corrected Perceived Noise Level. PNLT is a refinement of PNL that accounts for any strong tonal content in an individual spectrum.

QC Quota Count is a metric intended to reflect the contribution made by an aircraft to the total noise impact around an airport, the latter being expressed by the total Quota Count - the sum of the QC classifications of all arrivals and departures.

SEL The Sound Exposure Level generated by a single aircraft at the measurement point, measured in dBA. This accounts for the duration of the sound as well as its intensity. (SEL is referred to as LAE or LE in some texts.)

STN Stansted Airport.

APPENDIX B

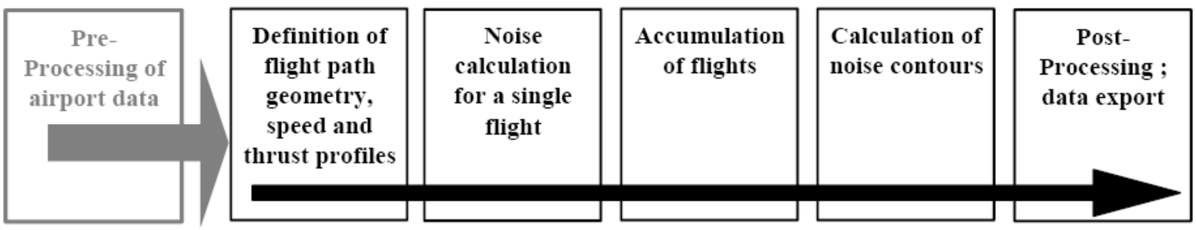
Overview of ANCON and ECAC-CEAC Doc 29 4th edition

Recommended practices for aircraft noise modelling have been published by three major aviation bodies: ICAO, ECAC and SAE. They offer guidance on how to construct a framework for modelling and how to use the manufacturer-supplied data. The level of detail varies, but there is a broad agreement on topics modellers need to consider and on areas where bodies have detailed agreement.

ECAC Doc. 29 is a standard method used for computing noise contours around civil airports, recommended for use in the 44 ECAC States, initially published in 1987 and developed by the ANCAT/AIRMOD Task Group of ECAC. Its Fourth Edition was adopted by ECAC-DGCA/147 on 7 December 2016. It allows for consistent computation of noise contours throughout ECAC States. It is also used as the reference methodology for EU noise legislation, including for the establishment of noise action plans, and contributes towards the global guidance from ICAO. The new edition of ECAC Doc. 29 includes several technical improvements to the modelling.

Figure B.1 is a description of the calculation process within ANCON. The aim is to calculate SEL and L_{Amax} at a given observer point for each specific combination of aircraft type, flight profile and flight path ("Single Event Calculation").

Figure B.1 Calculation process within ANCON



ANCON (UK Civil Aircraft Noise Contour Model) is the UK's civil aircraft noise model which is owned by the Department for Transport (DfT) and developed, maintained and operated by the CAA's Environmental Research and Consultancy Department (ERCD). It is a specialised suite of programmes, written in Fortran, and has been supported technically in-house for the last three decades and funded by the DfT through a Section 16 Letter of Agreement which is renewed annually. ANCON's mathematical model is based on ECAC Doc. 29 4th Edition (2016).

ANCON version 2.4 is the current version of the ANCON model. The model is used for the majority of ERCD's work for the DfT and its commercial clients. It predicts noise from aircraft in the vicinity of an airport and therefore provides the evidence basis which underpins noise management, policy, airspace and standards setting decisions made by the CAA, DfT, ECAC (European Civil Aviation Conference) and ICAO (International Civil Aviation Organization), amongst others.

ANCON basic principles

ANCON version 2 is the mathematical model based on ECAC-CEAC Doc 29. Its primary objective is to produce noise contours - that is, lines which enclose geographical areas where particular noise exposure levels are exceeded because of aircraft noise.

The noise exposure levels are generally expressed in terms of L_{Aeq} values. To achieve this objective the area around an airport is divided into a regular rectangular grid of observation points and the noise level from the input set of aircraft operations is calculated at each observation point. This is then converted into contours by interpolating between observation points.

The input set of aircraft operations can represent either each unique flight in terms of their flight trajectories or more commonly, a large number of flights of the same aircraft type on a given flight path can be grouped together and represented as a single flight, whilst making allowances for normal flight-to-flight variation in aircraft ground track and flight profile. The flight trajectory is broken down in a vertical (x-z) plane and the flight track over the ground in the horizontal (x-y) plane. This trajectory data provides, for each individual aircraft, a chronicle of position, height and speed. Algorithms within ANCON version 2 deduct from this data the likely engine thrust being applied at any stage of the flight. The model therefore has reliable information on the location, speed and thrust of every individual aircraft throughout its flight history within the geographical area of interest.

For specialist validation purposes, ANCON version 2 can also read flight data recorder information consisting of precise position, speed and thrust values for individual flights. This can be used with noise measurements from noise monitors deployed near the flight path to assess the effectiveness of the noise calculation algorithms.

APPENDIX C

Results by airport

Chapter 5 and 6 presented the combined results of eight airports for the baseline years and forecast years, for both High and Central scenarios. This Appendix presents the breakdown of the results presented in Chapters 5 and 6 to give visibility of the contribution from each airport to the results. The totals presented in the tables of this Appendix are for the eight airports included in the analysis carried out in Chapters 5 and 6: Birmingham Airport (Birmingham - BHX), Edinburgh Airport (Edinburgh - EDI), Glasgow Airport (Glasgow - GLA), London Gatwick Airport (Gatwick - LGW), London Heathrow Airport (Heathrow - LHR), Luton Airport (Luton - LTN), Manchester Airport (Manchester - MAN) and Stansted Airport (Stansted - STN). The scenario considered here account for Heathrow Airport expansion from 2030 onwards and is presentational only. If Heathrow Airport wasn’t expanding, the forecast for the other airports (presented as Total without LHR) would be different.

Table C.1 (a): Number of average summer day movements, High Scenario

	Scenario: High	No. of average summer day movements						
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	316.4	307.6	360.8	410.6	568.9	564.8	-2.8%	+83.6%
EDI	333.3	342.1	308.7	334.6	374.5	424.2	+2.6%	+24.0%
GLA	301.2	275.4	287.2	279.8	288.0	310.4	-8.6%	+12.7%
LGW	701.7	770.6	792.5	791.6	815.2	826.6	+9.8%	+7.3%
LHR NWR	1,248.0	1,266.7	1,296.2	1,982.5	2,008.6	2,022.0	+1.5%	+59.6%
LTN	288.5	337.9	321.6	311.2	295.8	317.2	+17.1%	-6.1%
MAN	638.2	543.5	628.0	652.8	774.5	990.7	-14.8%	+82.3%
STN	522.2	451.6	502.8	559.4	530.3	528.4	-13.5%	+17.0%
Total (with LHR)	4,349.5	4,295.3	4,497.8	5,322.5	5,655.9	5,984.3	-1.2%	+39.3%
Total (without LHR)	3,101.5	3,028.6	3,201.6	3,340.0	3,647.2	3,962.4	-2.4%	+30.8%

Table C.1 (b): Number of average summer night movements, High Scenario

	Scenario: High	No. of average summer night movements						
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	31.2	40.2	47.2	53.7	74.4	73.8	+28.7%	+83.7%
EDI	27.1	37.4	33.8	36.6	41.0	46.4	+38.1%	+24.0%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	116.7	127.1	130.7	130.5	134.4	136.3	+8.9%	+7.3%
LHR NWR	70.9	84.4	86.4	132.1	133.9	134.7	+19.1%	+59.6%
LTN	52.3	70.1	66.7	64.5	61.4	65.8	+34.1%	-6.1%
MAN	76.6	80.6	93.1	96.8	114.9	146.9	+5.2%	+82.3%
STN	79.5	82.3	91.6	101.9	96.6	96.3	+3.5%	+17.0%
Total (with LHR)	454.3	522.0	549.4	616.2	656.4	700.2	+14.9%	+34.1%
Total (without LHR)	383.4	437.6	463.0	484.0	522.6	565.5	+14.1%	+29.2%

Table C.1 (c): Number of average summer day movements, Central Scenario

	Scenario: Central			No. of average summer day movements				
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	316.4	307.6	342.5	374.2	539.8	572.2	-2.8%	+86.0%
EDI	333.3	342.1	304.7	321.7	361.8	398.6	+2.6%	+16.5%
GLA	301.2	275.4	276.7	271.2	274.9	296.0	-8.6%	+7.5%
LGW	701.7	770.6	789.8	776.4	804.5	818.4	+9.8%	+6.2%
LHR NWR	1,248.0	1,266.7	1,304.3	2,014.1	2,012.3	2,023.8	+1.5%	+59.8%
LTN	288.5	337.9	320.1	306.8	297.2	297.6	+17.1%	-11.9%
MAN	638.2	543.5	608.0	623.0	729.6	915.6	-14.8%	+68.5%
STN	522.2	451.6	449.1	543.0	582.0	583.6	-13.5%	+29.2%
Total (with LHR)	4,349.5	4,295.3	4,395.3	5,230.4	5,602.1	5,905.7	-1.2%	+37.5%
Total (without LHR)	3,101.5	3,028.6	3,090.0	3,216.4	3,589.7	3,881.9	-2.4%	+28.2%

Table C.1 (d): Number of average summer night movements, Central Scenario

	Scenario: Central			No. of average summer night movements				
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	31.2	40.2	44.8	48.9	70.6	74.8	+28.7%	+86.1%
EDI	27.1	37.4	33.3	35.2	39.6	43.6	+38.1%	+16.5%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	116.7	127.1	130.2	128.0	132.6	134.9	+8.9%	+6.2%
LHR NWR	70.9	84.4	86.9	134.2	134.1	134.9	+19.1%	+59.8%
LTN	52.3	70.1	66.4	63.6	61.6	61.7	+34.1%	-11.9%
MAN	76.6	80.6	90.2	92.4	108.2	135.8	+5.2%	+68.5%
STN	79.5	82.3	58.7	71.0	76.1	76.3	+3.5%	-7.3%
Total (with LHR)	454.3	522.0	510.5	573.3	622.8	662.0	+14.9%	+26.8%
Total (without LHR)	383.4	437.6	423.6	439.1	488.7	527.1	+14.1%	+20.4%

Table C.2 (a): Average summer day Quota Count, Scenario High

	Scenario: High QC Average summer day							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	139.1	124.3	147.1	148.5	150.1	160.1	-10.7%	+28.8%
EDI	107.6	133.4	109.3	107.7	86.0	94.6	+23.9%	-29.1%
GLA	104.3	100.1	117.1	102.3	73.4	73.1	-4.1%	-27.0%
LGW	447.4	405.5	419.0	385.8	261.8	250.8	-9.4%	-38.1%
LHR NWR	1,130.0	979.0	933.5	1,176.3	903.9	807.0	-13.4%	-17.6%
LTN	98.8	125.5	157.6	132.8	83.6	84.5	+27.1%	-32.7%
MAN	337.8	292.5	302.6	292.8	249.4	297.0	-13.4%	+1.5%
STN	331.7	310.3	266.8	267.8	158.0	155.9	-6.5%	-49.8%
Total (with LHR)	2,696.7	2,470.5	2,453.1	2,614.0	1,966.3	1,922.9	-8.4%	-22.2%
Total (without LHR)	1,566.7	1,491.5	1,519.6	1,437.8	1,062.4	1,115.9	-4.8%	-25.2%

Table C.2 (b): Average summer night Quota Count, Scenario High

	Scenario: High QC Average summer night							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	18.1	19.2	19.1	19.3	19.6	20.9	+5.7%	+8.7%
EDI	10.9	18.3	11.3	11.2	9.2	10.2	+68.1%	-44.4%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	62.6	56.6	61.3	56.9	40.1	39.0	-9.6%	-31.1%
LHR NWR	90.9	80.3	52.7	67.5	53.8	50.7	-11.7%	-36.8%
LTN	23.2	29.0	33.1	27.9	17.5	17.6	+24.8%	-39.2%
MAN	40.3	45.8	39.7	38.7	34.4	41.8	+13.8%	-8.6%
STN	55.3	50.4	44.7	45.2	27.7	27.4	-8.9%	-45.6%
Total (with LHR)	301.3	299.6	261.8	266.6	202.2	207.7	-0.6%	-30.7%
Total (without LHR)	210.4	219.3	209.1	199.2	148.4	156.9	+4.2%	-28.4%

Table C.2 (c): Average summer day Quota Count, Scenario Central

	Scenario: Central QC Average summer night							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	139.1	124.3	138.2	134.2	139.1	147.8	-10.7%	+18.9%
EDI	107.6	133.4	106.0	102.6	83.4	88.6	+23.9%	-33.6%
GLA	104.3	100.1	110.2	97.1	67.4	68.6	-4.1%	-31.4%
LGW	447.4	405.5	407.9	356.7	227.4	223.0	-9.4%	-45.0%
LHR NWR	1,130.0	979.0	928.2	1,185.6	890.4	776.9	-13.4%	-20.6%
LTN	98.8	125.5	157.2	131.8	85.3	82.4	+27.1%	-34.3%
MAN	337.8	292.5	287.6	277.5	230.2	263.1	-13.4%	-10.0%
STN	331.7	310.3	220.6	240.2	157.8	157.8	-6.5%	-49.1%
Total (with LHR)	2,696.7	2,470.5	2,355.9	2,525.7	1,881.1	1,808.2	-8.4%	-26.8%
Total (without LHR)	1,566.7	1,491.5	1,427.7	1,340.1	990.6	1,031.3	-4.8%	-30.9%

Table C.2 (d): Average summer night Quota Count, Scenario Central

	Scenario: Central QC Average summer night							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	18.1	19.2	17.9	17.4	18.1	19.3	+5.7%	+0.5%
EDI	10.9	18.3	10.9	10.7	8.9	9.5	+68.1%	-47.9%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	62.6	56.6	59.8	53.0	35.6	35.2	-9.6%	-37.8%
LHR NWR	90.9	80.3	52.4	68.0	53.1	48.9	-11.7%	-39.1%
LTN	23.2	29.0	33.0	27.7	17.8	17.2	+24.8%	-40.7%
MAN	40.3	45.8	37.7	36.7	31.8	37.5	+13.8%	-18.1%
STN	55.3	50.4	37.0	40.5	27.7	27.8	-8.9%	-44.9%
Total (with LHR)	301.3	299.6	248.9	254.0	193.0	195.4	-0.6%	-34.8%
Total (without LHR)	210.4	219.3	196.5	186.0	139.9	146.5	+4.2%	-33.2%

Table C.3 (a): Summary of average summer day 51dB L_{Aeq16h} noise contour area (High Scenario)

	Scenario: High AREA (km²) results LAeq16h 51 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	51.1	47.9	59.9	61.1	66.6	70.1	-6.3%	+46.6%
EDI	50.4	57.4	53.7	52.9	47.9	53.2	+13.8%	-7.2%
GLA	57.8	49.3	64.4	57.6	48.9	49.7	-14.7%	+0.9%
LGW	135.8	154.5	150.6	143.8	115.1	111.7	+13.7%	-27.7%
LHR NWR	391.1	329.4	291.2	360.1	314.7	293.3	-15.8%	-11.0%
LTN	42.5	60.4	65.2	57.3	41.8	41.8	+42.4%	-30.8%
MAN	108.4	97.3	108.4	105.5	100.1	113.5	-10.2%	+16.6%
STN	95.3	82.9	102.5	102.3	72.8	71.2	-13.0%	-14.1%
Total (with LHR)	932.3	879.0	895.9	940.5	807.7	804.6	-5.7%	-8.5%
Total (without LHR)	541.2	549.6	604.7	580.4	493.0	511.3	+1.6%	-7.0%

Table C.3 (b): Summary of average summer day 54dB L_{Aeq16h} noise contour area (High Scenario)

	Scenario: High AREA (km²) results LAeq16h 54 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	28.7	27.4	33.1	33.5	35.2	36.9	-4.7%	+34.6%
EDI	28.3	32.2	29.6	29.1	25.5	27.6	+13.8%	-14.4%
GLA	30.1	25.2	32.8	29.4	24.0	24.0	-16.0%	-4.8%
LGW	80.1	86.5	82.4	77.9	60.8	59.4	+8.0%	-31.3%
LHR NWR	220.6	184.3	166.5	207.6	177.7	165.8	-16.4%	-10.0%
LTN	23.2	33.2	36.5	31.1	21.6	21.8	+43.5%	-34.3%
MAN	64.0	55.9	62.2	60.5	58.3	68.0	-12.6%	+21.8%
STN	55.5	45.4	54.0	54.2	37.5	36.9	-18.3%	-18.6%
Total (with LHR)	530.4	490.2	497.1	523.2	440.6	440.5	-7.6%	-10.1%
Total (without LHR)	309.9	305.8	330.6	315.6	262.9	274.7	-1.3%	-10.2%

Table C.3 (c): Summary of average summer night 45dB L_{Aeq8h} noise contour area (High Scenario)

	Scenario: High AREA (km²) results LAeq8h 45 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	57.4	59.3	63.8	64.9	70.5	73.3	+3.3%	+23.6%
EDI	39.8	59.5	47.3	46.8	43.7	49.3	+49.6%	-17.2%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	151.7	189.7	179.7	172.3	149.4	147.5	+25.0%	-22.2%
LHR NWR	191.0	193.8	163.8	213.2	190.7	183.9	+1.4%	-5.1%
LTN	59.9	90.3	95.9	83.7	62.5	61.8	+50.8%	-31.6%
MAN	111.4	121.5	118.3	115.1	112.5	133.8	+9.1%	+10.1%
STN	105.1	105.7	130.0	130.5	97.1	95.4	+0.6%	-9.8%
Total (with LHR)	716.2	819.7	798.8	826.5	726.3	745.0	+14.4%	-9.1%
Total (without LHR)	525.2	626.0	635.0	613.3	535.7	561.1	+19.2%	-10.4%

Table C.3 (d): Summary of average summer night 48dB L_{Aeq8h} noise contour area (High Scenario)

	Scenario: High AREA (km²) results LAeq8h 48 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	32.1	31.7	34.7	35.1	37.4	39.5	-1.3%	+24.7%
EDI	21.5	32.9	25.2	24.9	22.3	24.4	+53.3%	-25.8%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	91.8	107.7	103.6	99.0	83.8	83.0	+17.3%	-22.9%
LHR NWR	114.5	115.2	95.2	118.6	104.6	100.9	+0.5%	-12.4%
LTN	33.4	53.5	57.4	49.7	34.9	35.2	+60.2%	-34.3%
MAN	63.6	70.2	70.7	69.3	68.8	80.2	+10.4%	+14.2%
STN	62.7	61.9	75.8	76.5	57.9	57.0	-1.2%	-8.0%
Total (with LHR)	419.6	473.0	462.6	473.2	409.7	420.1	+12.7%	-11.2%
Total (without LHR)	305.1	357.9	367.3	354.6	305.2	319.2	+17.3%	-10.8%

Table C.3 (e): Summary of average annual 24h 50dB L_{den} noise contour area (High Scenario)

	Scenario: High AREA (km²) results Lden 50 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	84.6	87.2	104.3	105.6	114.8	118.9	+3.1%	+36.4%
EDI	88.0	101.1	78.1	92.5	87.3	95.5	+14.9%	-5.6%
GLA	99.4	81.4	97.6	87.4	76.0	77.8	-18.1%	-4.4%
LGW	233.8	223.4	256.7	242.9	203.5	198.8	-4.4%	-11.0%
LHR NWR	636.1	498.1	437.3	537.1	473.9	446.0	-21.7%	-10.5%
LTN	82.3	132.1	123.9	107.9	80.2	79.2	+60.6%	-40.0%
MAN	167.4	164.9	175.6	170.2	162.3	186.6	-1.5%	+13.1%
STN	198.5	166.9	224.8	221.7	148.5	145.4	-15.9%	-12.9%
Total (with LHR)	1,590.0	1,455.2	1,498.2	1,565.2	1,346.6	1,348.3	-8.5%	-7.3%
Total (without LHR)	953.9	957.1	1,060.9	1,028.0	872.7	902.3	+0.3%	-5.7%

Table C.3 (f): Summary of average annual 24h 55dB L_{den} noise contour area (High Scenario)

	Scenario: High AREA (km²) results Lden 55 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	30.9	31.1	38.4	38.8	41.3	43.7	+0.7%	+40.7%
EDI	34.1	37.7	32.7	32.2	28.6	31.0	+10.4%	-17.8%
GLA	36.3	27.1	32.4	29.0	24.0	24.3	-25.5%	-10.4%
LGW	94.5	104.9	102.1	96.8	80.1	78.9	+11.1%	-24.8%
LHR NWR	244.7	198.0	176.3	222.0	192.8	183.0	-19.1%	-7.6%
LTN	33.7	47.7	53.4	45.5	31.4	31.4	+41.7%	-34.1%
MAN	68.2	64.1	67.7	65.8	64.3	75.8	-6.0%	+18.2%
STN	73.3	64.4	80.7	80.7	57.7	56.5	-12.1%	-12.4%
Total (with LHR)	615.6	575.1	583.7	610.8	520.3	524.5	-6.6%	-8.8%
Total (without LHR)	371.0	377.0	407.4	388.8	327.4	341.5	+1.6%	-9.4%

Table C.3 (g): Summary of average annual 8h night 45dB L_{night} noise contour area (High Scenario)

	Scenario: High AREA (km²) results Lnight 45 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	39.5	43.3	47.8	48.1	50.9	53.2	+9.6%	+22.9%
EDI	37.5	48.2	38.7	38.2	34.0	36.8	+28.5%	-23.6%
GLA	49.3	29.5	30.0	26.9	22.4	22.6	-40.2%	-23.4%
LGW	118.9	132.2	128.6	122.7	105.1	103.8	+11.2%	-21.5%
LHR NWR	198.5	174.8	154.7	198.6	179.1	174.6	-11.9%	-0.1%
LTN	44.4	72.4	77.0	67.4	48.9	48.8	+63.1%	-32.6%
MAN	81.6	90.6	87.3	84.0	83.5	98.5	+10.9%	+8.8%
STN	99.6	89.9	113.5	113.5	85.3	83.5	-9.7%	-7.1%
Total (with LHR)	669.3	680.9	677.6	699.4	609.1	621.9	+1.7%	-8.7%
Total (without LHR)	470.8	506.1	522.9	500.8	430.0	447.3	+7.5%	-11.6%

Table C.3 (h): Summary of average annual 8h night 50dB L_{night} noise contour area (High Scenario)

	Scenario: High AREA (km²) results Lnight 50 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	15.1	16.3	18.6	18.7	18.7	19.3	+8.0%	+18.7%
EDI	13.9	18.8	14.2	13.9	12.1	13.2	+35.2%	-29.6%
GLA	17.6	10.1	10.4	9.4	7.6	7.9	-43.0%	-21.9%
LGW	48.3	44.9	43.5	41.1	33.6	33.1	-7.0%	-26.3%
LHR NWR	84.4	74.0	59.1	78.6	70.4	69.3	-12.4%	-6.3%
LTN	16.4	26.1	28.3	24.0	16.6	16.8	+59.1%	-35.4%
MAN	32.8	32.9	30.4	29.5	28.7	34.8	+0.4%	+5.8%
STN	39.5	33.6	41.1	41.1	29.1	28.8	-14.8%	-14.6%
Total (with LHR)	268.0	256.7	245.6	256.4	216.9	223.2	-4.2%	-13.0%
Total (without LHR)	183.6	182.7	186.5	177.8	146.4	153.9	-0.5%	-15.7%

Table C.4 (a): Summary of average summer day 51dB L_{Aeq16h} population exposure (High Scenario)

	Scenario: High Population Exposed LAeq16h 51 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	90,200	87,400	114,600	119,500	132,500	142,200	-3.1%	+62.7%
EDI	19,800	34,000	30,400	30,100	22,000	24,800	+71.6%	-27.0%
GLA	76,700	74,100	86,700	81,500	72,300	72,600	-3.4%	-2.0%
LGW	24,500	27,300	29,100	27,200	18,200	17,500	+11.4%	-36.0%
LHR NWR	1,167,800	1,146,000	1,131,900	1,150,400	1,065,000	1,047,800	-1.9%	-8.6%
LTN	12,300	42,400	51,500	43,600	29,000	31,300	+244.3%	-26.2%
MAN	142,800	137,000	162,000	166,500	176,500	205,100	-4.1%	+49.8%
STN	16,300	12,600	16,300	17,500	11,800	11,500	-22.7%	-9.2%
Total (with LHR)	1,550,500	1,560,800	1,622,600	1,636,200	1,527,300	1,552,800	+0.7%	-0.5%
Total (without LHR)	382,700	414,800	490,700	485,800	462,300	505,000	+8.4%	+21.7%

Table C.4 (b): Summary of average summer day 54dB L_{Aeq16h} population exposure (High Scenario)

	Scenario: High Population Exposed LAeq16h 54 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	45,700	48,100	59,500	60,700	62,600	66,500	+5.1%	+38.2%
EDI	7,500	9,800	8,300	8,500	7,200	7,800	+31.4%	-20.8%
GLA	46,400	39,400	53,900	47,900	36,700	36,700	-15.0%	-6.9%
LGW	10,400	11,100	12,600	12,000	8,100	8,400	+6.9%	-24.4%
LHR NWR	628,800	588,900	561,400	609,300	539,900	530,100	-6.3%	-10.0%
LTN	5,200	13,000	15,100	14,000	10,200	10,400	+151.3%	-20.3%
MAN	74,900	66,200	85,400	86,800	100,700	130,700	-11.6%	+97.4%
STN	6,600	5,700	6,500	6,900	5,500	5,500	-13.5%	-4.6%
Total (with LHR)	825,400	782,300	802,700	846,000	771,000	796,000	-5.2%	+1.8%
Total (without LHR)	196,700	193,400	241,300	236,700	231,200	265,900	-1.7%	+37.5%

Table C.4 (c): Summary of average summer night 45dB L_{Aeq8h} population exposure (High Scenario)

	Scenario: High Population Exposed LAeq8h 45 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	95,900	100,600	116,600	120,400	124,100	129,200	+4.9%	+28.4%
EDI	12,500	24,600	20,500	19,900	14,800	17,100	+96.2%	-30.4%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	26,200	34,600	34,800	33,300	25,400	24,800	+32.2%	-28.4%
LHR NWR	663,500	811,800	752,100	793,700	744,900	757,800	+22.3%	-6.7%
LTN	30,200	71,100	80,800	71,100	55,500	56,100	+135.2%	-21.2%
MAN	171,300	185,900	195,700	200,800	218,400	256,400	+8.5%	+37.9%
STN	17,000	14,600	21,800	22,600	13,900	13,600	-14.3%	-6.3%
Total (with LHR)	1,016,600	1,243,200	1,222,300	1,261,900	1,197,000	1,255,000	+22.3%	+1.0%
Total (without LHR)	353,100	431,400	470,200	468,100	452,000	497,200	+22.2%	+15.3%

Table C.4 (d): Summary of average summer night 48dB L_{Aeq8h} population exposure (High Scenario)

	Scenario: High Population Exposed LAeq8h 48 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	55,000	56,800	63,400	64,200	64,400	65,900	+3.4%	+16.0%
EDI	3,900	7,100	6,500	7,000	6,000	7,000	+82.8%	-1.5%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	10,800	14,300	15,300	14,800	11,500	11,400	+32.2%	-19.8%
LHR NWR	340,000	417,500	343,300	331,300	307,100	317,100	+22.8%	-24.1%
LTN	8,800	35,200	42,100	33,800	17,000	20,300	+298.1%	-42.5%
MAN	96,000	117,800	125,400	128,900	144,300	174,900	+22.7%	+48.4%
STN	7,300	6,800	9,100	9,600	7,600	7,500	-7.1%	+11.6%
Total (with LHR)	521,700	655,500	605,300	589,600	557,800	604,100	+25.6%	-7.8%
Total (without LHR)	181,700	237,900	262,000	258,300	250,800	287,000	+30.9%	+20.6%

Table C.4 (e): Summary of average annual 24h 50dB L_{den} population exposure (High Scenario)

	Scenario: High	Population Exposed	Lden 50 dB					
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	142,800	153,500	196,900	205,100	231,800	241,400	+7.5%	+57.3%
EDI	48,100	51,500	35,100	48,000	42,000	45,300	+7.1%	-12.1%
GLA	104,600	100,600	111,200	106,700	95,800	95,800	-3.8%	-4.8%
LGW	50,400	45,600	60,800	56,300	37,500	36,800	-9.4%	-19.4%
LHR NWR	1,980,500	1,761,000	1,786,900	2,086,100	1,896,200	1,909,000	-11.1%	+8.4%
LTN	45,600	93,500	102,200	92,800	73,200	73,600	+105.1%	-21.3%
MAN	222,000	234,000	249,700	251,300	262,700	312,600	+5.4%	+33.6%
STN	36,000	34,800	45,000	47,200	29,000	28,800	-3.5%	-17.1%
Total (with LHR)	2,629,900	2,474,500	2,587,700	2,893,500	2,668,100	2,743,200	-5.9%	+10.9%
Total (without LHR)	649,400	713,500	800,800	807,500	771,900	834,200	+9.9%	+16.9%

Table C.4 (f): Summary of average annual 24h 55dB L_{den} population exposure (High Scenario)

	Scenario: High	Population Exposed	Lden 55 dB					
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	48,400	52,700	68,800	70,000	76,200	80,800	+8.8%	+53.4%
EDI	11,800	15,500	11,900	11,600	10,200	12,000	+31.9%	-22.6%
GLA	56,800	44,000	53,200	47,600	36,800	37,500	-22.5%	-14.9%
LGW	12,600	13,800	15,800	15,200	10,800	10,600	+9.9%	-23.0%
LHR NWR	756,100	689,400	652,600	709,100	637,400	633,900	-8.8%	-8.0%
LTN	8,900	24,400	34,600	25,000	14,800	14,900	+172.8%	-39.1%
MAN	93,000	101,600	114,000	115,500	126,400	155,100	+9.3%	+52.7%
STN	9,800	8,700	12,400	13,200	8,300	8,500	-11.1%	-1.7%
Total (with LHR)	997,300	950,000	963,400	1,007,200	920,700	953,200	-4.7%	+0.3%
Total (without LHR)	241,200	260,600	310,800	298,100	283,400	319,300	+8.1%	+22.5%

Table C.4 (g): Summary of average annual 8h night 45dB L_{night} population exposure (High Scenario)

	Scenario: High Population Exposed Lnight 45 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	62,700	80,000	93,400	95,400	98,000	102,800	+27.5%	+28.6%
EDI	15,800	26,100	17,800	17,700	14,100	17,000	+65.3%	-35.0%
GLA	70,200	48,800	48,800	42,600	33,000	33,800	-30.5%	-30.7%
LGW	16,300	19,400	20,600	19,700	15,000	14,400	+18.6%	-25.5%
LHR NWR	703,600	725,800	680,400	711,100	678,400	690,700	+3.2%	-4.8%
LTN	14,900	54,600	60,100	50,700	34,200	36,300	+267.0%	-33.6%
MAN	130,300	147,900	152,000	153,400	165,200	192,200	+13.5%	+30.0%
STN	15,300	14,500	20,500	21,700	14,000	13,900	-5.7%	-4.3%
Total (with LHR)	1,029,100	1,117,000	1,093,700	1,112,300	1,051,900	1,101,000	+8.5%	-1.4%
Total (without LHR)	325,500	391,200	413,200	401,200	373,500	410,300	+20.2%	+4.9%

Table C.4 (h): Summary of average annual 8h night 50dB L_{night} population exposure (High Scenario)

	Scenario: High Population Exposed Lnight 50 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	20,700	26,300	29,800	30,600	31,100	33,600	+26.9%	+27.5%
EDI	2,900	4,600	3,900	4,100	4,100	4,300	+57.7%	-6.7%
GLA	21,100	7,700	7,800	5,900	4,200	5,200	-63.4%	-32.1%
LGW	5,000	5,200	4,700	4,800	4,500	4,700	+5.4%	-10.5%
LHR NWR	207,200	221,200	185,000	208,100	201,000	208,500	+6.7%	-5.7%
LTN	2,600	10,400	12,100	11,500	7,800	8,000	+296.3%	-23.0%
MAN	40,900	44,100	39,700	39,700	42,900	60,600	+7.9%	+37.3%
STN	4,100	4,000	5,100	5,400	4,200	4,300	-2.7%	+8.3%
Total (with LHR)	304,600	323,600	288,100	310,100	299,900	329,300	+6.2%	+1.7%
Total (without LHR)	97,400	102,500	103,100	102,000	98,900	120,800	+5.2%	+17.9%

Table C.4 (i): Summary of average summer night N60, ≥5 events population exposure (High Scenario)

	Scenario: High		Population Exposed		N60, ≥5 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	166,100	229,000	245,000	259,800	281,600	294,700	+37.9%	+28.7%
EDI	58,000	71,100	63,200	64,300	59,900	61,100	+22.6%	-14.1%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	55,000	93,800	73,400	74,200	62,900	64,300	+70.7%	-31.5%
LHR NWR	1,078,700	1,325,100	1,289,300	1,456,100	1,348,400	1,331,600	+22.8%	+0.5%
LTN	97,800	127,100	142,800	129,000	111,400	114,400	+29.9%	-10.0%
MAN	299,200	269,200	280,100	288,200	324,800	430,100	-10.0%	+59.8%
STN	45,900	40,100	46,100	47,300	38,300	38,800	-12.6%	-3.4%
Total (with LHR)	1,800,700	2,155,400	2,139,800	2,318,800	2,227,300	2,335,000	+19.7%	+8.3%
Total (without LHR)	722,100	830,300	850,500	862,700	879,000	1,003,400	+15.0%	+20.8%

Table C.4 (j): Summary of average summer night N60, ≥10 events population exposure (High Scenario)

	Scenario: High		Population Exposed		N60, ≥10 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	79,600	140,600	146,000	153,900	178,900	181,100	+76.7%	+28.7%
EDI	37,800	48,300	41,800	44,400	43,700	46,000	+28.1%	-4.8%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	27,500	38,200	45,900	40,700	34,100	36,600	+38.9%	-4.1%
LHR NWR	791,400	928,200	892,700	1,054,200	995,300	1,014,600	+17.3%	+9.3%
LTN	50,700	99,900	104,800	96,900	86,200	87,300	+97.2%	-12.6%
MAN	206,300	191,700	195,700	201,100	219,800	256,800	-7.1%	+34.0%
STN	22,700	26,400	30,200	31,400	23,000	22,800	+16.3%	-13.6%
Total (with LHR)	1,215,900	1,473,400	1,457,100	1,622,500	1,580,900	1,645,200	+21.2%	+11.7%
Total (without LHR)	79,600	140,600	146,000	153,900	178,900	181,100	+76.7%	+28.7%

Table C.4 (k): Summary of average summer night N65, ≥10 events population exposure (High Scenario)

	Scenario: High		Population Exposed		N65, ≥10 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	225,600	197,400	225,100	229,700	229,200	237,200	-12.5%	+20.1%
EDI	61,000	69,800	66,400	65,100	57,100	56,700	+14.4%	-18.7%
GLA	116,200	119,000	129,600	126,000	116,200	115,000	+2.4%	-3.4%
LGW	39,300	30,200	33,300	36,700	22,600	22,600	-23.2%	-25.2%
LHR NWR	1,599,300	1,271,700	1,357,600	1,390,600	1,219,500	1,173,800	-20.5%	-7.7%
LTN	72,700	78,000	85,100	78,700	73,600	74,500	+7.3%	-4.5%
MAN	303,200	173,800	192,100	185,400	205,600	253,500	-42.7%	+45.8%
STN	32,300	25,100	34,900	32,900	22,100	21,700	-22.3%	-13.4%
Total (with LHR)	2,449,500	1,965,000	2,124,000	2,145,000	1,946,000	1,955,000	-19.8%	-0.5%
Total (without LHR)	850,300	693,300	766,400	754,400	726,400	781,200	-18.5%	+12.7%

Table C.4 (l): Summary of average summer day N70, ≥5 events population exposure (High Scenario)

	Scenario: High		Population Exposed		N70, ≥5 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	146,700	114,600	109,200	106,900	96,500	103,600	-21.8%	-9.6%
EDI	32,600	35,600	36,000	34,100	28,200	26,400	+9.2%	-26.0%
GLA	87,600	88,000	96,900	93,100	81,100	79,000	+0.5%	-10.3%
LGW	20,500	10,400	13,100	13,500	10,500	10,000	-49.2%	-3.7%
LHR NWR	917,000	680,800	719,800	615,800	528,900	462,100	-25.8%	-32.1%
LTN	20,100	21,200	25,500	23,900	21,700	21,700	+5.5%	+2.4%
MAN	145,800	102,500	105,300	98,300	84,200	104,500	-29.7%	+1.9%
STN	9,100	8,600	10,400	10,600	9,900	10,000	-4.9%	+15.9%
Total (with LHR)	1,379,300	1,061,800	1,116,100	996,300	861,000	817,300	-23.0%	-23.0%
Total (without LHR)	462,300	381,000	396,300	380,500	332,100	355,200	-17.6%	-6.8%

Table C.4 (m): Summary of average summer day N70, ≥10 events population exposure (High Scenario)

	Scenario: High Population Exposed N70, ≥10 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	104,300	94,200	87,900	86,600	76,400	72,600	-9.7%	-23.0%
EDI	26,500	27,800	28,100	25,300	19,200	19,400	+5.2%	-30.4%
GLA	72,700	72,700	82,100	78,000	68,600	67,400	+0.1%	-7.3%
LGW	14,200	7,500	10,800	11,700	9,400	9,400	-46.9%	+24.8%
LHR NWR	632,300	538,200	567,800	493,800	409,700	383,400	-14.9%	-28.8%
LTN	12,700	19,900	23,500	21,300	19,400	20,100	+57.3%	+0.9%
MAN	105,000	70,600	71,700	69,500	66,600	80,200	-32.8%	+13.6%
STN	7,000	7,800	8,200	8,300	6,200	6,100	+11.6%	-21.1%
Total (with LHR)	974,600	838,700	880,100	794,400	675,500	658,500	-13.9%	-21.5%
Total (without LHR)	342,300	300,600	312,300	300,600	265,800	275,100	-12.2%	-8.5%

Table C.5 (a): Summary of average summer day 51dB L_{Aeq16h} noise contour area (Central Scenario)

	Scenario: Central AREA (km²) results LAeq16h 51 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	51.1	47.9	57.5	55.8	62.3	65.9	-6.3%	+37.7%
EDI	50.4	57.4	52.5	50.8	46.3	49.7	+13.8%	-13.3%
GLA	57.8	49.3	61.3	55.3	45.8	47.4	-14.7%	-3.8%
LGW	135.8	154.5	146.4	133.0	105.6	104.0	+13.7%	-32.6%
LHR NWR	391.1	329.4	290.6	363.2	311.8	286.4	-15.8%	-13.1%
LTN	42.5	60.4	65.1	56.9	42.2	40.5	+42.4%	-32.9%
MAN	108.4	97.3	105.1	101.9	95.3	104.4	-10.2%	+7.2%
STN	95.3	82.9	86.5	93.3	72.8	72.0	-13.0%	-13.1%
Total (with LHR)	932.3	879.0	865.2	910.2	782.1	770.4	-5.7%	-12.4%
Total (without LHR)	541.2	549.6	574.5	546.9	470.3	484.0	+1.6%	-11.9%

Table C.5 (b): Summary of average summer day 54dB L_{Aeq16h} noise contour area (Central Scenario)

	Scenario: Central AREA (km²) results LAeq16h 54 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	28.7	27.4	31.8	30.9	33.0	34.8	-4.7%	+26.8%
EDI	28.3	32.2	29.0	28.1	24.8	26.2	+13.8%	-18.8%
GLA	30.1	25.2	31.3	28.2	22.7	23.0	-16.0%	-9.0%
LGW	80.1	86.5	79.8	71.1	54.7	54.3	+8.0%	-37.2%
LHR NWR	220.6	184.3	166.2	209.6	175.8	161.2	-16.4%	-12.6%
LTN	23.2	33.2	36.5	30.9	21.8	21.1	+43.5%	-36.5%
MAN	64.0	55.9	59.9	59.5	56.1	63.5	-12.6%	+13.6%
STN	55.5	45.4	45.1	48.8	37.5	37.4	-18.3%	-17.6%
Total (with LHR)	530.4	490.2	479.5	507.2	426.4	421.3	-7.6%	-14.0%
Total (without LHR)	309.9	305.8	313.3	297.6	250.6	260.1	-1.3%	-14.9%

Table C.5 (c): Summary of average summer night 45dB L_{Aeq8h} noise contour area (Central Scenario)

	Scenario: Central AREA (km²) results LAeq8h 45 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	57.4	59.3	61.3	59.6	66.3	69.4	+3.3%	+17.0%
EDI	39.8	59.5	46.2	44.8	42.1	45.9	+49.6%	-22.9%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	151.7	189.7	179.7	160.4	138.0	138.4	+25.0%	-27.0%
LHR NWR	191.0	193.8	163.7	215.1	189.2	180.2	+1.4%	-7.0%
LTN	59.9	90.3	95.6	83.0	63.0	60.1	+50.8%	-33.5%
MAN	111.4	121.5	114.0	110.3	106.7	120.1	+9.1%	-1.2%
STN	105.1	105.7	110.9	119.3	97.1	96.4	+0.6%	-8.8%
Total (with LHR)	716.2	819.7	771.3	792.5	702.4	710.4	+14.4%	-13.3%
Total (without LHR)	525.2	626.0	607.7	577.4	513.2	530.2	+19.2%	-15.3%

Table C.5 (d): Summary of average summer night 48dB L_{Aeq8h} noise contour area (Central Scenario)

	Scenario: Central AREA (km²) results LAeq8h 48 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	32.1	31.7	33.4	32.4	35.0	37.1	-1.3%	+17.2%
EDI	21.5	32.9	24.6	23.9	21.7	23.1	+53.3%	-29.9%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	91.8	107.7	103.6	92.9	78.1	78.2	+17.3%	-27.3%
LHR NWR	114.5	115.2	95.1	119.7	103.6	98.4	+0.5%	-14.5%
LTN	33.4	53.5	57.3	49.3	35.3	34.0	+60.2%	-36.5%
MAN	63.6	70.2	68.4	67.7	65.8	73.6	+10.4%	+4.8%
STN	62.7	61.9	64.6	70.3	57.9	57.6	-1.2%	-6.9%
Total (with LHR)	419.6	473.0	447.0	456.2	397.3	402.1	+12.7%	-15.0%
Total (without LHR)	305.1	357.9	351.9	336.5	293.7	303.6	+17.3%	-15.2%

Table C.5 (e): Summary of average annual 24h 50dB L_{den} noise contour area (Central Scenario)

	Scenario: Central AREA (km²) results Lden 50 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	84.6	87.2	100.4	97.3	108.3	112.8	+3.1%	+29.4%
EDI	88.0	101.1	91.0	88.0	84.5	90.5	+14.9%	-10.6%
GLA	99.4	81.4	92.9	83.9	71.5	74.3	-18.1%	-8.7%
LGW	233.8	223.4	249.2	225.7	188.4	186.6	-4.4%	-16.5%
LHR NWR	636.1	498.1	436.7	542.1	470.1	436.6	-21.7%	-12.3%
LTN	82.3	132.1	123.5	106.9	80.8	77.2	+60.6%	-41.6%
MAN	167.4	164.9	170.3	162.5	152.5	170.7	-1.5%	+3.5%
STN	198.5	166.9	182.2	197.6	148.5	146.9	-15.9%	-12.0%
Total (with LHR)	1,590.0	1,455.2	1,446.1	1,504.1	1,304.5	1,295.6	-8.5%	-11.0%
Total (without LHR)	953.9	957.1	1,009.5	962.0	834.4	859.0	+0.3%	-10.2%

Table C.5 (f): Summary of average annual 24h 55dB L_{den} noise contour area (Central Scenario)

	Scenario: Central AREA (km²) results Lden 55 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	30.9	31.1	36.9	35.8	38.7	41.0	+0.7%	+31.8%
EDI	34.1	37.7	32.0	31.1	27.9	29.4	+10.4%	-21.9%
GLA	36.3	27.1	30.8	27.9	22.6	23.2	-25.5%	-14.5%
LGW	94.5	104.9	99.6	90.3	73.9	73.6	+11.1%	-29.9%
LHR NWR	244.7	198.0	176.0	224.2	190.8	177.8	-19.1%	-10.2%
LTN	33.7	47.7	53.3	45.1	31.7	30.4	+41.7%	-36.2%
MAN	68.2	64.1	65.1	64.0	61.4	69.7	-6.0%	+8.7%
STN	73.3	64.4	67.6	73.2	57.6	57.2	-12.1%	-11.1%
Total (with LHR)	615.6	575.1	561.5	591.5	504.6	502.3	-6.6%	-12.7%
Total (without LHR)	371.0	377.0	385.5	367.3	313.8	324.5	+1.6%	-13.9%

Table C.5 (g): Summary of average annual 8h night 45dB L_{night} noise contour area (Central Scenario)

	Scenario: Central	AREA (km²) results	Lnight 45 dB					
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	39.5	43.3	45.8	44.3	47.5	49.9	+9.6%	+15.2%
EDI	37.5	48.2	38.0	36.8	33.1	34.9	+28.5%	-27.6%
GLA	49.3	29.5	28.6	25.8	21.1	21.6	-40.2%	-26.7%
LGW	118.9	132.2	125.6	115.2	97.7	97.8	+11.2%	-26.0%
LHR NWR	198.5	174.8	154.6	200.5	177.7	170.8	-11.9%	-2.3%
LTN	44.4	72.4	76.9	66.9	49.4	47.3	+63.1%	-34.7%
MAN	81.6	90.6	83.6	80.4	78.0	89.7	+10.9%	-1.0%
STN	99.6	89.9	97.3	104.2	85.2	84.5	-9.7%	-6.0%
Total (with LHR)	669.3	680.9	650.4	674.1	589.9	596.4	+1.7%	-12.4%
Total (without LHR)	470.8	506.1	495.8	473.6	412.2	425.6	+7.5%	-15.9%

Table C.5 (h): Summary of average annual 8h night 50dB L_{night} noise contour area (Central Scenario)

	Scenario: Central	AREA (km²) results	Lnight 50 dB					
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	15.1	16.3	17.8	17.2	17.6	18.3	+8.0%	+12.2%
EDI	13.9	18.8	13.9	13.4	11.7	12.5	+35.2%	-33.4%
GLA	17.6	10.1	9.9	9.0	7.2	7.5	-43.0%	-25.7%
LGW	48.3	44.9	42.4	38.3	30.6	30.6	-7.0%	-32.0%
LHR NWR	84.4	74.0	59.0	79.2	69.8	67.7	-12.4%	-8.5%
LTN	16.4	26.1	28.3	23.8	16.8	16.3	+59.1%	-37.4%
MAN	32.8	32.9	29.2	29.8	27.9	31.9	+0.4%	-3.0%
STN	39.5	33.6	34.1	37.1	29.1	29.1	-14.8%	-13.5%
Total (with LHR)	268.0	256.7	234.7	247.8	210.7	213.9	-4.2%	-16.7%
Total (without LHR)	183.6	182.7	175.7	168.6	140.9	146.1	-0.5%	-20.0%

Table C.6 (a): Summary of average summer day 51dB L_{Aeq16h} population exposure (Central Scenario)

	Scenario: Central			Population Exposed		LAeq16h 51 dB		
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	90,200	87,400	110,000	109,300	123,100	133,000	-3.1%	+52.2%
EDI	19,800	34,000	29,700	28,500	21,100	22,800	+71.7%	-32.9%
GLA	76,700	74,100	83,900	79,900	69,200	70,200	-3.4%	-5.3%
LGW	24,500	27,300	28,600	25,600	15,900	15,700	+11.4%	-42.5%
LHR NWR	1,167,800	1,146,000	1,132,800	1,164,400	1,057,800	1,027,600	-1.9%	-10.3%
LTN	12,300	42,400	51,500	43,300	29,400	28,700	+244.7%	-32.3%
MAN	142,800	137,000	157,900	161,500	172,000	198,700	-4.1%	+45.0%
STN	16,300	12,600	12,500	15,200	11,800	11,700	-22.7%	-7.1%
Total (with LHR)	1,550,500	1,560,800	1,606,900	1,627,800	1,500,400	1,508,400	+0.7%	-3.4%
Total (without LHR)	382,700	414,800	474,200	463,400	442,600	480,800	+8.4%	+15.9%

Table C.6 (b): Summary of average summer day 54dB L_{Aeq16h} population exposure (Central Scenario)

	Scenario: Central			Population Exposed		LAeq16h 54 dB		
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	45,700	48,100	57,500	56,400	59,000	62,800	+5.3%	+30.6%
EDI	7,500	9,800	8,000	7,300	7,200	7,600	+30.7%	-22.4%
GLA	46,400	39,400	51,100	45,600	33,600	34,500	-15.1%	-12.4%
LGW	10,400	11,100	11,800	10,300	7,200	7,300	+6.7%	-34.2%
LHR NWR	628,800	588,900	560,600	618,400	532,400	509,800	-6.3%	-13.4%
LTN	5,200	13,000	15,000	14,000	10,400	10,100	+150.0%	-22.3%
MAN	74,900	66,200	82,000	77,000	88,000	119,400	-11.6%	+80.4%
STN	6,600	5,700	5,700	6,500	5,500	5,500	-13.6%	-3.5%
Total (with LHR)	825,400	782,300	791,600	835,400	743,400	757,000	-5.2%	-3.2%
Total (without LHR)	196,700	193,400	231,100	217,000	211,000	247,200	-1.7%	+27.8%

Table C.6 (c): Summary of average summer night 45dB L_{Aeq8h} population exposure (Central Scenario)

	Scenario: Central			Population Exposed		LAeq8h 45 dB		
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	95,900	100,600	112,100	110,800	117,800	123,000	+4.9%	+22.3%
EDI	12,500	24,600	19,300	18,500	14,200	15,500	+96.8%	-37.0%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	26,200	34,600	34,800	30,900	22,200	22,500	+32.1%	-35.0%
LHR NWR	663,500	811,800	752,900	806,200	740,000	741,500	+22.4%	-8.7%
LTN	30,200	71,100	80,800	70,700	55,700	54,400	+135.4%	-23.5%
MAN	171,300	185,900	191,700	199,000	212,300	246,400	+8.5%	+32.5%
STN	17,000	14,600	17,800	20,000	13,900	14,000	-14.1%	-4.1%
Total (with LHR)	1,016,600	1,243,200	1,209,300	1,256,200	1,176,000	1,217,300	+22.3%	-2.1%
Total (without LHR)	353,100	431,400	456,400	449,900	436,000	475,800	+22.2%	+10.3%

Table C.6 (d): Summary of average summer night 48dB L_{Aeq8h} population exposure (Central Scenario)

	Scenario: Central			Population Exposed		LAeq8h 48 dB		
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	55,000	56,800	60,700	59,900	60,700	62,400	+3.3%	+9.9%
EDI	3,900	7,100	6,400	6,600	5,800	6,600	+82.1%	-7.0%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	10,800	14,300	15,300	13,400	10,700	10,900	+32.4%	-23.8%
LHR NWR	340,000	417,500	343,500	335,100	303,200	306,800	+22.8%	-26.5%
LTN	8,800	35,200	42,100	33,200	17,500	18,400	+300.0%	-47.7%
MAN	96,000	117,800	121,100	124,000	136,200	163,200	+22.7%	+38.5%
STN	7,300	6,800	7,800	8,900	7,600	7,500	-6.8%	+10.3%
Total (with LHR)	521,700	655,500	597,000	581,000	541,800	576,000	+25.6%	-12.1%
Total (without LHR)	181,700	237,900	253,500	245,900	238,600	269,100	+30.9%	+13.1%

Table C.6 (e): Summary of average annual 24h 50dB L_{den} population exposure (Central Scenario)

	Scenario: Central		Population Exposed		Lden 50 dB			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	142,800	153,500	189,700	190,900	220,300	234,000	+7.5%	+52.4%
EDI	48,100	51,500	48,600	48,100	43,200	44,500	+7.1%	-13.6%
GLA	104,600	100,600	108,000	104,800	92,000	92,600	-3.8%	-8.0%
LGW	50,400	45,600	59,300	53,000	34,600	34,000	-9.5%	-25.4%
LHR NWR	1,980,500	1,761,000	1,787,800	2,115,200	1,876,900	1,851,400	-11.1%	+5.1%
LTN	45,600	93,500	101,900	91,600	73,900	71,900	+105.0%	-23.1%
MAN	222,000	234,000	242,500	244,200	252,500	292,800	+5.4%	+25.1%
STN	36,000	34,800	35,900	42,100	29,000	29,100	-3.3%	-16.4%
Total (with LHR)	2,629,900	2,474,500	2,573,700	2,889,900	2,622,400	2,650,300	-5.9%	+7.1%
Total (without LHR)	649,400	713,500	785,900	774,700	745,600	798,900	+9.9%	+12.0%

Table C.6 (f): Summary of average annual 24h 55dB L_{den} population exposure (Central Scenario)

	Scenario: Central		Population Exposed		Lden 55 dB			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	48,400	52,700	65,800	64,100	71,000	76,800	+8.9%	+45.7%
EDI	11,800	15,500	11,300	10,900	9,700	10,900	+31.4%	-29.7%
GLA	56,800	44,000	50,400	45,400	33,800	35,000	-22.5%	-20.5%
LGW	12,600	13,800	15,100	13,600	10,200	10,200	+9.5%	-26.1%
LHR NWR	756,100	689,400	653,000	718,700	628,500	610,300	-8.8%	-11.5%
LTN	8,900	24,400	34,500	24,300	14,900	14,700	+174.2%	-39.8%
MAN	93,000	101,600	109,000	105,100	114,700	143,300	+9.2%	+41.0%
STN	9,800	8,700	9,000	10,800	8,300	8,600	-11.2%	-1.1%
Total (with LHR)	997,300	950,000	948,100	992,800	890,900	909,700	-4.7%	-4.2%
Total (without LHR)	241,200	260,600	295,100	274,100	262,400	299,400	+8.0%	+14.9%

Table C.6 (g): Summary of average annual 8h night 45dB L_{night} population exposure (Central Scenario)

	Scenario: Central Population Exposed Lnight 45 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	62,700	80,000	88,000	86,000	91,800	95,600	+27.6%	+19.5%
EDI	15,800	26,100	17,200	16,300	13,700	15,600	+65.2%	-40.2%
GLA	70,200	48,800	46,100	39,700	30,900	31,900	-30.5%	-34.6%
LGW	16,300	19,400	19,900	18,000	13,300	13,200	+19.0%	-32.0%
LHR NWR	703,600	725,800	680,700	719,300	672,600	673,800	+3.2%	-7.2%
LTN	14,900	54,600	60,400	49,900	34,600	33,700	+266.4%	-38.3%
MAN	130,300	147,900	145,900	146,500	156,300	180,300	+13.5%	+21.9%
STN	15,300	14,500	16,600	19,000	14,000	14,100	-5.2%	-2.8%
Total (with LHR)	1,029,100	1,117,000	1,074,800	1,094,600	1,027,200	1,058,200	+8.5%	-5.3%
Total (without LHR)	325,500	391,200	394,100	375,300	354,600	384,300	+20.2%	-1.8%

Table C.6 (h): Summary of average annual 8h night 50dB L_{night} population exposure (Central Scenario)

	Scenario: Central Population Exposed Lnight 50 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	20,700	26,300	27,900	26,700	28,500	30,100	+27.1%	+14.4%
EDI	2,900	4,600	3,900	4,000	4,000	4,200	+58.6%	-8.7%
GLA	21,100	7,700	7,000	4,900	3,300	4,500	-63.5%	-41.6%
LGW	5,000	5,200	4,600	3,900	3,300	3,700	+4.0%	-28.8%
LHR NWR	207,200	221,200	184,800	209,800	199,500	202,100	+6.8%	-8.6%
LTN	2,600	10,400	12,100	11,400	7,900	7,800	+300.0%	-25.0%
MAN	40,900	44,100	37,700	37,900	39,700	50,000	+7.8%	+13.4%
STN	4,100	4,000	4,400	4,900	4,200	4,300	-2.4%	+7.5%
Total (with LHR)	304,600	323,600	282,400	303,600	290,400	306,700	+6.2%	-5.2%
Total (without LHR)	97,400	102,500	97,500	93,800	90,900	104,600	+5.2%	+2.0%

Table C.6 (i): Summary of average summer night N60, ≥5 events population exposure (Central Scenario)

	Scenario: Central		Population Exposed		N60, ≥5 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	166,100	229,000	241,000	244,700	273,100	289,200	+37.9%	+26.3%
EDI	58,000	71,100	62,800	62,700	59,000	60,200	+22.6%	-15.3%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	55,000	93,800	72,900	72,500	59,400	61,800	+70.5%	-34.1%
LHR NWR	1,078,700	1,325,100	1,287,100	1,463,200	1,343,000	1,318,500	+22.8%	-0.5%
LTN	97,800	127,100	142,800	128,800	111,800	113,500	+30.0%	-10.7%
MAN	299,200	269,200	263,100	282,200	309,500	396,300	-10.0%	+47.2%
STN	45,900	40,100	39,500	42,400	38,300	38,900	-12.6%	-3.0%
Total (with LHR)	1,800,700	2,155,400	2,109,200	2,296,500	2,194,100	2,278,400	+19.7%	+5.7%
Total (without LHR)	722,100	830,300	822,100	833,300	851,100	959,800	+15.0%	+15.6%

Table C.6 (j): Summary of average summer night N60, ≥10 events population exposure (Central Scenario)

	Scenario: Central		Population Exposed		N60, ≥10 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	79,600	140,600	140,700	143,100	167,200	181,300	+76.6%	+28.9%
EDI	37,800	48,300	41,100	42,900	42,700	44,600	+27.8%	-7.7%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	27,500	38,200	45,400	38,100	29,500	33,600	+38.9%	-12.0%
LHR NWR	791,400	928,200	896,400	1,065,100	992,500	1,006,200	+17.3%	+8.4%
LTN	50,700	99,900	104,700	96,300	86,100	86,900	+97.0%	-13.0%
MAN	206,300	191,700	192,700	198,100	214,400	245,400	-7.1%	+28.0%
STN	22,700	26,400	25,500	28,900	23,000	23,200	+16.3%	-12.1%
Total (with LHR)	1,215,900	1,473,400	1,446,500	1,612,600	1,555,400	1,621,200	+21.2%	+10.0%
Total (without LHR)	424,500	545,100	550,100	547,500	563,000	615,000	+28.4%	+12.8%

Table C.6 (k): Summary of average summer night N65, ≥5 events population exposure (Central Scenario)

	Scenario: Central	Population Exposed	N65, ≥10 events					
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	300,500	250,600	275,400	273,000	269,400	278,400	-16.6%	+11.1%
EDI	72,800	91,100	80,100	79,600	68,700	67,600	+25.1%	-25.8%
GLA	135,400	135,100	146,100	144,900	135,300	133,500	-0.2%	-1.2%
LGW	72,300	42,600	39,100	38,400	25,300	23,900	-41.1%	-43.9%
LHR NWR	2,389,300	1,678,700	1,728,000	1,680,300	1,533,800	1,317,300	-29.7%	-21.5%
LTN	98,300	87,800	96,800	95,100	79,700	78,800	-10.7%	-10.3%
MAN	523,900	283,000	284,100	279,000	318,700	359,400	-46.0%	+27.0%
STN	52,800	39,900	48,200	47,700	32,300	32,400	-24.4%	-18.8%
Total (with LHR)	3,645,400	2,608,800	2,697,700	2,638,100	2,463,300	2,291,300	-28.4%	-12.2%
Total (without LHR)	1,256,100	930,100	969,700	957,800	929,400	974,000	-26.0%	+4.7%

Table C.6 (l): Summary of average summer night N65, ≥10 events population exposure (Central Scenario)

	Scenario: Central	Population Exposed	N65, ≥10 events					
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	225,600	197,400	224,200	220,800	222,200	231,200	-12.5%	+17.1%
EDI	61,000	69,800	66,100	63,800	56,900	56,600	+14.4%	-18.9%
GLA	116,200	119,000	127,400	125,000	114,600	113,800	+2.4%	-4.4%
LGW	39,300	30,200	25,200	24,700	20,400	20,500	-23.2%	-32.1%
LHR NWR	1,599,300	1,271,700	1,350,900	1,389,800	1,208,300	1,135,800	-20.5%	-10.7%
LTN	72,700	78,000	84,900	78,800	73,600	74,400	+7.3%	-4.6%
MAN	303,200	173,800	185,200	181,800	196,400	235,300	-42.7%	+35.4%
STN	32,300	25,100	29,700	31,100	22,100	22,000	-22.3%	-12.4%
Total (with LHR)	2,449,500	1,965,000	2,093,500	2,115,800	1,914,400	1,889,600	-19.8%	-3.8%
Total (without LHR)	850,300	693,300	742,600	726,000	706,200	753,800	-18.5%	+8.7%

Table C.6 (m): Summary of average summer day N70, ≥5 events population exposure (Central Scenario)

	Scenario: Central		Population Exposed		N70, ≥5 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	146,700	114,600	109,000	103,700	93,000	92,200	-21.9%	-19.5%
EDI	32,600	35,600	35,900	34,200	28,100	26,200	+9.2%	-26.4%
GLA	87,600	88,000	95,800	92,200	80,000	78,200	+0.5%	-11.1%
LGW	20,500	10,400	12,600	12,200	9,400	7,700	-49.3%	-26.0%
LHR NWR	917,000	680,800	712,800	617,100	519,800	438,400	-25.8%	-35.6%
LTN	20,100	21,200	25,500	23,900	21,700	21,700	+5.5%	+2.4%
MAN	145,800	102,500	90,300	63,700	74,400	81,500	-29.7%	-20.5%
STN	9,100	8,600	10,200	10,500	9,900	10,000	-5.5%	+16.3%
Total (with LHR)	1,379,300	1,061,800	1,092,100	957,300	836,400	755,900	-23.0%	-28.8%
Total (without LHR)	462,300	381,000	379,300	340,200	316,600	317,500	-17.6%	-16.7%

Table C.6 (n): Summary of average summer day N70, ≥10 events population exposure (Central Scenario)

	Scenario: Central		Population Exposed		N70, ≥10 events			
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	104,300	94,200	87,300	84,700	72,100	68,600	-9.7%	-27.2%
EDI	26,500	27,800	27,400	24,700	18,500	18,800	+4.9%	-32.4%
GLA	72,700	72,700	80,000	76,900	67,400	66,800	+0.0%	-8.1%
LGW	14,200	7,500	9,200	7,300	4,900	4,900	-47.2%	-34.7%
LHR NWR	632,300	538,200	564,300	496,100	407,400	371,700	-14.9%	-30.9%
LTN	12,700	19,900	23,600	21,300	19,400	20,100	+56.7%	+1.0%
MAN	105,000	70,600	65,200	49,300	60,100	62,100	-32.8%	-12.0%
STN	7,000	7,800	7,900	8,300	6,200	6,100	+11.4%	-21.8%
Total (with LHR)	974,600	838,700	864,800	768,500	656,100	619,100	-13.9%	-26.2%
Total (without LHR)	342,300	300,600	300,500	272,400	248,700	247,400	-12.2%	-17.7%

Table C.7 (a): Average Individual Exposure (AIE), number of events above 70dB L_{Amax} for areas experiencing at least 5 events per average summer day High Scenario

	Scenario: HIGH, AIE (70) , ≥5 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	36.0	52.0	62.0	66.1	80.8	82.8	+44.4%	+59.1%
EDI	39.0	46.0	41.0	41.6	40.6	47.9	+17.9%	+4.1%
GLA	52.0	55.0	61.1	57.3	54.9	58.4	+5.8%	+6.3%
LGW	43.0	61.1	67.1	67.1	72.5	76.1	+42.0%	+24.6%
LHR NWR	47.5	70.1	70.8	95.3	96.3	111.7	+47.7%	+59.3%
LTN	41.5	82.5	75.2	71.8	66.1	67.4	+99.0%	-18.3%
MAN	56.6	74.8	81.1	83.8	113.0	119.7	+32.1%	+60.1%
STN	60.8	85.4	69.7	72.3	49.1	50.1	+40.6%	-41.3%
Average (with LHR)	47.0	65.9	66.0	69.4	71.7	76.8	+40.0%	+16.6%
Average (without LHR)	47.0	65.2	65.3	65.7	68.2	71.8	+38.9%	+10.0%

Table C.7 (b): Average Individual Exposure (AIE), number of events above 70dB L_{Amax} for areas experiencing at least 10 events per average summer day High Scenario

	Scenario: HIGH, AIE (70) , ≥10 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	48.0	61.0	75.0	80.3	99.5	113.9	+27.1%	+86.7%
EDI	46.0	56.0	51.1	52.8	55.5	62.6	+21.7%	+11.8%
GLA	61.0	65.0	71.3	67.4	63.9	67.1	+6.6%	+3.2%
LGW	61.0	82.1	79.0	75.6	80.5	81.4	+34.6%	-0.9%
LHR NWR	62.7	86.6	87.8	116.9	122.7	133.7	+38.2%	+54.4%
LTN	62.7	85.9	79.4	80.2	73.9	74.8	+37.0%	-12.9%
MAN	76.2	106.1	115.9	113.8	139.7	152.9	+39.2%	+44.1%
STN	76.5	93.4	87.1	89.9	72.9	76.7	+22.0%	-17.9%
Average (with LHR)	61.8	79.5	80.8	84.6	88.6	95.4	+28.7%	+20.0%
Average (without LHR)	61.6	78.5	79.8	80.0	83.7	89.9	+27.4%	+14.5%

Table C.7 (c): Persons Event Index (PEI) ≥5 events 70dB L_{Amax} High Scenario

	Scenario: High, PEI (70), ≥5 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	5,331,400	5,939,000	6,757,300	7,124,200	7,841,800	8,712,700	+11.4%	+46.7%
EDI	1,248,800	1,635,600	1,475,700	1,422,400	1,153,200	1,269,400	+31.0%	-22.4%
GLA	4,635,400	4,887,300	5,953,300	5,367,300	4,474,900	4,634,000	+5.4%	-5.2%
LGW	1,033,200	634,500	868,700	904,400	765,000	769,700	-38.6%	+21.3%
LHR NWR	44,814,900	47,811,900	51,134,600	58,826,800	51,067,300	52,000,300	+6.7%	+8.8%
LTN	849,100	1,719,000	1,963,000	1,752,400	1,493,500	1,570,800	+102.4%	-8.6%
MAN	8,287,300	7,689,500	8,597,900	8,724,300	9,532,900	12,570,300	-7.2%	+63.5%
STN	554,300	737,000	752,200	755,800	492,200	510,900	+33.0%	-30.7%
Total (with LHR)	66,754,500	71,053,600	77,502,800	84,877,700	76,820,800	82,038,300	+6.4%	+15.5%
Total (without LHR)	21,939,500	23,241,700	26,368,200	26,050,900	25,753,500	30,037,900	+5.9%	+29.2%

Table C.7 (d): Persons Event Index (PEI) ≥10 events 70dB L_{Amax} High Scenario

	Scenario: High, PEI (70), ≥10 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	5,038,200	5,795,100	6,604,100	6,973,700	7,693,900	8,499,500	+15.0%	+46.7%
EDI	1,204,600	1,579,700	1,415,500	1,364,200	1,087,400	1,218,200	+31.1%	-22.9%
GLA	4,527,700	4,775,100	5,838,100	5,251,000	4,383,500	4,554,000	+5.5%	-4.6%
LGW	978,000	614,700	885,500	892,600	756,100	764,900	-37.1%	+24.4%
LHR NWR	43,012,100	46,784,300	50,013,400	57,915,700	50,199,800	51,429,300	+8.8%	+9.9%
LTN	794,700	1,712,000	1,952,200	1,730,200	1,474,600	1,553,600	+115.4%	-9.3%
MAN	8,003,300	7,465,300	8,349,400	8,506,000	9,410,800	12,395,500	-6.7%	+66.0%
STN	539,600	731,200	737,200	741,500	463,200	481,600	+35.5%	-34.1%
Total (with LHR)	64,098,100	69,457,300	75,795,300	83,375,000	75,469,400	80,896,600	+8.4%	+16.5%
Total (without LHR)	21,086,000	22,673,000	25,781,900	25,459,300	25,269,600	29,467,300	+7.5%	+30.0%

Table C.8 (a): Average Individual Exposure (AIE), number of events above 70dB L_{Amax} for areas experiencing at least 5 events per average summer day Central Scenario

	Scenario: Central, AIE (70) , ≥5 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	36.0	52.0	58.9	76.5	76.5	86.7	+44.4%	+66.8%
EDI	39.0	46.0	40.2	39.9	39.6	45.3	+17.9%	-1.4%
GLA	52.0	55.0	58.9	55.8	52.4	56.2	+5.8%	+2.2%
LGW	43.0	61.1	66.9	66.8	69.8	88.2	+42.0%	+44.5%
LHR NWR	47.5	70.1	71.3	96.7	96.7	114.0	+47.7%	+62.6%
LTN	41.5	82.5	75.1	71.0	65.8	65.0	+99.0%	-21.2%
MAN	56.6	74.8	85.4	89.1	109.5	126.9	+32.1%	+69.8%
STN	60.8	85.4	60.5	64.1	49.0	50.9	+40.6%	-40.4%
Average (with LHR)	47.0	65.9	64.6	70.0	69.9	79.2	+40.0%	+20.2%
Average (without LHR)	47.0	65.2	63.7	66.2	66.1	74.2	+38.9%	+13.7%

Table C.8 (b): Average Individual Exposure (AIE), number of events above 70dB L_{Amax} for areas experiencing at least 10 events per average summer day Central Scenario

	Scenario: Central, AIE (70) , ≥10 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	48.0	61.0	71.8	95.7	95.7	112.9	+27.1%	+85.0%
EDI	46.0	56.0	50.1	51.4	55.2	59.5	+21.7%	+6.2%
GLA	61.0	65.0	68.9	65.5	61.2	64.6	+6.6%	-0.6%
LGW	61.0	82.1	87.0	103.6	116.6	132.3	+34.6%	+61.1%
LHR NWR	62.7	86.6	88.2	118.3	122.8	135.2	+38.2%	+56.1%
LTN	62.7	85.9	79.2	79.3	74.4	72.1	+37.0%	-16.1%
MAN	76.2	106.1	116.2	117.3	132.5	164.7	+39.2%	+55.3%
STN	76.5	93.4	75.0	79.4	72.8	78.1	+22.0%	-16.4%
Average (with LHR)	61.8	79.5	79.5	88.8	91.4	102.4	+28.7%	+28.8%
Average (without LHR)	61.6	78.5	78.3	84.6	86.9	97.7	+27.4%	+24.5%

Table C.8 (c): Persons Event Index (PEI) for areas experiencing at least ≥5 events 70dB L_{Amax} per average summer day Central Scenario

	Scenario: Central, PEI (70), ≥5 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	5,331,400	5,939,000	6,467,100	7,283,200	7,283,200	8,130,600	+11.4%	+36.9%
EDI	1,248,800	1,635,600	1,441,700	1,365,900	1,120,100	1,198,900	+31.0%	-26.7%
GLA	4,635,400	4,887,300	5,662,300	5,155,000	4,217,400	4,421,400	+5.4%	-9.5%
LGW	1,033,200	634,500	850,600	811,900	661,800	676,400	-38.6%	+6.6%
LHR NWR	44,814,900	47,811,900	51,075,400	59,558,200	50,524,700	50,542,000	+6.7%	+5.7%
LTN	849,100	1,719,000	1,958,600	1,732,800	1,484,900	1,514,700	+102.4%	-11.9%
MAN	8,287,300	7,689,500	7,756,100	7,681,800	8,094,000	10,357,000	-7.2%	+34.7%
STN	554,300	737,000	619,400	676,500	491,600	519,800	+33.0%	-29.5%
Total (with LHR)	66,754,500	71,053,600	75,831,100	84,265,200	73,877,700	77,360,800	+6.4%	+8.9%
Total (without LHR)	21,939,500	23,241,700	24,755,800	24,707,000	23,353,000	26,818,800	+5.9%	+15.4%

Table C.8 (c): Persons Event Index (PEI) for areas experiencing at least ≥10 events 70dB L_{Amax} per average summer day Central Scenario

	Scenario: Central, PEI (70), 10 events							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	5,038,200	5,795,100	6,313,900	7,129,700	7,129,700	7,974,800	+15.0%	+37.6%
EDI	1,204,600	1,579,700	1,381,700	1,303,700	1,050,100	1,147,900	+31.1%	-27.3%
GLA	4,527,700	4,775,100	5,546,400	5,040,200	4,124,600	4,340,900	+5.5%	-9.1%
LGW	978,000	614,700	825,200	776,700	635,200	659,400	-37.1%	+7.3%
LHR NWR	43,012,100	46,784,300	49,969,400	58,657,500	49,682,700	49,992,800	+8.8%	+6.9%
LTN	794,700	1,712,000	1,947,600	1,710,800	1,505,700	1,497,300	+115.4%	-12.5%
MAN	8,003,300	7,465,300	7,576,200	7,533,200	7,998,100	10,217,500	-6.7%	+36.9%
STN	539,600	731,200	604,400	661,400	462,600	490,400	+35.5%	-32.9%
Total (with LHR)	64,098,100	69,457,300	74,164,700	82,813,200	72,588,800	76,321,000	+8.4%	+9.9%
Total (without LHR)	21,086,000	22,673,000	24,195,300	24,155,600	22,906,200	26,328,200	+7.5%	+16.1%

Table C.9 (a): Number of people highly sleep-disturbed exposed to at least L_{night} 45dB. High Scenario

	Scenario: High			No. of people highly sleep-disturbed Lnight 45 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	4,400	5,600	6,600	6,700	6,800	7,200	+26.4%	+27.8%
EDI	1,000	1,700	1,200	1,100	900	1,100	+67.5%	-33.5%
GLA	4,800	3,100	3,100	2,700	2,100	2,200	-36.0%	-30.4%
LGW	1,100	1,300	1,400	1,400	1,000	1,000	+15.7%	-25.0%
LHR NWR	51,100	52,100	46,700	49,300	46,600	47,700	+2.1%	-8.5%
LTN	900	3,600	4,000	3,400	2,200	2,400	+287.5%	-34.2%
MAN	9,300	10,500	10,500	10,600	11,500	13,800	+13.0%	+32.4%
STN	1,100	1,000	1,400	1,400	900	900	-11.6%	-3.6%
Total (with LHR)	73,800	78,900	74,800	76,600	72,100	76,300	+6.9%	-3.3%
Total (without LHR)	22,700	26,700	28,100	27,300	25,500	28,600	+17.7%	+6.9%

Table C.9 (b): Number of people highly sleep-disturbed exposed to at least L_{night} 50dB. High Scenario

	Scenario: High			No. of people highly sleep-disturbed Lnight 50 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	1,900	2,400	2,700	2,800	2,800	3,000	+26.3%	+26.2%
EDI	300	400	400	400	400	400	+60.8%	-9.8%
GLA	1,800	600	600	500	300	400	-64.7%	-32.1%
LGW	500	500	400	400	400	400	+1.4%	-14.8%
LHR NWR	20,600	21,600	17,200	19,600	18,600	19,300	+4.8%	-10.5%
LTN	300	1,000	1,200	1,100	700	700	+246.1%	-28.3%
MAN	3,900	4,200	3,700	3,700	4,000	5,700	+6.5%	+36.2%
STN	400	400	500	500	400	400	-8.7%	+5.3%
Total (with LHR)	29,600	31,100	26,700	28,800	27,500	30,300	+4.8%	-2.4%
Total (without LHR)	9,000	9,500	9,400	9,300	9,000	11,000	+4.9%	+16.3%

Table C.9 (c): Number of people highly annoyed exposed to at least L_{den} 51dB. High Scenario

	Scenario: High			No. of people Highly annoyed Lden 51 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	13,400	14,400	18,500	19,200	21,100	22,400	+7.2%	+56.2%
EDI	3,900	4,600	4,100	4,100	3,600	3,800	+15.6%	-15.6%
GLA	11,400	9,800	11,400	10,500	9,100	9,100	-14.0%	-6.8%
LGW	3,900	4,500	4,600	4,300	3,100	3,000	+15.2%	-32.5%
LHR NWR	182,500	172,400	168,600	181,900	164,100	163,300	-5.5%	-5.3%
LTN	3,200	8,300	9,300	8,100	5,900	6,000	+161.8%	-27.3%
MAN	23,100	23,700	25,600	25,700	27,400	33,300	+3.0%	+40.4%
STN	2,700	2,500	3,500	3,700	2,400	2,500	-5.6%	-3.2%
Total (with LHR)	244,000	240,200	245,500	257,600	236,600	243,500	-1.6%	+1.4%
Total (without LHR)	61,500	67,800	76,900	75,700	72,500	80,300	+10.1%	+18.4%

Table C.9 (d): Number of people highly annoyed exposed to at least L_{den} 54dB. High Scenario

	Scenario: High			No. of people Highly annoyed Lden 54 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	9,000	9,900	12,800	13,200	14,100	15,200	+10.0%	+54.4%
EDI	2,300	3,000	2,400	2,400	2,000	2,400	+28.4%	-20.2%
GLA	9,300	7,300	8,800	7,900	6,400	6,500	-21.4%	-10.8%
LGW	2,300	2,600	2,800	2,700	2,000	1,900	+10.9%	-26.4%
LHR NWR	136,700	125,600	118,700	129,300	117,700	116,200	-8.1%	-7.5%
LTN	1,600	4,900	6,300	5,100	3,000	3,300	+217.4%	-32.3%
MAN	17,600	18,300	20,000	20,200	21,700	27,000	+3.7%	+48.1%
STN	1,700	1,600	2,200	2,300	1,400	1,400	-3.1%	-11.9%
Total (with LHR)	180,500	173,200	174,100	183,100	168,500	174,000	-4.0%	+0.5%
Total (without LHR)	43,800	47,600	55,400	53,800	50,800	57,900	+8.7%	+21.6%

Table C.10 (a): Number of people highly sleep-disturbed exposed to at least L_{night} 45dB. Central Scenario

	Scenario: Central			No. of people highly sleep-disturbed Lnight 45 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	4,400	5,600	6,200	6,000	6,400	6,600	+27.3%	+17.9%
EDI	1,000	1,700	1,100	1,100	900	1,000	+70.0%	-41.2%
GLA	4,800	3,100	2,900	2,500	1,900	2,000	-35.4%	-35.5%
LGW	1,100	1,300	1,300	1,200	900	900	+18.2%	-30.8%
LHR NWR	51,100	52,100	46,700	50,000	46,200	46,400	+2.0%	-10.9%
LTN	1,000	3,600	4,000	3,300	2,300	2,200	+273.6%	-38.9%
MAN	9,300	10,500	10,000	9,900	10,600	12,600	+12.9%	+20.0%
STN	1,100	1,000	1,100	1,300	900	1,000	-9.1%	+0.0%
Total (with LHR)	73,800	78,900	73,400	75,300	70,200	72,800	+6.9%	-7.7%
Total (without LHR)	22,700	26,700	26,700	25,300	24,000	26,400	+17.6%	-1.1%

Table C.10 (b): Number of people highly sleep-disturbed exposed to at least L_{night} 50dB. Central Scenario

	Scenario: Central			No. of people highly sleep-disturbed Lnight 50 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	1,900	2,400	2,500	2,400	2,500	2,700	+26.3%	+12.5%
EDI	300	400	400	400	400	400	+33.3%	+0.0%
GLA	1,800	600	600	400	300	400	-66.7%	-33.3%
LGW	500	500	400	400	300	300	+0.0%	-40.0%
LHR NWR	20,600	21,600	17,200	19,800	18,400	18,700	+4.9%	-13.4%
LTN	200	1,000	1,200	1,100	700	700	+333.3%	-30.0%
MAN	3,900	4,200	3,500	3,400	3,600	4,600	+7.7%	+9.5%
STN	400	400	400	400	400	400	+0.0%	+0.0%
Total (with LHR)	29,600	31,100	26,100	28,200	26,600	28,100	+5.1%	-9.6%
Total (without LHR)	9,000	9,500	8,900	8,500	8,200	9,500	+5.6%	+0.0%

Table C.10 (c): Number of people highly annoyed exposed to at least L_{den} 51dB. Central Scenario

	Scenario: Central			No. of people Highly annoyed Lden 51 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	13,400	14,400	17,600	17,500	19,700	21,200	+7.5%	+47.2%
EDI	3,900	4,600	4,000	3,900	3,500	3,700	+17.9%	-19.6%
GLA	11,400	9,800	10,900	10,100	8,600	8,700	-14.0%	-11.2%
LGW	3,900	4,500	4,500	4,000	2,700	2,700	+15.4%	-40.0%
LHR NWR	182,500	172,400	168,600	184,600	162,400	158,600	-5.5%	-8.0%
LTN	3,200	8,300	9,300	8,100	5,900	5,800	+159.4%	-30.1%
MAN	23,100	23,700	24,600	24,600	25,700	30,500	+2.6%	+28.7%
STN	2,700	2,500	2,700	3,200	2,400	2,500	-7.4%	+0.0%
Total (with LHR)	244,000	240,200	242,300	255,900	230,900	233,800	-1.6%	-2.7%
Total (without LHR)	61,500	67,800	73,700	71,300	68,500	75,100	+10.2%	+10.8%

Table C.10 (d): Number of people highly annoyed exposed to at least L_{den} 54dB. Central Scenario

	Scenario: Central			No. of people Highly annoyed Lden 54 dB				
Airports	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	9,000	9,900	12,200	11,800	12,900	14,100	+10.0%	+42.4%
EDI	2,300	3,000	2,300	2,200	1,900	2,200	+30.4%	-26.7%
GLA	9,300	7,300	8,400	7,500	6,000	6,100	-21.5%	-16.4%
LGW	2,300	2,600	2,700	2,400	1,700	1,800	+13.0%	-30.8%
LHR NWR	136,700	125,600	118,700	131,000	116,700	113,300	-8.1%	-9.8%
LTN	1,600	4,900	6,300	5,000	3,100	3,100	+206.3%	-36.7%
MAN	17,600	18,300	19,100	18,900	20,100	24,500	+4.0%	+33.9%
STN	1,700	1,600	1,700	2,100	1,400	1,500	-5.9%	-6.3%
Total (with LHR)	180,500	173,200	171,300	181,000	163,800	166,500	-4.0%	-3.9%
Total (without LHR)	43,800	47,600	52,700	50,000	47,100	53,200	+8.7%	+11.8%

Table C.11 (a) Average summer day L_{Aeq16h} 51dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			LAeq16h 51 dB	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	90,200	87,400	110,700	111,900	118,900	124,400	-3.1%	+42.3%
EDI	19,800	34,000	29,600	28,700	20,100	22,800	+71.7%	-32.9%
GLA	76,700	74,100	86,100	80,400	71,000	71,600	-3.4%	-3.4%
LGW	24,500	27,300	27,600	25,000	16,400	15,500	+11.4%	-43.2%
LHR NWR	1,167,800	1,146,000	1,076,600	1,042,400	928,200	887,900	-1.9%	-22.5%
LTN	12,300	42,400	49,500	40,800	25,000	26,500	+244.7%	-37.5%
MAN	142,800	137,000	158,700	158,900	164,200	185,800	-4.1%	+35.6%
STN	16,300	12,600	15,500	15,800	10,200	9,700	-22.7%	-23.0%
Total (with LHR)	1,550,500	1,560,800	1,554,300	1,503,900	1,354,000	1,344,200	+0.7%	-13.9%
Total (without LHR)	382,700	414,800	477,700	461,500	425,700	456,300	+8.4%	+10.0%

Table C.11 (b) Average summer day L_{Aeq16h} 54dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			LAeq16h 54 dB	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	45,700	48,100	57,200	57,000	56,500	58,200	+5.3%	+21.0%
EDI	7,500	9,800	8,000	7,600	6,200	6,500	+30.7%	-33.7%
GLA	46,400	39,400	54,200	47,500	36,400	36,800	-15.1%	-6.6%
LGW	10,400	11,100	12,100	11,300	7,400	7,400	+6.7%	-33.3%
LHR NWR	628,800	588,900	533,400	553,800	470,500	449,300	-6.3%	-23.7%
LTN	5,200	13,000	13,700	11,700	8,000	7,900	+150.0%	-39.2%
MAN	74,900	66,200	83,900	83,300	93,900	118,900	-11.6%	+79.6%
STN	6,600	5,700	6,200	6,300	4,800	4,700	-13.6%	-17.5%
Total (with LHR)	825,400	782,300	768,700	778,600	683,700	689,800	-5.2%	-11.8%
Total (without LHR)	196,700	193,400	235,200	224,800	213,300	240,500	-1.7%	+24.4%

Table C.11 (c) Average summer night L_{Aeq8h} 45dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			LAeq8h 45 dB	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	95,900	100,600	112,600	112,700	111,500	113,200	+4.9%	+12.5%
EDI	12,500	24,600	19,800	18,700	13,200	15,300	+96.8%	-37.8%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	26,200	34,600	33,100	30,600	22,800	21,700	+32.1%	-37.3%
LHR NWR	663,500	811,800	716,600	722,700	653,900	647,000	+22.4%	-20.3%
LTN	30,200	71,100	77,800	67,100	50,100	49,500	+135.4%	-30.4%
MAN	171,300	185,900	191,900	191,400	202,500	231,700	+8.5%	+24.6%
STN	17,000	14,600	20,600	20,500	12,000	11,500	-14.1%	-21.2%
Total (with LHR)	1,016,600	1,243,200	1,172,500	1,163,800	1,066,100	1,090,000	+22.3%	-12.3%
Total (without LHR)	353,100	431,400	455,800	441,100	412,200	443,000	+22.2%	+2.7%

Table C.11 (c) Average summer night L_{Aeq8h} 48dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			LAeq8h 48 dB	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	55,000	56,800	61,100	60,500	58,100	57,900	+3.3%	+1.9%
EDI	3,900	7,100	6,200	6,200	5,100	5,900	+82.1%	-16.9%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	10,800	14,300	14,800	13,800	10,500	10,200	+32.4%	-28.7%
LHR NWR	340,000	417,500	325,800	299,900	265,400	265,600	+22.8%	-36.4%
LTN	8,800	35,200	39,800	31,300	13,800	16,500	+300.0%	-53.1%
MAN	96,000	117,800	123,200	123,400	134,500	159,000	+22.7%	+35.0%
STN	7,300	6,800	8,700	8,700	6,500	6,300	-6.8%	-7.4%
Total (with LHR)	521,700	655,500	579,600	543,800	493,800	521,300	+25.6%	-20.5%
Total (without LHR)	181,700	237,900	253,800	244,000	228,400	255,700	+30.9%	+7.5%

Table C.11 (d) Average annual 24h L_{den} 50dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop		Population Exposure results			Lden 50 dB		
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	142,800	153,500	189,600	191,000	207,400	211,400	+7.5%	+37.7%
EDI	48,100	51,500	34,000	45,300	38,700	41,800	+7.1%	-18.8%
GLA	104,600	100,600	110,200	104,700	93,700	93,700	-3.8%	-6.9%
LGW	50,400	45,600	58,100	51,600	33,200	31,900	-9.5%	-30.0%
LHR NWR	1,980,500	1,761,000	1,691,800	1,902,100	1,655,000	1,619,300	-11.1%	-8.0%
LTN	45,600	93,500	98,000	86,900	66,300	65,200	+105.0%	-30.3%
MAN	222,000	234,000	244,300	239,100	243,600	282,500	+5.4%	+20.7%
STN	36,000	34,800	43,000	43,300	25,400	24,500	-3.3%	-29.6%
Total (with LHR)	2,629,900	2,474,500	2,468,900	2,663,900	2,363,300	2,370,300	-5.9%	-4.2%
Total (without LHR)	649,400	713,500	777,100	761,800	708,200	751,100	+9.9%	+5.3%

Table C.11 (e) Average annual 24h L_{den} 55dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop		Population Exposure results			Lden 55 dB		
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	48,400	52,700	66,300	65,800	68,700	70,900	+8.9%	+34.5%
EDI	11,800	15,500	11,300	10,600	8,800	10,500	+31.4%	-32.3%
GLA	56,800	44,000	53,200	47,400	36,500	37,000	-22.5%	-15.9%
LGW	12,600	13,800	15,200	14,200	9,800	9,400	+9.5%	-31.9%
LHR NWR	756,100	689,400	621,200	645,200	557,300	539,700	-8.8%	-21.7%
LTN	8,900	24,400	33,000	22,800	11,500	11,400	+174.2%	-53.3%
MAN	93,000	101,600	112,400	110,500	117,800	141,000	+9.2%	+38.8%
STN	9,800	8,700	11,900	12,000	7,300	7,300	-11.2%	-16.1%
Total (with LHR)	997,300	950,000	924,500	928,400	817,600	827,200	-4.7%	-12.9%
Total (without LHR)	241,200	260,600	303,400	283,200	260,400	287,500	+8.0%	+10.3%

Table C.11 (f) Average annual 8h L_{night} 45dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			Lnight 45 dB	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	62,700	80,000	90,100	89,500	88,100	90,100	+27.6%	+12.6%
EDI	15,800	26,100	17,200	16,500	12,600	15,300	+65.2%	-41.4%
GLA	70,200	48,800	48,900	42,400	33,100	33,900	-30.5%	-30.5%
LGW	16,300	19,400	19,800	18,200	13,600	12,700	+19.0%	-34.5%
LHR NWR	703,600	725,800	649,400	648,600	595,700	589,200	+3.2%	-18.8%
LTN	14,900	54,600	58,000	47,500	29,900	30,600	+266.4%	-44.0%
MAN	130,300	147,900	149,000	146,600	153,900	174,500	+13.5%	+18.0%
STN	15,300	14,500	19,400	19,600	12,100	11,700	-5.2%	-19.3%
Total (with LHR)	1,029,100	1,117,000	1,051,800	1,028,900	938,900	958,000	+8.5%	-14.2%
Total (without LHR)	325,500	391,200	402,400	380,300	343,200	368,800	+20.2%	-5.7%

Table C.11 (g) Average annual 8h L_{night} 50dB population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			Lnight 50 dB	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	20,700	26,300	28,800	28,700	28,000	29,300	+27.1%	+11.4%
EDI	2,900	4,600	3,600	3,600	3,400	3,500	+58.6%	-23.9%
GLA	21,100	7,700	8,000	6,100	4,300	5,500	-63.5%	-28.6%
LGW	5,000	5,200	4,600	4,500	4,000	4,000	+4.0%	-23.1%
LHR NWR	207,200	221,200	173,900	188,900	174,000	175,100	+6.8%	-20.8%
LTN	2,600	10,400	10,800	9,400	6,500	6,400	+300.0%	-38.5%
MAN	40,900	44,100	39,200	38,500	40,700	55,700	+7.8%	+26.3%
STN	4,100	4,000	4,900	5,000	3,700	3,700	-2.4%	-7.5%
Total (with LHR)	304,600	323,600	273,900	284,600	264,600	283,300	+6.2%	-12.5%
Total (without LHR)	97,400	102,500	100,100	95,700	90,600	108,200	+5.2%	+5.6%

Table C.11 (h) Average summer night N60, ≥5 events population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			N60, ≥5 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	166,100	229,000	236,500	242,500	252,400	257,800	+37.9%	+12.6%
EDI	58,000	71,100	61,600	61,100	56,000	56,800	+22.6%	-20.1%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	55,000	93,800	70,500	68,500	56,900	56,700	+70.5%	-39.6%
LHR NWR	1,078,700	1,325,100	1,221,900	1,327,700	1,179,900	1,133,600	+22.8%	-14.5%
LTN	97,800	127,100	137,000	121,200	101,300	101,600	+30.0%	-20.1%
MAN	299,200	269,200	273,900	273,300	300,000	389,900	-10.0%	+44.8%
STN	45,900	40,100	43,700	43,000	33,300	32,900	-12.6%	-18.0%
Total (with LHR)	1,800,700	2,155,400	2,045,300	2,137,200	1,979,800	2,029,300	+19.7%	-5.9%
Total (without LHR)	722,100	830,300	823,300	809,500	800,000	895,700	+15.0%	+7.9%

Table C.11 (i) Average summer night N60, ≥10 events population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			N60, ≥10 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	79,600	140,600	140,800	143,500	160,100	157,900	+76.6%	+12.3%
EDI	37,800	48,300	40,700	42,100	40,700	42,900	+27.8%	-11.2%
GLA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LGW	27,500	38,200	43,900	37,400	31,100	32,700	+38.9%	-14.4%
LHR NWR	791,400	928,200	848,500	960,000	871,600	863,300	+17.3%	-7.0%
LTN	50,700	99,900	100,400	91,200	78,500	77,800	+97.0%	-22.1%
MAN	206,300	191,700	191,500	191,600	203,500	232,000	-7.1%	+21.0%
STN	22,700	26,400	28,600	28,400	19,900	19,200	+16.3%	-27.3%
Total (with LHR)	1,215,900	1,473,400	1,394,400	1,494,200	1,405,400	1,425,800	+21.2%	-3.2%
Total (without LHR)	424,500	545,100	545,800	534,200	533,800	562,600	+28.4%	+3.2%

Table C.11 (j) Average summer day N65, ≥5 events population exposure using 2016 population database. High scenario.

	Scenario: High with 2016_Pop			Population Exposure results			N65, ≥5 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	300,500	250,600	268,800	261,500	249,200	252,900	-16.6%	+0.9%
EDI	72,800	91,100	78,800	76,400	31,100	63,300	+25.1%	-30.5%
GLA	135,400	135,100	145,800	143,800	134,500	132,100	-0.2%	-2.2%
LGW	72,300	42,600	39,600	39,500	25,700	23,400	-41.1%	-45.1%
LHR NWR	2,389,300	1,678,700	1,653,100	1,536,600	1,362,700	1,148,200	-29.7%	-31.6%
LTN	98,300	87,800	93,100	89,700	71,700	70,000	-10.7%	-20.3%
MAN	523,900	283,000	284,000	271,100	303,500	345,700	-46.0%	+22.2%
STN	52,800	39,900	51,600	46,200	28,000	27,000	-24.4%	-32.3%
Total (with LHR)	3,645,400	2,608,800	2,614,700	2,464,800	2,206,200	2,062,600	-28.4%	-20.9%
Total (without LHR)	1,256,100	930,100	961,600	928,200	843,500	914,400	-26.0%	-1.7%

Table C.11 (k) Average summer day N65, ≥10 events population exposure using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			N65, ≥10 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	225,600	197,400	217,200	214,500	205,800	207,800	-12.5%	+5.3%
EDI	61,000	69,800	65,100	61,800	16,500	53,300	+14.4%	-23.6%
GLA	116,200	119,000	128,700	124,100	113,900	112,600	+2.4%	-5.4%
LGW	39,300	30,200	32,100	33,900	20,400	19,900	-23.2%	-34.1%
LHR NWR	1,599,300	1,271,700	1,288,900	1,271,400	1,069,300	999,700	-20.5%	-21.4%
LTN	72,700	78,000	82,000	74,100	66,700	66,000	+7.3%	-15.4%
MAN	303,200	173,800	187,600	176,500	189,900	228,300	-42.7%	+31.4%
STN	32,300	25,100	33,100	29,800	19,100	18,200	-22.3%	-27.5%
Total (with LHR)	2,449,500	1,965,000	2,034,700	1,986,100	1,701,600	1,705,900	-19.8%	-13.2%
Total (without LHR)	850,300	693,300	745,800	714,700	632,300	706,200	-18.5%	+1.9%

Table C.11 (l) Average summer day N70, ≥5 events population exposure using 2016 population database. High scenario.

	Scenario: High with 2016_Pop			Population Exposure results			N70, ≥5 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	146,700	114,600	105,000	100,000	86,600	90,400	-21.9%	-21.1%
EDI	32,600	35,600	34,900	32,300	26,200	24,200	+9.2%	-32.0%
GLA	87,600	88,000	96,100	91,200	79,800	77,800	+0.5%	-11.6%
LGW	20,500	10,400	12,700	12,600	9,500	8,900	-49.3%	-14.4%
LHR NWR	917,000	680,800	681,700	557,100	458,200	388,600	-25.8%	-42.9%
LTN	20,100	21,200	24,100	21,300	17,800	17,200	+5.5%	-18.9%
MAN	145,800	102,500	103,000	94,000	78,800	95,000	-29.7%	-7.3%
STN	9,100	8,600	9,900	9,600	8,600	8,400	-5.5%	-2.3%
Total (with LHR)	1,379,300	1,061,800	1,067,400	918,100	765,400	710,500	-23.0%	-33.1%
Total (without LHR)	462,300	381,000	385,700	361,000	307,200	321,900	-17.6%	-15.5%

Table C.11 (m) Average summer day N70, ≥10 events population exposure using 2016 population database. High scenario.

	Scenario: High with 2016_Pop			Population Exposure results			N70, ≥10 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	104,300	94,200	84,700	81,200	68,500	63,600	-9.7%	-32.5%
EDI	26,500	27,800	27,400	24,100	17,600	17,600	+4.9%	-36.7%
GLA	72,700	72,700	81,800	76,900	67,500	66,800	+0.0%	-8.1%
LGW	14,200	7,500	10,500	10,800	8,400	8,100	-47.2%	+8.0%
LHR NWR	632,300	538,200	537,700	446,100	354,500	322,000	-14.9%	-40.2%
LTN	12,700	19,900	22,100	18,300	15,600	15,700	+56.7%	-21.1%
MAN	105,000	70,600	70,800	66,800	62,500	73,200	-32.8%	+3.7%
STN	7,000	7,800	7,900	7,600	5,500	5,300	+11.4%	-32.1%
Total (with LHR)	974,600	838,700	842,900	731,900	600,100	572,300	-13.9%	-31.8%
Total (without LHR)	342,300	300,600	305,200	285,700	245,600	250,300	-12.2%	-16.7%

Table C.12 (a): Average Individual Exposure (AIE), number of events above 70dB L_{Amax} for areas experiencing at least 5 events per average summer day using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			AIE(70), ≥5 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	36.0	52.0	61.8	65.9	80.1	82.1	+44.4%	+57.9%
EDI	39.0	46.0	40.7	40.7	38.2	45.0	+17.9%	-2.2%
GLA	52.0	55.0	61.9	58.3	55.8	59.5	+5.8%	+8.2%
LGW	43.0	61.1	67.0	64.8	69.0	67.0	+42.0%	+9.7%
LHR NWR	47.5	70.1	70.5	97.5	98.5	114.3	+47.7%	+63.1%
LTN	41.5	82.5	72.7	67.5	63.3	64.2	+99.0%	-22.2%
MAN	56.6	74.8	81.9	89.0	114.7	121.8	+32.1%	+63.0%
STN	60.8	85.4	73.9	72.8	50.9	51.9	+40.6%	-39.3%
Average (with LHR)	47.0	65.9	66.3	69.6	71.3	75.7	+40.0%	+15.0%
Average (without LHR)	47.0	65.2	65.7	65.6	67.4	70.2	+38.9%	+7.6%

Table C.12 (b): Average Individual Exposure (AIE), number of events above 70dB L_{Amax} for areas experiencing at least 10 events per average summer day using 2016 population database. High scenario

	Scenario: High with 2016_Pop			Population Exposure results			AIE(70), ≥10 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	48.0	61.0	74.9	79.7	98.6	112.7	+27.1%	+84.8%
EDI	46.0	56.0	50.3	51.3	52.5	58.8	+21.7%	+5.0%
GLA	61.0	65.0	71.7	68.1	64.8	68.3	+6.6%	+5.1%
LGW	61.0	82.1	79.3	73.7	76.9	79.3	+34.6%	-3.4%
LHR NWR	62.7	86.6	87.4	119.9	125.8	137.2	+38.2%	+58.5%
LTN	62.7	85.9	77.2	75.9	71.8	73.3	+37.0%	-14.7%
MAN	76.2	106.1	116.4	123.0	141.3	155.3	+39.2%	+46.4%
STN	76.5	93.4	90.3	87.5	73.6	78.0	+22.0%	-16.5%
Average (with LHR)	61.8	79.5	80.9	84.9	88.2	95.4	+28.7%	+19.9%
Average (without LHR)	61.6	78.5	80.0	79.9	82.8	89.4	+27.4%	+13.9%

Table C.13 (a): Persons Event Index (PEI) above 70dB L_{Amax} for areas experiencing at least 5 events per average summer day. High Scenario 2016 population database

	Scenario: High with 2016_Pop			Population Exposure results			PEI(70), ≥5 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	5,331,400	5,939,000	6,479,100	6,634,500	6,967,600	7,544,600	+11.4%	+27.0%
EDI	1,248,800	1,635,600	1,416,400	1,313,100	1,002,800	1,091,200	+31.0%	-33.3%
GLA	4,635,400	4,887,300	5,973,400	5,345,200	4,463,000	4,642,300	+5.4%	-5.0%
LGW	1,033,200	634,500	855,900	813,000	657,300	649,900	-38.6%	+2.4%
LHR NWR	44,814,900	47,811,900	48,187,900	54,457,000	45,289,700	44,804,100	+6.7%	-6.3%
LTN	849,100	1,719,000	1,782,800	1,477,100	1,182,100	1,216,400	+102.4%	-29.2%
MAN	8,287,300	7,689,500	8,492,100	8,397,600	9,046,800	11,642,100	-7.2%	+51.4%
STN	554,300	737,000	729,500	697,400	439,600	443,900	+33.0%	-39.8%
Total (with LHR)	66,754,500	71,053,600	73,917,200	79,134,900	69,048,800	72,034,600	+6.4%	+1.4%
Total (without LHR)	21,939,500	23,241,700	25,729,300	24,677,900	23,759,100	27,230,500	+5.9%	+17.2%

Table C.13 (b): Persons Event Index (PEI) above 70dB L_{Amax} for areas experiencing at least 10 events per average summer day. High Scenario 2016 population database

	Scenario: High with 2016_Pop			Population Exposure results			PEI(70), ≥10 events	
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	5,038,200	5,795,100	6,335,400	6,495,500	6,834,400	7,358,900	+15.0%	+27.0%
EDI	1,204,600	1,579,700	1,359,900	1,258,500	940,300	1,044,000	+31.1%	-33.9%
GLA	4,527,700	4,775,100	5,864,200	5,236,400	4,373,900	4,562,600	+5.5%	-4.4%
LGW	978,000	614,700	839,100	800,800	649,100	638,400	-37.1%	+3.9%
LHR NWR	43,012,100	46,784,300	47,124,000	53,626,000	44,534,200	44,316,300	+8.8%	-5.3%
LTN	794,700	1,712,000	1,771,400	1,455,700	1,164,600	1,198,200	+115.4%	-30.0%
MAN	8,003,300	7,465,300	8,252,400	8,200,200	8,934,300	11,484,900	-6.7%	+53.8%
STN	539,600	731,200	716,000	685,100	416,000	420,000	+35.5%	-42.6%
Total (with LHR)	64,098,100	69,457,300	72,262,500	77,758,200	67,846,700	71,023,400	+8.4%	+2.3%
Total (without LHR)	21,086,000	22,673,000	25,138,500	24,132,200	23,312,500	26,707,100	+7.5%	+17.8%

Table C.14 (a): Number of people highly sleep disturbed exposed to at least 45dB L_{night}. High Scenario 2016 population database

	Scenario: High with 2016_Pop			No. of people highly sleep-disturbed Lnight 45 dB				
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	4,400	5,600	6,300	6,300	6,100	6,300	+26.4%	+11.9%
EDI	1,000	1,700	1,100	1,100	800	1,000	+67.5%	-41.0%
GLA	4,800	3,100	3,100	2,700	2,100	2,200	-36.0%	-29.8%
LGW	1,100	1,300	1,300	1,400	900	900	+15.7%	-34.2%
LHR NWR	51,100	52,100	44,400	45,100	41,000	34,000	+2.1%	-34.8%
LTN	1,000	3,600	3,800	3,100	1,900	2,000	+273.6%	-45.0%
MAN	9,300	10,500	10,300	10,100	10,700	12,600	+13.0%	+20.5%
STN	1,100	1,000	1,300	1,300	800	800	-11.6%	-18.3%
Total (with LHR)	73,800	78,900	71,800	71,000	64,400	59,700	+6.9%	-24.3%
Total (without LHR)	22,700	26,700	27,300	25,900	23,400	25,700	+17.5%	-4.0%

Table C.14 (b): Number of people highly sleep disturbed exposed to at least 50dB L_{night}. High Scenario 2016 population database

	Scenario: High with 2016_Pop			No. of people highly sleep-disturbed Lnight 50 dB				
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	1,900	2,400	2,600	2,600	2,500	2,600	+26.3%	+9.8%
EDI	300	400	300	300	300	300	+60.8%	-26.4%
GLA	1,800	600	700	500	400	500	-64.7%	-28.5%
LGW	500	500	400	400	400	300	+1.4%	-27.4%
LHR NWR	20,600	21,600	16,200	17,900	16,200	16,600	+4.8%	-23.3%
LTN	200	1,000	1,100	900	600	600	+333.1%	-42.5%
MAN	3,900	4,200	3,600	3,600	3,800	5,200	+6.5%	+25.3%
STN	400	400	400	400	300	300	-8.7%	-8.8%
Total (with LHR)	29,600	31,100	25,300	26,600	24,400	26,400	+5.0%	-14.9%
Total (without LHR)	9,000	9,500	9,100	8,700	8,200	9,900	+5.6%	+4.2%

Table C.15 (a): Number of people highly annoyed exposed to at least 51dB L_{den}. High Scenario 2016 population database

	Scenario: High with 2016_Pop No. of people highly annoyed Lden 51 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	13,400	14,400	17,800	18,000	18,800	19,600	+7.2%	+36.3%
EDI	3,900	4,600	3,900	3,800	3,200	3,500	+15.6%	-23.5%
GLA	11,400	9,800	11,400	10,400	8,900	9,000	-14.0%	-7.9%
LGW	3,900	4,500	4,400	4,000	2,700	2,600	+15.2%	-41.1%
LHR NWR	182,500	172,400	159,900	165,700	143,500	131,200	-5.5%	-23.9%
LTN	3,200	8,300	8,900	13,400	5,200	5,200	+161.8%	-37.4%
MAN	23,100	23,700	25,100	24,600	25,500	30,300	+3.0%	+27.6%
STN	2,700	2,500	3,300	3,300	2,100	2,100	-5.6%	-18.2%
Total (with LHR)	244,000	240,200	234,600	243,200	210,100	203,500	-1.6%	-15.3%
Total (without LHR)	61,500	67,800	74,800	77,500	66,600	72,300	+10.1%	+6.7%

Table C.15 (b): Number of people highly annoyed exposed to at least 54dB L_{den}. High Scenario 2016 population database

	Scenario: High with 2016_Pop No. of people highly annoyed Lden 54 dB							
Airport	2006	2016	2025	2030	2040	2050	% change 2006-2016	% change 2016-2050
BHX	9,000	9,900	12,400	12,400	12,700	13,300	+10.0%	+35.2%
EDI	2,300	3,000	2,300	2,200	1,800	2,100	+28.4%	-29.7%
GLA	9,300	7,300	8,900	7,900	6,400	6,500	-21.4%	-11.2%
LGW	2,300	2,600	2,700	2,500	1,800	1,700	+10.9%	-35.4%
LHR NWR	136,700	125,600	112,800	117,800	102,900	88,900	-8.1%	-29.2%
LTN	1,600	4,900	6,000	10,500	2,500	2,700	+217.4%	-44.8%
MAN	17,600	18,300	19,700	19,400	20,300	24,600	+3.7%	+34.9%
STN	1,700	1,600	2,100	2,100	1,300	1,200	-3.1%	-25.1%
Total (with LHR)	180,500	173,200	166,800	174,800	149,700	141,100	-4.0%	-18.5%
Total (without LHR)	43,800	47,600	54,000	57,000	46,700	52,200	+8.7%	+9.6%

APPENDIX D

Noise forecast results excluding Heathrow

Table D.1: Summary of noise metric results (excluding LHR NWR), Scenario: HIGH

	Scenario: High	Summary excluding LHR NWR							
KPI type	**Period**	**Threshold**	**2006**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Traffic	Average summer day 16h ATMs	-	3,101.5	3,028.6	3,201.6	3,340.0	3,647.2	3,962.4	+30.8%
	Average summer night 8h ATMs	-	266.7	310.6	332.4	353.5	522.6	565.5	+29.2%
Noise emission	Average summer day 16h QC	-	1,566.7	1,491.5	1,519.6	1,437.8	1,062.4	1,115.9	-25.2%
	Average summer night 8h QC	-	210.4	219.3	209.1	199.2	148.4	156.9	-28.4%
Area exposure	Average summer day LAeq16h	>54 dB	309.9	305.8	330.6	315.6	262.9	274.7	-10.2%
	Average summer night LAeq8h	>48 dB	305.1	357.9	367.3	354.6	305.2	319.2	-10.8%
	Average annual 24h Lden	>55 dB	371.0	377.0	407.4	388.8	327.4	341.5	-9.4%
	Average Annual 8h Lnight	>50 dB	183.6	182.7	186.5	177.8	146.4	153.9	-15.7%
Population exposure	Average summer day LAeq16h	>54 dB	196,700	193,400	241,300	236,700	231,200	265,900	+37.5%
	Average summer night LAeq8h	>48 dB	181,700	237,900	262,000	258,300	250,800	287,000	+20.6%
	Average annual 24h Lden	>55 dB	241,200	260,600	310,800	298,100	283,400	319,300	+22.5%
	Average Annual 8h Lnight	>50 dB	97,400	102,500	103,100	102,000	98,900	120,800	+17.9%
	Average summer night 8h N60	≥10 events	424,500	545,100	564,400	568,300	178,900	181,100	+15.7%
	Average summer day 16h N65	≥10 events	850,300	693,300	766,400	754,400	726,400	781,200	+12.7%
	Average summer day 16h N70	≥10 events	342,300	300,600	312,300	300,600	265,800	275,100	-8.5%
	Average Individual Exposure (70)	≥10 events	431.4	549.5	564.4	574.0	610.5	653.0	+18.8%
	Person Events Index (70)	≥10 events	21,086,000	22,673,000	25,525,000	25,473,900	25,242,100	29,436,800	+29.8%
Noise impact	No. of people highly sleep-disturbed Average Annual 8h Lnight	>45 dB	22,700	26,700	28,100	27,300	25,500	28,600	+6.9%
	No. of people highly annoyed Average annual 24h Lden	>54 dB	43,800	47,600	55,400	53,800	50,800	57,900	+21.6%

Table D.2: Summary of noise metric results (excluding LHR NWR), Scenario: Central

	Scenario: Central Summary excluding LHR NWR								
KPI type	**Period**	**Threshold**	**2006**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Traffic	Average summer day 16h ATMs	-	3,101.5	3,028.6	3,090.0	3,216.4	3,589.7	3,881.9	+28.2%
	Average summer night 8h ATMs	-	383.4	437.6	423.6	439.1	488.7	527.1	+20.4%
Noise emission	Average summer day 16h QC	-	1,566.7	1,491.5	1,427.7	1,340.1	990.6	1,031.3	-30.9%
	Average summer night 8h QC	-	210.4	219.3	196.5	186.0	139.9	146.5	-33.2%
Area exposure	Average summer day LAeq16h	>54	309.9	305.8	313.3	297.6	250.6	260.1	-14.9%
	Average summer night LAeq8h	>48	305.1	357.9	351.9	336.5	293.7	303.6	-15.2%
	Average annual 24h Lden	>55	371.0	377.0	385.5	367.3	313.8	324.5	-13.9%
	Average Annual 8h Lnight	>50	183.6	182.7	175.7	168.6	140.9	146.1	-20.0%
Population exposure	Average summer day LAeq16h	>54	196,700	193,400	231,100	217,000	211,000	247,200	+27.8%
	Average summer night LAeq8h	>48	181,700	237,900	253,500	245,900	238,600	269,100	+13.1%
	Average annual 24h Lden	>55	241,200	260,600	295,100	274,100	262,400	299,400	+14.9%
	Average Annual 8h Lnight	>50	97,400	102,500	97,500	93,800	90,900	104,600	+2.1%
	Average summer night 8h N60	>10 events	424,500	545,100	550,100	547,500	563,000	615,000	+12.8%
	Average summer day 16h N65	>10 events	850,300	693,300	742,600	726,000	706,200	753,800	+8.7%
	Average summer day 16h N70	>10 events	342,300	300,600	300,500	272,400	248,700	247,400	-17.7%
	Average Individual Exposure (70)	>10 events	431.4	549.5	555.4	576.4	616.0	693.0	+26.1%
	Person Events Index (70)	>10 events	21,086,000	22,673,000	24,090,900	23,351,100	22,856,000	26,295,100	+16.0%
Noise impact	No. of people highly sleep-disturbed Average Annual 8h Lnight	>45dB Lnight	22,700	26,700	26,700	25,300	24,000	26,400	-1.1%
	No. of people Highly annoyed Average annual 24h Lden	>54 dB Lden	43,800	47,600	52,700	50,000	47,100	53,200	+11.8%

Table D.3: Summary of noise metric results (excluding LHR NWR), Scenario: High with no population growth

	Scenario: High with no population growth	Summary excluding LHR NWR						
KPI type	**Period**	**Threshold**	**2006**	**2016**	**2025**	**2030**	**2040**	**2050**	**% change 2016-2050**
Traffic	Average summer day 16h ATMs	-	3,101.5	3,028.6	3,201.6	3,340.0	3,647.2	3,962.4	+30.8%
	Average summer night 8h ATMs	-	383.4	437.6	463.0	484.0	522.6	565.5	+29.2%
Noise emission	Average summer day 16h QC	-	1,566.7	1,491.5	1,519.6	1,437.8	1,062.4	1,115.9	-25.2%
	Average summer night 8h QC	-	210.4	219.3	209.1	199.2	148.4	156.9	-28.4%
Area exposure	Average summer day LAeq16h	>54	309.9	305.8	330.6	315.6	262.9	274.7	-10.2%
	Average summer night LAeq8h	>48	305.1	357.9	367.3	354.6	305.2	319.2	-10.8%
	Average annual 24h Lden	>55	371.0	377.0	407.4	388.8	327.4	341.5	-9.4%
	Average Annual 8h Lnight	>50	183.6	182.7	186.5	177.8	146.4	153.9	-15.7%
Population exposure	Average summer day LAeq16h	>54	196,700	193,400	235,200	224,800	213,300	240,500	+24.4%
	Average summer night LAeq8h	>48	181,700	237,900	253,800	244,000	228,400	255,700	+7.5%
	Average annual 24h Lden	>55	241,200	260,600	303,400	283,200	260,400	287,500	+10.3%
	Average Annual 8h Lnight	>50	97,400	102,500	100,100	95,700	90,600	108,200	+5.6%
	Average summer night 8h N60	>10 events	424,500	545,100	545,800	534,200	533,800	562,600	+3.2%
	Average summer day 16h N65	>10 events	850,300	693,300	745,800	714,700	632,300	706,200	+1.9%
	Average summer day 16h N70	>10 events	342,300	300,600	305,200	285,700	245,600	250,300	-16.7%
	Average Individual Exposure (70)	>10 events	431.4	549.5	560.1	559.2	579.5	625.8	+13.9%
	Person Events Index (70)	>10 events	21,086,000	22,673,000	25,138,500	24,132,200	23,312,500	26,707,100	+17.8%
Noise impact	No. of people highly sleep-disturbed Average Annual 8h Lnight	>45dB Lnight	22,700	26,700	27,300	26,000	23,400	25,700	-4.0%
	No. of people Highly annoyed (daytime) Average annual 24h Lden	>54 dB Lden	43,200	47,600	54,000	51,300	46,700	52,200	+9.6%

Environmental Research and Consultancy Department

Environmental charging – Review of impact of noise and NOx landing charges

CAP 1119

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Environmental Research and Consultancy Department

CAP 1119

Environmental charging – Review of impact of noise and NOx landing charges

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Contents

Summary

This review has been prepared to provide information in relation to the Department for Transport's (DfT) Aviation Policy Framework (APF) and new Night Noise Restrictions at Heathrow, Gatwick and Stansted, and to meet an objective of the Civil Aviation Authority's (CAA) Environmental Strategy.

Noise-related and NOx emissions-related landing charging schemes have been reviewed for the airports designated by the Secretary of State for noise management, and three non-designated UK airports for comparison. Historical charging data has been obtained covering the last twelve years.

Background information is presented on how environmental charges should be applied, including the governing legislation and parameters used to set the charges. An analysis of how they are actually applied in practice, and then any possible effects arising due to the charges is presented. In light of this, issues that should be considered when setting new charging schemes and developing proposals for new policy options are also explored.

The main finding is that although differential environmental landing charges have some incentive effects but they are unlikely to be the main financial driver for using quieter and less-polluting aircraft. More effective charging schemes could be developed which drive improvements through the setting of more appropriate charge differentials, and by earlier introduction of the higher charges for categories of aircraft that exhibit poor noise and NOx performance relative to emerging standards.

Under the CAA's current price regulation of Heathrow, Gatwick and Stansted, increases in environmental landing charges would have to be counter-balanced by decreases in other airport charges. As noise and emissions-related landing charges are relatively low compared to per-passenger charges there could be scope to do this.

However, there is a possibility that increasing charges significantly above current rates would become operating restrictions before driving fleet changes. Options to increase incentives may therefore be restricted to increasing differentials rather than absolute charges, while addressing potential trade-offs with other environmental and economic factors, and factors relating to consumer choice and experience.

The study concludes by highlighting a number of principles which we consider to constitute good practice in the setting of airport noise and emissions charges:

a) Noise charging categories should be based on ICAO certification data, namely the margin to Chapter 3, to incentivise best-in-class.

b) Noise charging categories should of equal width, typically 5 EPNdB, or narrower, to ensure adequate differentiation of noise performance.

c) The noise charging categories used at a given airport should cover the full range of aircraft in operation at the airport. This range should be reviewed periodically and modified as appropriate.

d) Noise charges for operations occurring at night should be greater than those that occur during the day.

e) Where noise-related charge differentials occur depending on the time of day of an operation, the scheduled time of the operation should be used as oppose to the actual time. Penalties may be used to disincentivise operations scheduled to occur on the cusp of the night period that regularly fall into the night period.

f) There should be a clear distinction between noise-related landing charges and any non-noise-related charges, e.g. demand-related charges.

g) Charging schemes should ideally be harmonised across airports within the UK. Aircraft should be treated similarly from one airport to another, even if the charges at each airport are different.

SECTION 1

Purpose and scope

This review aims to provide information relating to the Department for Transport's (DfT) Aviation Policy Framework (APF) and new Night Noise Restrictions at Heathrow, Gatwick and Stansted, and to meet an objective of the Civil Aviation Authority's (CAA) Environmental Strategy.

In the Aviation Policy Framework[1] the Government recognises that 'the acceptability of any growth in aviation depends to a large extent on the industry tackling its noise impact'. It accepts, however, 'that it is neither reasonable nor realistic for such actions to impose unlimited costs on industry. Instead, efforts should be proportionate to the extent of the noise problem and numbers of people affected'.

As part of the range of options available for reducing noise, the Government states that 'airports should consider using differential landing charges to incentivise quieter aircraft'. Consequently, it has asked the CAA to investigate the use of differential landing fees in order to ensure that airports and airlines are better incentivised to use aircraft that are best in class, and to ensure that the cost of noise disturbance, particularly at night, is sufficiently reflected in these fees.

The next Night Noise Restrictions regime is due to come into force in 2014. In line with the Government's aspirations as presented in the APF, these may cause, or at least need to reflect, changes to penalties, landing charges and monitoring arrangements.

The CAA has published its environmental strategy (CAA and the Environment) which sets out a work programme to ensure that the CAA takes a coordinated and consistent approach to addressing the importance of environmental issues. One area of the work programme (IM5) involves working with Government and stakeholders to identify how noise and emissions (principally oxides of nitrogen, NOx) related landing charges may incentivise the introduction of new quieter and cleaner aircraft technology.

This paper has been prepared in response to all of the above, beginning with sections 2 to 4 which address noise charging, followed by sections 5 to 7 which address emissions charging (where emissions refers specifically to NOx emissions which affect local air quality). These sections cover background information on how

1 Aviation Policy Framework, Department for Transport, March 2013

environmental charges should be applied, a review of how they are actually applied in practice, and any possible effects arising due to the charges. Issues that should be considered when setting new charging schemes and developing proposals for new policy options are explored in section 8. Conclusions are presented in section 9, including a list of principles which we consider to constitute good practice in the setting of airport noise and emissions charges.

Noise-related and emissions-related charging schemes have been reviewed for the airports designated by the Secretary of State for noise management, i.e. Heathrow (LHR), Gatwick (LGW) and Stansted (STN), as these are of particular interest to the DfT. Charging schemes for Manchester (MAN), East Midlands (EMA) and Birmingham (BHX) have also been assessed for comparison, at DfT's request, since these are also among the busiest airports in the UK. Historical charging data has been obtained covering the last twelve years.

SECTION 2

Principles of noise-related charging

Previous studies

Studies into noise-related landing charges have previously been published. Some examples of such studies are presented in Appendix A. One of the studies highlighted the desirability for standardisation and harmonisation of charging schemes.

The legal position

UK Law

Under subsection (1) of Section 38 of the Civil Aviation Act 2006[2], an aerodrome authority may fix its charges in respect of an aircraft or a class of aircraft by reference (among other things) to:

a) any fact or matter relevant to the amount of noise caused by the aircraft or the extent or nature of any inconvenience resulting from such noise, for the purpose of encouraging the use of quieter aircraft and reducing inconvenience from aircraft noise;

b) (paragraph relates to emissions, see section 5, page 35);

c) any fact or matter relevant to the effect of the aircraft on the level of noise or atmospheric pollution at any place in or in the vicinity of the aerodrome, for the purpose of controlling the level of noise or atmospheric pollution in or in the vicinity of the aerodrome so far as attributable to aircraft taking off or landing at the aerodrome;

d) any failure by the operator of the aircraft to secure that any noise or emissions requirements applying to the aircraft are complied with, for the purpose of promoting compliance with noise or emissions requirements.

Subsection (4) gives the Secretary of State a power to direct specific aerodrome authorities to fix their charges in exercise of any power conferred by subsection (1); and any such order may contain directions as to the manner in which those charges are to be so fixed. The fixing of charges may be implemented through setting differential landing fees.

2 Civil Aviation Act 2006, Chapter 34, Part I, Section 38: Aerodrome charges: noise and emissions

Additionally, subsection (5) says that in directing an aerodrome, the Secretary of State shall have regard to the interests of persons who live in the area in which the aerodrome is situated.

In Section 38, 'aerodrome authority' means a person owning or managing an aerodrome licensed under an Air Navigation Order; and 'charges', in relation to an aerodrome authority, means the charges the authority makes for the use of an aerodrome so licensed which is owned or managed by the authority.

The Airport Charges Regulations 2011[3] implements Airport Charges Directive (see below) in the UK. Regulation 14 identifies that 'Airport charges set by a regulated airport operator must not discriminate between airport users'. This 'does not prevent a regulated airport operator from varying airport charges for reasons relating to the public and general interest, including for reasons relating to the environment, where the criteria used for varying the charges are relevant, objective and transparent'.

European Law

The Airport Charges Directive[4] sets common principles for the levying of airport charges (not including charges for the remuneration of en route, terminal air navigation and ground-handling services, and assistance to passengers with disabilities and reduced mobility) at Community airports. This Directive shall apply to any airport located in a territory subject to the Treaty and open to commercial traffic whose annual traffic is over five million passenger movements and to the airport with the highest passenger movement in each Member State.

This Directive and the UK implementing regulations require that airports publish their airport charges. Article 3 of the Directive says that airport charges should not discriminate among airport users, but this does not mean that airports must charge everyone the same amount. Article 3 also says that charges may be modulated for issues of public and general interest, including environmental issues. Article 10 states that the level of airport charges may be differentiated according to the quality and scope of such services and their costs or any other objective and transparent justification.

Our interpretation is that the Directive is concerned with flexibility rather than firmly enunciated principle. Article 3 prohibits discrimination, but expressly does not prevent modulation of charges for issues of general interest including environmental issues, and 'the criteria used for such a modulation shall be

3 Statutory Instrument 2011 No. 2491 Transport. The Airport Charges Regulations 2011

4 Directive 2009/12/EC of the European Parliament and of the Council of 11 March 2009 on airport charges

relevant, objective and transparent'. The Directive also operates without prejudice to the right of States to apply additional regulatory measures that are not incompatible with it, including economic oversight measures, such as the approval of charging systems and/or the level of charges (Article 1(5)). The key to the ACD is consultation and transparency. This is followed through in the UK Airport Charges Regulations 2011, in Regulation 14 for example.

Article 4(1) of the 'Balanced Approach' Directive 2002/30/EC[5] states that in addition to the Balanced Approach, Member States 'may also consider economic incentives as a noise management measure'. The UK Aerodromes Regulations 2003[6] transpose this into UK law at Regulation 5(1)(b).

There is also governance on charges other than those strictly related to landing aircraft. For example, under the Single European Sky Charging Regulations for Air Navigation Services, Article 16 addresses the modulation of air navigation charges. As such, Member States may, following consultation, modulate such charges incurred by airlines to reflect their efforts to 'reduce the environmental impact of flying'. This may apply to en route charges or terminal air navigation charges, the latter often being wrapped up in the airport's wider charges to airlines.

Guidance on noise-related charges

Noise-related charges are one of several types of airport charge. Guidance on airport charges is provided by the International Civil Aviation Organisation (ICAO) in their Document ref. 9082 ICAO's Policies on Charges for Airports and Air Navigation Services[7].

Consultation on changes to charging systems and levels is required to ensure that airports give adequate information to operators relating to the proposed changes and gives proper consideration to the views of operators and the effect the charges will have on them. Agreement between airports and operators is desirable, but where it is not reached, the airport is free to impose the charges proposed, subject to a right of appeal.

5 Directive 2002/30/EC of the European Parliament and of the Council of 26 March 2002 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports

6 Statutory Instrument 2003 No. 1742 Civil Aviation. The Aerodromes (Noise Restrictions) (Rules and Procedures) Regulations 2003

7 Document 9082, ICAO's Policies on Charges for Airports and Air Navigation Services, Ninth Edition, ICAO, 2012

According to Regulation 9 of the Airport Charges Regulations 2011, if a regulated airport operator intends to change the system or level of airport charges at an airport that it manages, it must give at least four months notice before the change has effect unless there are exceptional circumstances. This would not give airlines enough time to change their fleet; however, it may influence decisions on the allocation of aircraft to particular routes. Structural changes such as increasing the differentials for noisier aircraft are often signalled around a year in advance of their implementation.

ICAO Doc 9082 provides guidance on noise-related charges. According to section II paragraph 8, noise-related charges should:

- be levied only at airports experiencing noise problems;
- be designed to recover no more than the costs applied to the alleviation or prevention of actual noise problems;
- be associated with the landing fee, possibly by means of surcharges or rebates, taking into account the noise certification provisions of ICAO Annex 16 in respect of aircraft noise levels;
- be non-discriminatory between users; and
- not be established at such levels as to be prohibitively high for the operation of certain aircraft.

Measures to alleviate or prevent noise problems, which are funded by the noise-related charges, are described in Appendix 1 of Doc 9082 as:

- Noise-monitoring systems, noise-suppressing equipment and noise barriers;
- Land or property acquired around airports; and
- Soundproofing of buildings near airports and other noise alleviation measures arising from legal or governmental requirements.

ICAO recommends the costs incurred in implementing such measures may, at the discretion of states, be attributed to airports and recovered from the users, and that states have the flexibility to decide on the method of cost recovery and charging to be used in the light of local circumstances. When noise-related charges are to be levied, consultations should take place on any items of expenditure to be recovered from users.

The guidance in ICAO Doc 9562 Airport Economics Manual[8] suggests that the 'effective perceived noise level (EPNL) of the aircraft concerned could be used

8 ICAO Document 9562, Airport Economics Manual, First Edition, ICAO, Second Edition

as a charging or rebating parameter'. This is embodied in the guidance in section II.8 of Doc 9082, referred to above, whereby the certification provisions of ICAO Annex 16 are based on EPNL. Doc 9562 also clarifies that 'the sophistication or complexity in the design of the scale would vary according to local circumstances and requirements' and that the 'scale could be linear or in steps'[9].

ICAO's Environmental committee, in reviewing the future of the noise certification scheme, agreed the following purpose for noise certification[10]:

'The prime purpose of noise certification is to ensure that the latest available noise reduction technology is incorporated into aircraft design demonstrated by procedures which are relevant to day to day operations, to ensure that noise reduction offered by technology is reflected in reductions around airports.'

The reference to 'latest available noise reduction technology' emphasises that noise certification standards are intended to be technology-following, rather than driving the development of new technology. A key reason for this is to ensure that standards can be met with safe certified technology. The standards therefore act primarily as a back stop to the process of phasing out older aircraft.

The European Civil Aviation Conference ECAC-CEAC document ECAC/24-1 Noise Charges and Rebates gives additional recommendations on: a common framework and methodology for how charges (and rebates) should be calculated; characterisation of arrival and departure noise levels; maximum variation of noise charges; information to the public, evaluation and proportionality of noise charges to noise impacts. The latter advises that unit noise charges at arrival and at departure should reflect the relative impacts of arrivals and departures for populations around the airport (Article 3).

Finally, one of the principal elements of the ICAO's Balanced Approach to Aircraft Noise Management[11] is Land-use planning and management measures. This can be categorized as planning, mitigation and financial instruments. As well as capital improvements and tax incentives, the latter includes noise-related airport charges. The financial instruments are intended to generate revenue to assist in funding noise mitigation efforts.

The Balanced Approach reflects the provisions of the Civil Aviation Act 1982 that noise-related airport charges may be levied by national governments, local governments or the airport authority at airports experiencing noise problems. It

9 'Linear' is taken to refer to a 'continuous', rather than 'stepped' scale. In the case of noise, a continuous scale could be used but the relationship could be either linear or logarithmic

10 ICAO Document 9886, Report of the Seventh Meeting of the ICAO Committee for Aviation Environmental Protection, February 2007.

11 ICAO Document 9829, Guidance on the Balanced Approach to Aircraft Noise Management

identifies that the application of noise-related charges should follow the relevant principles in ICAO's Policies on Charges for Airports and Air Navigation Services (Doc 9082), as mentioned above.

Cost sources associated with noise-related charges are set out in the Balanced Approach as: the cost of the charge to airlines, and downstream administrative and legal costs.

Charging parameters

ICAO noise certification

According to the seventh meeting of the Committee on Aviation Environment Protection (CAEP) in 2007, 'the prime purpose of noise certification is to ensure that the latest available noise reduction technology is incorporated into aircraft design demonstrated by procedures which are relevant to day to day operations, to ensure that noise reduction offered by technology is reflected in reductions around airports'.

Where EPNL is used as a charging (or rebating) parameter, as explained in the previous section, the recommendation is that the certification provisions of ICAO Annex 16 are used.

Type certification of aircraft includes noise certification, whereby testing is undertaken to measure noise levels during the take-off and landing phases of operation. Three measurements are taken: flyover and sideline (lateral) during take-off, and approach during landing. These tests are carried out in a controlled manner and the three certification noise levels are first compared with the limits as defined in ICAO Annex 16 to establish compliance with the various chapter standards.

The Chapter 2 standard became applicable in 1972 as the first noise standard for subsonic jet aeroplanes. The phase out of Chapter 2 aircraft was completed on 1 April 2002[12].

The Chapter 3 standard became applicable in 1978 and set a limit on the cumulative noise level (based on the arithmetic sum of the three certification noise levels) around 16 dB lower than the Chapter 2 limit. Chapter 3 then became a reference against which the subsequent noise standard was defined. For aircraft below the Chapter 3 limits, the cumulative margin is then calculated by summing the margin under the Chapter 3 limits for the three measurements.

12 Since 2002, 'Chapter 2' aircraft (of over 34 tonnes maximum take-off weight or with more than 19 seats) have no longer been allowed to operate at EU airports

The Chapter 4 standard required all new aircraft type designs to have a cumulative margin of 10 EPNdB or more as of 1 January 2006. In other words, the Chapter 4 limit represents an increase in stringency of 10 EPNdB (cumulative) relative to the Chapter 3 limit.

The new Chapter 14 standard was agreed in February 2013 as the fourth ICAO noise standard for large transport aeroplanes. It represents an increase in stringency of 7 EPNdB (cumulative) relative to the Chapter 4 cumulative levels and will apply to new aircraft types submitted for certification on or after 31 December 2017. For aircraft of maximum certificated take-off mass of less than 55 tonnes, the new standard will apply on or after 31 December 2020. Additionally, this is the first standard that incorporates even more stringent limit criteria for aircraft with a maximum certificated take-off mass of less than 8,618 kg.

Limits may be exceeded for one or two of the three noise measurements provided that:

- The sum of the exceedances is not greater than 3 EPNdB for Chapter 3 (4 EPNdB for Chapter 2);
- No single exceedance is greater than 2 EPNdB for Chapter 3 (3 EPNdB for Chapter 2); and
- The total exceedance is offset by the margin under the limit(s) for the remaining measurements.
- The Chapter 3 limits are not exceeded at any of the measurement points, and the sum of the differences at any two measurement points between the certification noise levels and the Chapter 3 limits are not less than 2 EPNdB for the Chapter 4 standard.
- The measurements are not less than 1 EPNdB below the Chapter 3 limits at each certification point for the Chapter 14 standard.

The ICAO limits, within chapter standards, vary with Maximum Take-off Weight (MTOW) in order that aircraft are treated comparably taking account of their size (weight). As such, the system is designed to address ‘in-class’ noise performance in order that the oldest and noisiest aircraft are phased out over time.

ACI Aircraft Noise Rating Index

Beyond the ICAO Chapter categories, there are further subdivisions again based on the cumulative margin below the Chapter 3 limit. These categories accord with the cumulative margin thresholds for the Airports Council International (ACI) Aircraft Noise Rating Index and are used in some airport charging systems to achieve a greater level of refinement in the noise categorisation of aircraft types.

The aircraft noise categories for different cumulative margins are as follows:

- Chapter 3 High - Cumulative Margin of between 0 and 5 EPNdB
- Chapter 3 Base - Cumulative Margin of between 5 and 10 EPNdB
- Chapter 4 High - Cumulative Margin of between 10 and 15 EPNdB
- Chapter 4 Base - Cumulative Margin of between 15 and 20 EPNdB
- Chapter 4 Low - Cumulative Margin of 20 EPNdB or more

Table 1 below shows examples of aircraft types meeting the various noise category criteria. Different airframe/engine variants of a given aircraft type may have different cumulative margins and therefore the aircraft type may fall into more than one noise category.

Table 1: Proportions of aircraft noise certification variants[13]

Aircraft Type	Chapter 2	Chapter 3 High	Chapter 3 Base	Chapter 4 High	Chapter 4 Base	Chapter 4 Low
A319				4%	80%	16%
A320				33%	59%	8%
A321			34%	58%	8%	
A330				56%	39%	4%
A340						100%
A380						100%
B737-700				50%	50%	
B737-800/900				89%	11%	0%
B747-200		52%	42%	7%		
B747-400			5%	61%	32%	2%
B757-200				30%	38%	32%
B767-300		3%	9%	30%	49%	9%
B767-400					100%	
B777-200				5%	46%	49%
B777-300				7%	91%	2%
EMB-170			8%	92%		
MD82			21%	77%	2%	

13 Data from: European Aviation Safety Agency (EASA) Type-certificate data sheet for noise database (TCDSN), Jets Issue 14

Quota Count

Some charging systems use the Quota Count (QC) system as a charging parameter.

The Quota Count (QC) system was introduced as part of a new night restrictions regime for Heathrow, Gatwick and Stansted in 1993 (Ref 1). Aircraft movements (arrivals or departures) count against a noise quota for each airport according to their QC classifications. The method by which QC classifications are determined was based on a 1991 analysis of aircraft noise data that was then available. The QC classification is intended to reflect the contribution made by an aircraft to the total noise impact around an airport, the latter being expressed by the total Quota Count, i.e. the sum of the QC classifications of all arrivals and departures. Classifications are assigned separately for arrivals and departures.

QC classifications describe absolute noise levels, but in relative terms on a scale: a QC/1 aircraft is deemed to have twice the impact of a QC/0.5 aircraft, a QC/2 aircraft has four times the impact and so on. The QC classifications of aircraft are determined from their certificated noise levels, which are measured in EPNdB. Although certificated EPNLs can fall anywhere within a wide range, they are grouped for practical QC purposes into 3 EPNdB-wide bands (although the highest and lowest bands are unlimited). Because a 3 EPNdB difference in noise level corresponds to a two-fold difference in noise energy, successive QC classifications increase by multiples of two.

QC classifications make no allowance for the MTOW of the aircraft. Therefore, as smaller aircraft are generally quieter than larger aircraft, they will generally be described by a lower QC classification.

SECTION 3

Noise-related charging in practice

The charging elements relevant to this study, i.e. those which could be used to incentivise the use of quieter aircraft, are discussed in this section which looks at the current (or latest available) noise charges.

Charging elements and values (as applied in 2013/14)

Information on the charging systems adopted by individual airports is available from the airports themselves. Further information on the sources of information used in this study is given in Appendix B. Details of the charging systems in use at the study airports reviewed are presented in Table 2.

Table 2: Summary of charging systems at the study airports (2013/14)

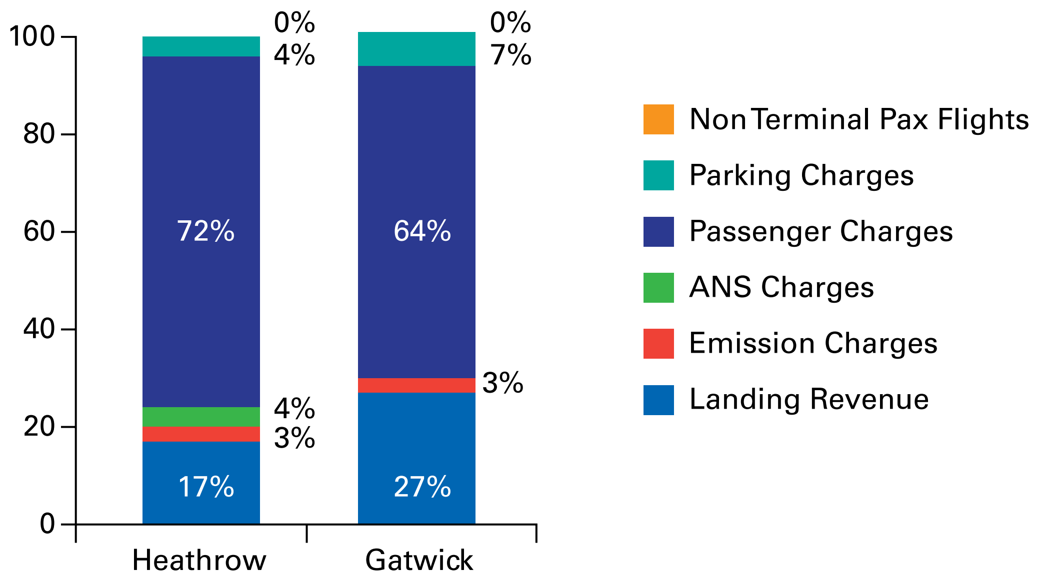
		Heathrow	Gatwick	Stansted	Manchester	Birmingham	East Midlands
Runway charge	Type	Landing	Landing and Departure	Landing	Departure	Departure	Departure (landing and departure separately for freight)
	Weight parameter	MTOW (stepped)	MTOW (stepped)	MTOW (stepped)	'Maximum Take Off Weight Authorised' (semi-continuous, rate changes at 25t and 120t)	MTOW (continuous)	MTOW (> 5.8t continuous)
	Noise parameter(s)	ICAO/ACI noise category	ICAO/ACI noise category & QC	ICAO/ACI noise category & QC	ICAO/ACI noise category & QC	n/a	QC
Relative Charges re. Chapter 3 base	Ch2	300%	300-338%	300%	170%	n/a	n/a
	Ch3 high	300%	150%	150%	100%	n/a	n/a
	Ch3 base	100%	100%	100%	100%	n/a	n/a
	Ch3 minus	n/a	90%	90%	n/a	n/a	n/a
	Ch4 high	60%	85%	90%	100%	n/a	n/a
	Ch4 base	50%	85%	90%	100%	n/a	n/a
	Ch4 minus	30%	85%	90%	100%	n/a	n/a
Night period (where relevant to landing charges)	Night period, local time	01:00-04:30	n/a	n/a	n/a	n/a	23:30-06:00
	Night surcharge	150%	0%	0%	0%	0%	25% (if QC/4+)
	Night surcharge, Freight (if different to passenger)	n/a	n/a	n/a	n/a	n/a	Shoulder periods (06:01-07:00 & 21:01-23:29): 306% Night period (23:30-06:00): 410-479% depending on QC.
Off-peak	Off-peak criteria, local time	n/a	Winter 24h per day, and Summer 13:00-18:00 & 20:00-07:00	Winter 24h per day	Reduced winter rates. Combinations of QC values and time periods from 05:30-22:59	n/a	n/a
	Off-peak reduction	n/a	67-71% (summer), 67-100% (winter)	74%	19% (MTOW>25t) >19% (MTOW>120t)	n/a	n/a
	Off-peak reduction, Freight (if different to passenger)	n/a	n/a	n/a	48%	n/a	n/a

At the designated airports, it is only the runway landing charges which are relevant to noise management. The charge on landing is assessed and payable on the basis of the Maximum Total Weight Authorised[14] as recorded by the airport companies on 1 April of each year, and noise certification values for side-line, flyover and approach for all flights. The other charging categories have no clear dependency on the noisiness of the aircraft or what time of day the aircraft are flying. This is perhaps with the exception of the per-passenger charge which will be greater for larger aircraft which tend to be noisier than the smaller lower capacity aircraft.

Figure 1 below illustrates the revenue that Heathrow and Gatwick forecast for 2013/14 proportionally according to the various types of charge imposed. Total revenues of £1.5bn and £300m were anticipated at Heathrow and Gatwick respectively during this year. These revenues were calculated using the information given in the conditions of use consultation documents[15] for these airports.

Figure 1

Forecast revenues at Heathrow and Gatwick



At the non-designated airports studied, various charging parameters are in use. Many of these are relevant to noise management, though none are specifically

14 Maximum Total Weight Authorised in relation to an aircraft means the maximum total weight of the aircraft and its contents at which the aircraft may take-off anywhere in the world in the most favourable circumstances in accordance with the Certificate of Airworthiness in force in respect of the aircraft

15 Heathrow Airport, Airport Charges for 2013/14, Consultation Document, Date: 26th October 2012 and Gatwick Airport Charges Group – Consultation on airport charges 2013/14, 31st October 2012.

charges on landing so strictly speaking cannot be considered noise-related charges according to ICAO Doc 9082.

Historical charges

The ICAO noise standards exist to ensure, in the most part, comprehensive uptake of new aircraft technology by certain dates as described below. They also put some pressure on the aviation industry to design and manufacture quieter aircraft. To summarise the history of how the various standards came into effect:

- Aircraft that did not meet the Chapter 2 standard[16] were not permitted to be operated at European airports from 2002, unless exempted under very narrow circumstances (e.g. a Head of State flight, mercy flight or maintenance positioning flight).
- In the same year the Chapter 3 'marginally compliant'[17] definition was introduced in the EU, and the rules governing the phasing out of such aircraft transposed into UK law via the implementation regulations[18] which took effect on 6th August 2003.
- In June 2001, on the basis of recommendations made by the fifth meeting of the Committee on Aviation Environmental Protection (CAEP/5), the Council adopted the Chapter 4 noise standard, and on 1 January 2006, the new standard became applicable to newly certificated aeroplanes and to Chapter 3 aeroplanes for which re-certification to Chapter 4 is requested.
- Looking to the future (thus for information only in this retrospective study), the new ICAO Chapter 14 noise standard was agreed in February 2013 and will come into effect from 31st December 2017 for aircraft with MTOW of 55 tonnes or higher, and 31st December 2020 for aircraft with MTOWs less than 55 tonnes.

While there has been a progressive tightening of international aircraft noise standards, noise-related charges at all six airports have also risen over the years. For example at Heathrow, considering the lowest noise category in 2001/2 (Chapter 3 Minus) and 2012/13 (Chapter 4 Minus), and accounting for an average inflation rate over this period of 3.2%, the increase in equivalent charge is 35% of the charge in 2001/2.

16 Specifically, civil jet aeroplanes exceeding 34 tonnes Maximum Total Weight Authorised (MTWA)

17 Aircraft with a cumulative margin of between 0 and 5 EPNdB. This made the distinction between Chapter 3 aircraft that were within the noisy and quiet halves of the range. Also described as Chapter 3 High.

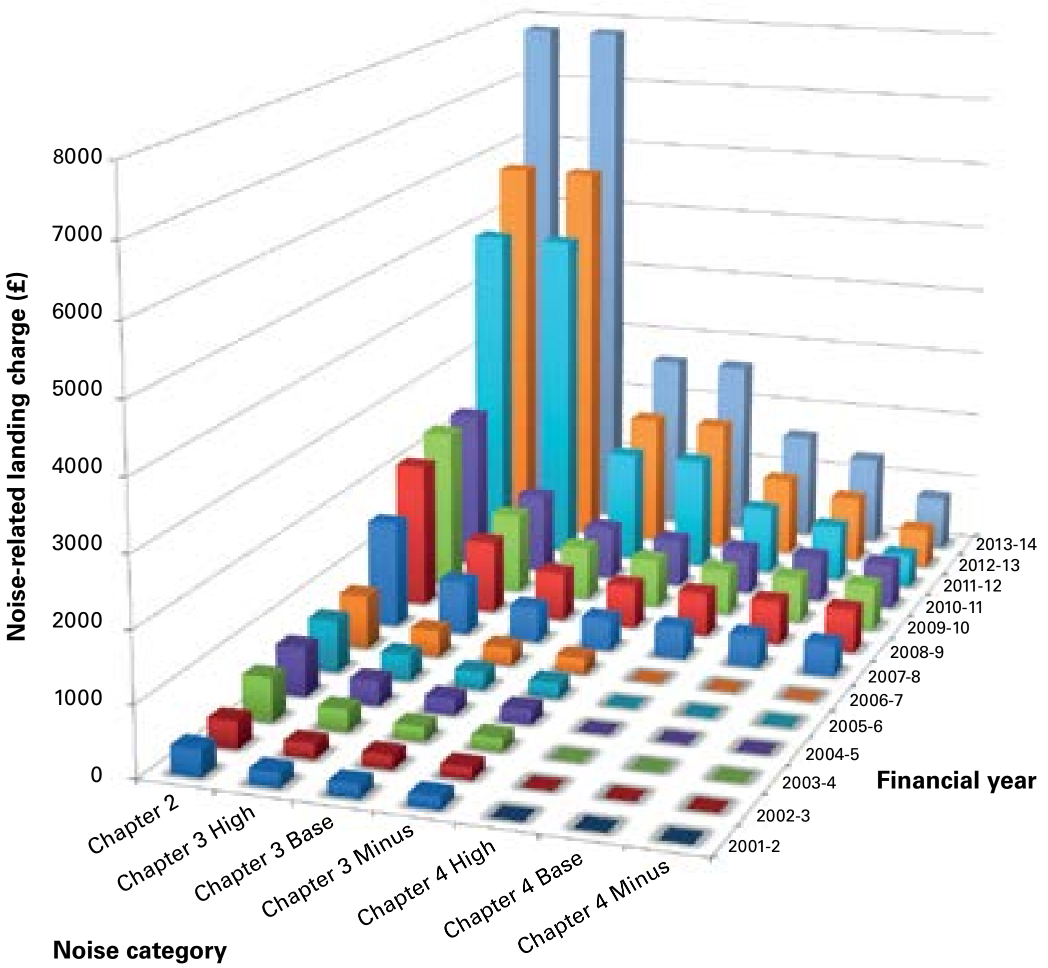
18 Statutory Instrument 2003 No. 1742 Civil Aviation. The Aerodromes (Noise Restrictions) (Rules and Procedures) Regulations 2003

There has also been an upward trend in charges within noise categories, presumably intended to incentivise the use of quieter aircraft. For example at Heathrow, scaling up the charge for a Chapter 3 Base aircraft in 2001/2 to 2012/13, again assuming inflation at a rate of 3.2%, and comparing this with the charge for a Chapter 3 base in 2012/13, there is an increase in charge of over 300%.

Charging categories have also changed over time, with the introduction of categories with lower noise level criteria (namely the Chapter 4 categories described in section 2, page 17) to accommodate the emerging aircraft types with improving noise performance.

The noise-related (landing) charges, per noise category, between 2001/2 and 2013/14 at Heathrow are illustrated in Figure 2 below.

Figure 2
Noise-related charges at Heathrow Airport[19]



19 In the absence of data for 2002-3, mindful that charges increase from one year to the next, the 2001-2 charges have been presented for this year.

Figure 2 shows that the most significant relative increases in charge for Chapter 2 and 3 aircraft compared with the quieter Chapter 4 aircraft occurred in 2011/12. This shows that there was a lag of around five years between the introduction of the Chapter 4 standard in 2006 and any appreciable noise-related landing charge incentives.

Aircraft not meeting the Chapter 2 standard have not been permitted to operate at EU airports since 2002, nearly a decade before the significant relative increase in landing charge for Chapter 2 aircraft. Furthermore, the voluntary phasing out of Chapter 3 'marginally compliant' aircraft began in 2003 and, again, it took around eight years for relevant charges to rise significantly.

This highlights that charging rates have followed changes in aircraft technology rather than driven them. As previously mentioned, this is the declared ICAO policy for all environmental standards, i.e. they should be technology-following, not technology-forcing. However, fleet decisions may be made in the light of an expectation of changes to charging regimes (as well as other factors such as quotas and bans), not least because aircraft are such long-term assets. If noisier aircraft are expected to become more expensive, then that may change buying decisions in advance of the charging regimes actually being introduced.

Charges for a given year are usually announced during the preceding year. When airports make changes to their structure of charges, they may be announced up to three years in advance. As these time-frames are less than the five to ten years lag between the introduction of new noise standards and incentivising pricing, any expectation of increasing charges for noisier aircraft will most likely be founded on industry precedence rather than specific changes to airport charging schemes.

Charges relating to time of day

The charges at all the airports which were reviewed, except Stansted, incorporate an element which depends upon the time of day when a chargeable operation occurs.

Our current understanding is that noise from night-time aircraft operations causes a greater adverse effect in humans than noise from daytime operations[20]. As such, some noise charging schemes disincentivise night operations.

The time of the chargeable operation may be defined as the actual time or the scheduled time of the operation. Using the actual time of operation perhaps appears to better reflect the 'polluter pays' principle than using the scheduled

20 As concluded in report: Perceptions of Aircraft Noise, Sleep and Health. University of Southampton, Cardiff University, Queen Mary and Westfield College, and BRE to Civil Aviation Authority, December 2000

departure time, i.e. the airline pays for the disturbance of a daytime or a night-time noise event accordingly. However, a daytime operation scheduled to occur on the cusp of the night period may be delayed or brought forward into the night period for reasons outside the airline's control. The higher charge would therefore be levied, whether or not it is the fault of the airline. Using the scheduled time as a basis for noise-related landing charges will result in more predictable charges and may be more effective in influencing airlines' scheduling decisions. An additional system of penalties may be applied to deter daytime scheduled services from regularly falling into the night period.

Of the six airports studied, the simplest case of setting time-of-day charge differentials occurs at Heathrow whereby all aircraft landing during the night period will incur charges that are 2.5 times the normal charges in the day period. Of the airports, Heathrow's night charge provides the greatest incentive against night-time operations considering only the effect of charging. As night-time capacity is scarce at Heathrow due to the night restrictions, the elevated charges may also reflect demand.

The temporal charging scheme is relatively complex at Gatwick. Base charges are around 3-3.5 times higher at peak times compared with off-peak times during the summer. The peak periods broadly occupy the morning and early evening rather than the night period. As the off-peak periods include night-time hours up to 07:00, there is, in effect, an incentive to operate at night instead of during the day in the summer months. There is no peak/off-peak differentiation in winter which means that the same rate applies for operations of aircraft in a given noise category irrespective of the time of operation. There is no charge for Chapter 3 Base and Chapter 4 aircraft during the winter, during the day or night. The temporal element of the charging system at Gatwick therefore appears to offer incentives to operate during the sensitive night period in the summer, and no disincentives to operate during the night in winter.

Birmingham Airport operates a night noise violation surcharge which although has a noise-management function, does not constitute a noise-related charge. It has therefore not been given further consideration in this study.

An off-peak charge is levied at Manchester for aircraft which meet certain QC values departing at certain times of day, presumably based on demand. These off-peak times include 05:30-06:59 during the night period, and the evening period 19:00-22:59 (local times based on scheduled departure times). This, in effect, provides an adverse noise incentive, i.e. offering 19% and 48% lower charges to some passenger and freight aircraft respectively, which operate during the early morning and evening. These periods are generally considered to be more sensitive than the daytime. As QC values are a measure of the absolute noise produced by an aircraft, airport charges set on the basis of QC values, like those at Manchester, use higher charges to deter noisier aircraft (with higher QC ratings) and lower charges to encourage quieter aircraft (with lower QC ratings). Conversely, as ICAO standards vary with MTOW, other airports which set their charges on the basis of these and the ACI Aircraft Noise Rating Index aim to incentivise best-in-class performance.

At East Midlands, a passenger aircraft night surcharge of 25% of the runway charge applies to all passenger aircraft departing during the core night period that fall into QC categories above QC/2. Additional charges are levied on cargo aircraft which equate to an increase of over 300% for arrivals and/or departures between 06:00-07:00 or 21:01-23:29, and a 410-479% (depending on the noisiness of the aircraft) increase for arrivals and/or departures between 23:30-06:00 local time. East Midland's charging structure does offer a significant incentive against night-time operations by noisier aircraft types, and in particular, against night-time freight operations. As for Manchester airport, East Midlands uses QC values as a charging basis, i.e. considering absolute rather than relative noise levels. All runway charges, shoulder/night supplement charges and noise surcharges for freight are based on the time recorded by East Midlands Airport Air Traffic Control (ATC) that the aircraft wheels either touched down on the runway on arrival or left the runway on departure.

The charging structures at Heathrow and East Midlands provide means for the airlines to internalise some of the costs of night-time noise disturbance. Birmingham offers disincentives for night-time operations, though not through noise-related charging per se. Some of the charges at Gatwick and Manchester, by contrast, incentivise operating at night. Stansted does not incorporate an element which depends upon the time of day when a chargeable operation occurs.

SECTION 4

Possible effects of noise-related charges

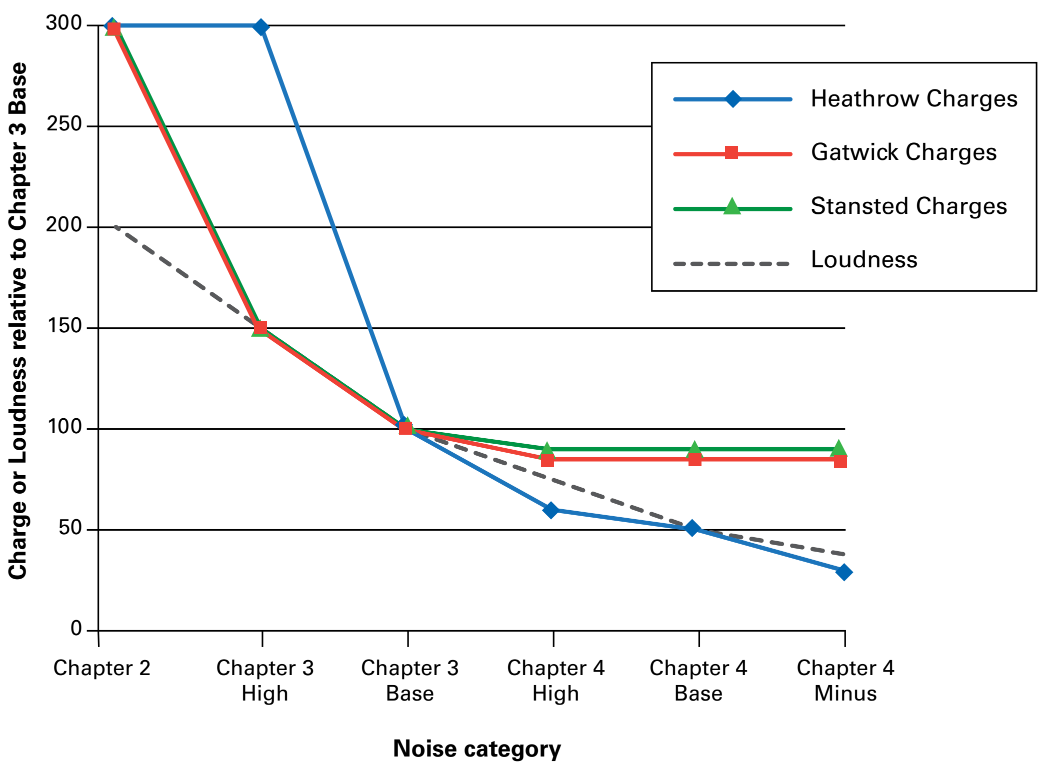
Charge differentials

The analysis here considers only the charging differentials between aircraft of different noise categories at airports which levy such charges (i.e. the designated airports) for the charging year 2013/14. Figure 3 shows typical noise-related (landing) charges for each noise category, normalised to the Chapter 3 Base charge for each airport (data from Table 2).

An additional line is plotted which indicates the relative loudness of the categories. Adopting the commonly used rule-of-thumb that a 10 dB increase approximately equates to a doubling of loudness, the dashed line is normalised to the Chapter 3 Base level of loudness.

Figure 3

Relative noise charges for different noise categories[21] at the designated airports



21 Based on 2013/14 charges at Heathrow (for aircraft >16T, daytime), Gatwick (peak) and Stansted (for aircraft >16T and <55T, peak).

It can be seen that all airports impose relatively much higher charges for the prohibited Chapter 2 aircraft compared to the Chapter 3 Base charge, i.e. no less than 300%. Charges for Chapter 3 High are closer to the base charge, with the exception of Heathrow which imposes the same charge as for Chapter 2 operations. This analysis suggests significant disincentives for use of a Chapter 2 aircraft (exemptions are permitted under exceptional circumstances), and at Heathrow, Chapter 3 High aircraft as well. However, as the law dictates that Chapter 2 aircraft should not operate, the disincentive to use Chapter 2 aircraft will have no material effect.

Heathrow levies progressively lower charges for categories that are quieter than Chapter 3 Base. Considering the relative loudness curves, Heathrow's charges reflect the noisiness of the categories reasonably well; except, as mentioned above, for the Chapter 3 High charge which appropriately disincentivises the use of aircraft which have been, or are in the process of being, phased out.

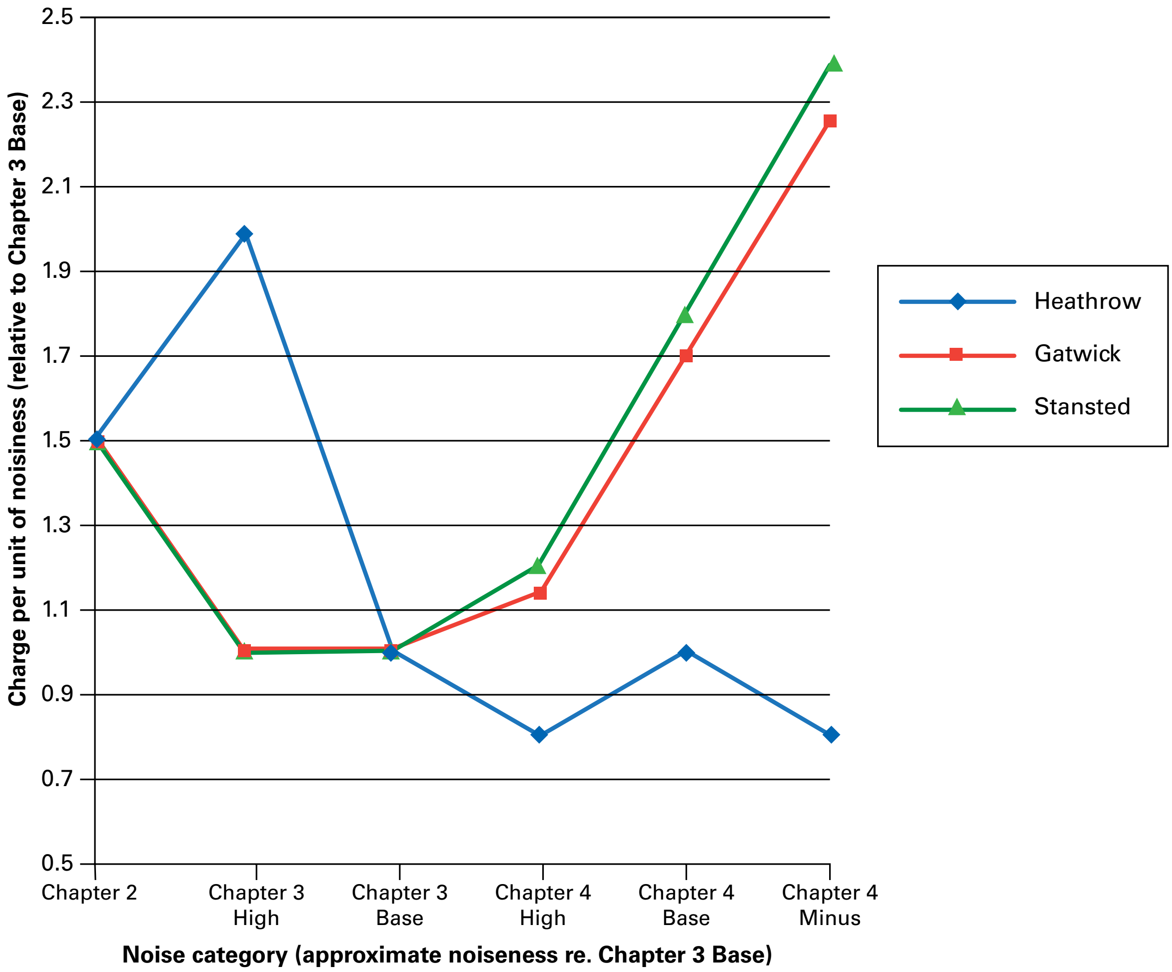
At Gatwick and Stansted, there is a marginal lower charge relative to the base charge for all categories which are quieter than Chapter 3 Base. The Chapter 4 charges at these airports clearly do not reflect the reducing noisiness of these categories. This is discussed in more detail in relation to Figure 5 later in this section.

There is also a marginal incentive to use a Chapter 3 Minus over a Chapter 3 Base aircraft at Gatwick and Stansted. This category is not included in the figure as it is based on the same cumulative margin criteria as Chapter 3 Base, but requires aircraft to be QC/1 or less on both arrival and departures.

This data can also be expressed as the ratio of charge per 'unit of loudness', to illustrate the relative 'noise value for money' of the category charges at the designated airports. This is presented in Figure 4, which shows that at Heathrow, operating the quieter Chapter 4 aircraft is less expensive, per unit of noise, than operating the noisier Chapter 3 and Chapter 2 aircraft. This may mean that airlines operating the relatively noisier aircraft at Heathrow internalise some of the cost of their enterprise.

Figure 4 also shows that at Gatwick and Stansted, the worst noise value for money is offered for the use of the quieter Chapter 4 aircraft, and the best value is offered for the noisier Chapter 3 aircraft. This model may therefore disincentivise airlines from using these quieter aircraft.

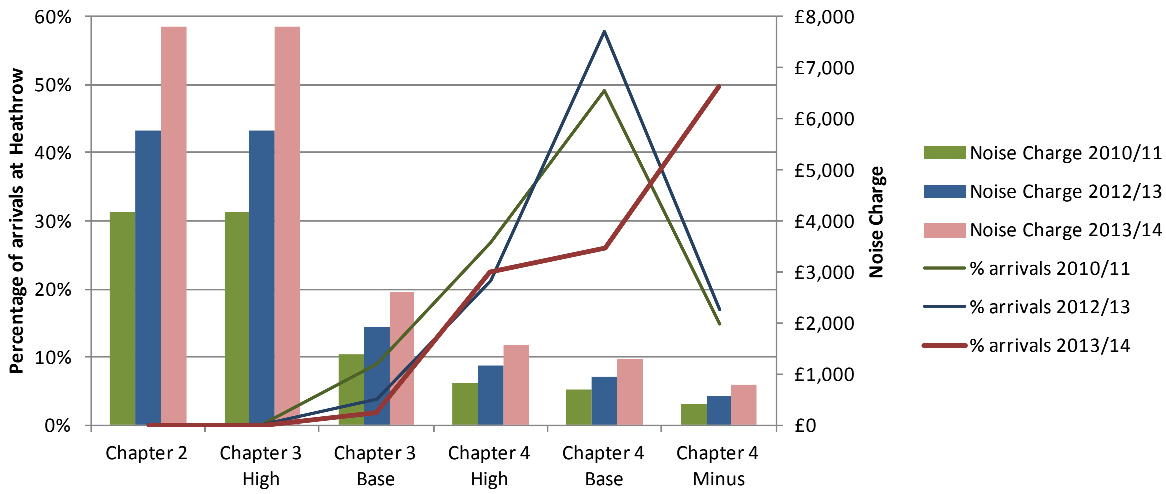
Figure 4
Relative noise charges per unit noisiness relative to Chapter 3 Base at the designated airports



The majority of modern aircraft operating in Europe fall within Chapter 4. This is illustrated by the lines in Figure 5 which represent the proportions of arrivals of aircraft in different noise categories anticipated at Heathrow in 2010/11, 2012/13 and 2013/14. The bars indicate the landing charges levied at Heathrow for aircraft of different noise categories in the corresponding years.

Figure 5

Proportion of arrivals, and charges, for aircraft in different noise categories at Heathrow

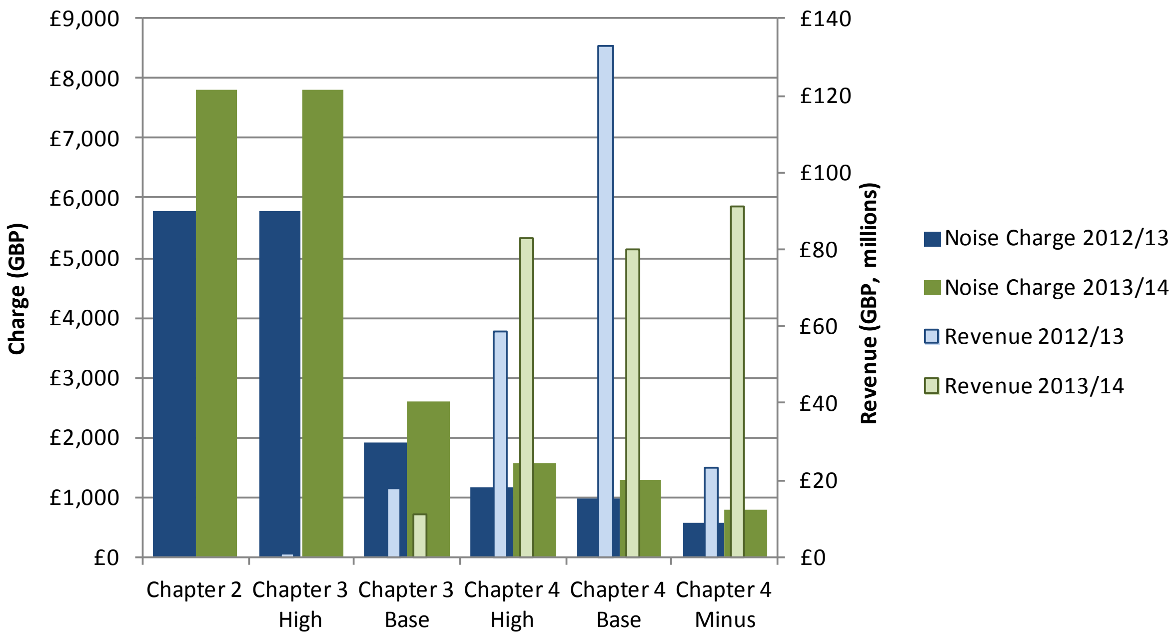


The majority of aircraft at Heathrow fall within the quieter Chapter 4 noise categories, and face the lower landing charges. Between the 2010/11 and 2013/14, the anticipated fleet mix profile moved towards the quieter Chapter 4 aircraft, with a stark move to Chapter 4 Minus aircraft in 2013/14. Considering the differences between the Chapter 4 category charges, there is a modest incentive to move towards the quieter end of Chapter 4 at Heathrow. Considering Table 2 and Figure 3, however, at Gatwick and Stansted there is no additional landing charge incentive to use an aircraft that is quieter than the Chapter 4 High and Chapter 3 Minus category respectively, which make up the majority of aircraft types operating at these airports.

In this context, the high charges for Chapter 2 and Chapter 3 High, which on face value appear to offer a clear disincentive to use noisy aircraft, have a limited ability to 'bite' owing to the relatively low numbers of aircraft to which they apply. The most meaningful charge differentials, where they exist, are therefore between the quieter Chapter 4 categories.

An alternative illustration is provided in Figure 6 below, which shows that at Heathrow in 2012/13, the highest revenues from landing charges were predicted to come from aircraft meeting the Chapter 4 Base standard. In 2013/14, the revenues were predicted to be more evenly distributed across Chapter 4. In both cases, revenues for the Chapter 2 and Chapter 3 High aircraft make up a negligible proportion of the total charges which reflects the low numbers of operations of these aircraft.

Figure 6
Charges and revenues from noise-related charges for Heathrow in 2012/13 and 2013/14



Currently there is insufficient differentiation between the aircraft with higher cumulative margins that make up the vast majority of operations. The system could introduce greater incentives by further differentiating the charges for aircraft with higher cumulative margins.

Noise-related charges in the context of overall airport charges

Noise-related (landing) charges are a component of the airport charges (see section 3 and Figure 1). Airport charges typically comprise:

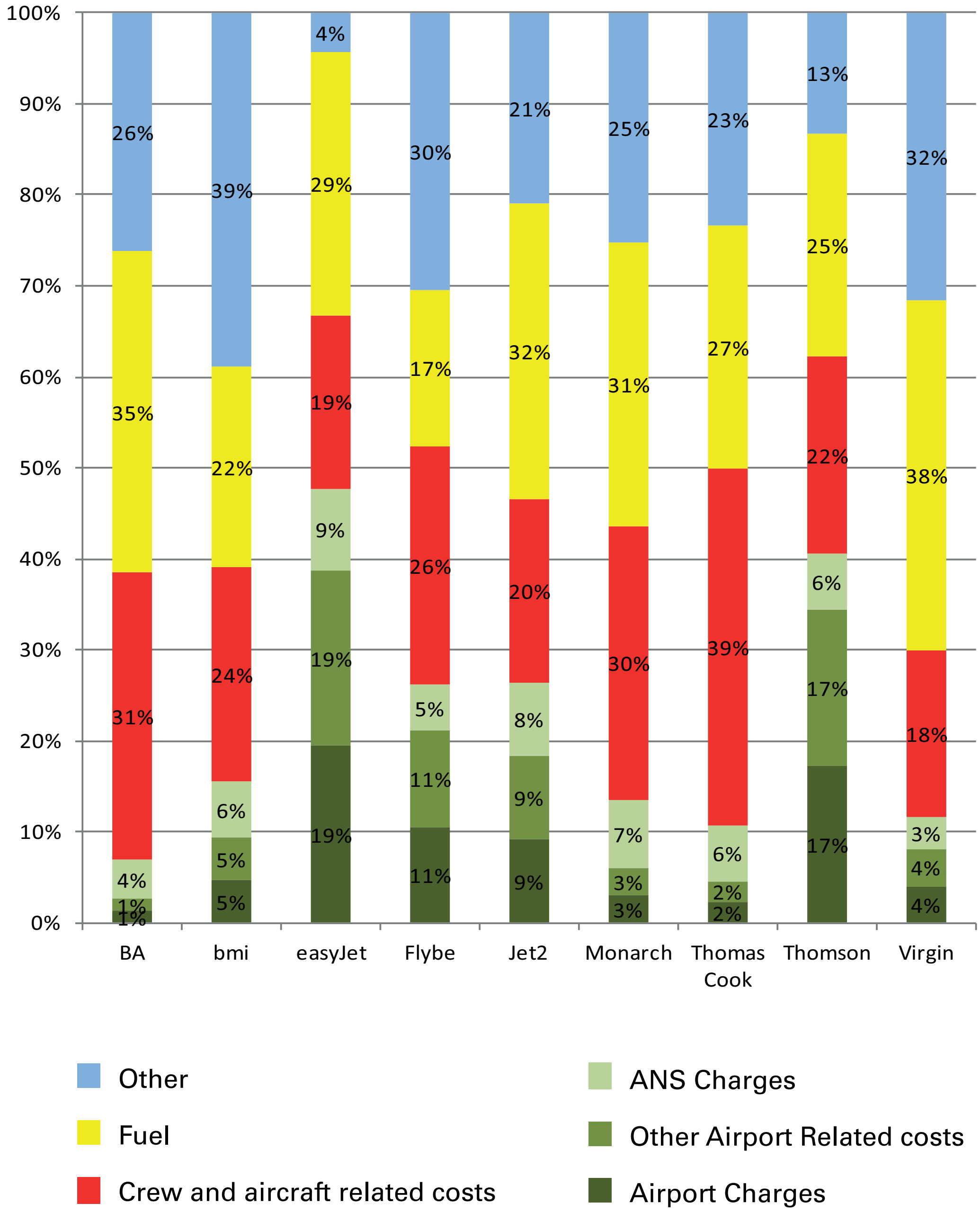
- Landing and departure fees;
- Emissions charges
- Air Navigation Services (ANS) charges
- Passenger charges
- Parking charges; and
- Charges relating to non-terminal passenger flights

Referring to Figure 1, in 2013/14, landing charges were forecast to account for 17% of a total of £1.5bn revenue at Heathrow, and 27% of £300m at Gatwick for example.

Further to this, the airport charges (of which landing charges are a component) constitute only a proportion of the total charges which an airline faces. Figure 7 below shows the cost breakdown by type for various airlines in 2011/12.

Figure 7

Airline cost breakdown (2011/12)[22]



22 Source: CAA UK Airline Financial Tables, based on annual profit and loss, airline appropriation and balance sheet statistics collected from major UK Airlines

Based on this information, airport charges range from 1% for British Airways to 19% for easyJet. As seen in the examples for Heathrow and Gatwick above, around a quarter of the airport charges constitute the landing/runway charges. Therefore, the noise-related landing charges may comprise from less than 1% up to around 5% of total charges according to the available data.

Any landing/runway charge differentials would in turn only apply to a proportion of the total charges for the operations of an airline's fleet. These differentials consequently make a limited relative contribution to an airline's costs, diluting the incentives when considered in terms of the total charges faced by airlines. Viewed in isolation, these relatively small differences may not appear to be able to have a significant influence on purchasing and/or operating decisions when balanced with factors such as fuel-efficiency or adherence to departure noise limits. However, their contribution is likely to be meaningful as one of a basket of measures (including penalties for departure noise and track-keeping infringements).

Comparing noise-related landing charge costs with fuel costs, for airlines such as BA and Virgin who operate a significant proportion of long-haul services, fuel may be up to 38% of total costs yet the noise-related landing charge is about 1%.

Once legislative requirements are met, commercial considerations would have a large influence on the decisions made by airlines on which aircraft types to use. The aim would be to save costs in the areas which contribute most to the overall airline costs. This might prioritise the use of higher capacity aircraft that can reduce per passenger costs, as well as the reduction of fuel costs, both in preference to reducing noise related landing charges.

This approach would incentivise replacing fleets with newer, larger, more fuel-efficient aircraft. By virtue of being newer, these aircraft will typically be quieter in class than the older models they replace, as they will need to meet ICAO chapter standards which become more stringent over the course of the service life of the aircraft.

Obtaining further incremental reductions in noise levels produced by new aircraft types often incurs a reduction in fuel efficiency. E.g. fitting sound absorbing linings to engine cowls adds weight which increases fuel-burn. This may either disincentivise the use of quieter aircraft types, or result in a fuel-efficiency trade-off where meeting certain noise limits has significant commercial implications.

Airline purchases of aircraft are a long-term decision, with potentially significant lead times from order to delivery depending on the state of an aircraft manufacturer's order book. A time lag between imposing higher charges on noisier aircraft and the greater use of quieter aircraft at the airport would therefore be expected. If airlines have a mix of aircraft types in their fleet, with some being noisier than others, they might be expected to react more quickly to incentives to use quieter aircraft at a particular airport.

An additional factor is the differences between airlines' regarding their flexibility in fleet planning and aircraft route allocation. For instance, an airline based at one airport only may not be able to move an aircraft out of the airport but a foreign flag carrier with a varied fleet may allocate the noisy aircraft in the fleet to an airport with less onerous noise-related charges.

Depending upon an airline's circumstances, differential charges may therefore accelerate the replacement of aircraft by the order of one to two years, and may influence the choice of aircraft used for a new service. Any influence the charges may have on such decisions would be in the balance with other drivers for which priorities may be higher or lower.

We have also seen that some airports also have peak/off-peak differential landing charges to encourage airlines to use larger aircraft during peak times. Conversely they may have very low, or even zero landing charges at off-peak times to encourage airlines to use slots that otherwise would not be used. Being intended to provide incentives for operations at certain times of day, these may lead to beneficial noise effects if peak periods are chosen to coincide with times of day when people are most sensitive to noise (i.e. night-time). However, where other periods are chosen (for other reasons such as spreading slot demand), adverse noise effects may result. Either way, for transparency and to avoid unintended consequences such as these, there should be a clear distinction between demand-related and noise-related differential landing charges.

Overall, differential landing charges would have some incentivising effects but they are unlikely to be the main financial driver for introducing quieter aircraft. The improvements in aircraft technology appear to have been driven by other factors such as tightening international noise standards and meeting other noise restrictions (e.g. departure noise limits and quota count criteria). To have a more significant impact, landing charge differentials would need to increase within the Chapter 4 noise categories thus incentivising only the quietest aircraft types. Landing charges for noisier aircraft may also have to rise considerably to have any real impact.

SECTION 5

Principles of emissions-related charging

Previous studies

Studies into NOx emissions landing charges have previously been published. Some examples of such studies are presented in Appendix A.

The legal position

UK Law

Under subsection (1) of Section 38 of the Civil Aviation Act 2006[23], an aerodrome authority may fix its charges in respect of an aircraft or a class of aircraft by reference (among other things) to:

a) (paragraph relates to noise, see section 2, page 10);

b) any fact or matter relevant to the amount or nature of emissions produced by the aircraft or the extent or nature of any atmospheric pollution resulting from such emissions, for the purpose of encouraging the use of aircraft which produce lower emissions of any substance which contributes to atmospheric pollution;

c) any fact or matter relevant to the effect of the aircraft on the level of noise or atmospheric pollution at any place in or in the vicinity of the aerodrome, for the purpose of controlling the level of noise or atmospheric pollution in or in the vicinity of the aerodrome so far as attributable to aircraft taking off or landing at the aerodrome;

d) any failure by the operator of the aircraft to secure that any noise or emissions requirements applying to the aircraft are complied with, for the purpose of promoting compliance with noise or emissions requirements.

Subsection (4) gives the Secretary of State a power to direct specific aerodrome authorities to fix their charges exercise of any power conferred by subsection (1); and any such order may contain directions as to the manner in which those charges are to be so fixed. The fixing of charges may be implemented through setting differential landing fees.

23 Civil Aviation Act 2006, Chapter 34, Part I, Section 38: Aerodrome charges: noise and emissions

Additionally, subsection (5) says that in directing an aerodrome, the Secretary of State shall have regard to the interests of persons who live in the area in which the aerodrome is situated.

In Section 38, 'aerodrome authority' means a person owning or managing an aerodrome licensed under an Air Navigation Order; and 'charges', in relation to an aerodrome authority, means the charges the authority makes for the use of an aerodrome so licensed which is owned or managed by the authority.

European Law

Repeating the elements of section 2, page 11 which apply to emissions as well as noise, the Airport Charges Directive[24] sets common principles for the levying of airport charges (not including charges for the remuneration of en route, terminal air navigation and ground-handling services, and assistance to passengers with disabilities and reduced mobility) at Community airports. This Directive applies to any airport located in a territory subject to the Treaty and open to commercial traffic whose annual traffic is over five million passenger movements and to the airport with the highest passenger movement in each Member State.

This Directive and the UK implementing regulations require that airports publish their airport charges. Article 3 of the Directive says that airport charges should not discriminate among airport users, but this does not mean that airports must charge everyone the same amount. Article 3 also says that charges may be modulated for issues of public and general interest, including environmental issues. Article 10 states that the level of airport charges may be differentiated according to the quality and scope of such services and their costs or any other objective and transparent justification.

There is also governance on charges other than those strictly related to landing aircraft. For example, under the Single European Sky Charging Regulations for Air Navigation Services, Article 16 addresses the modulation of air navigation charges. As such, Member States may, following consultation, modulate such charges incurred by airlines to reflect their efforts to 'reduce the environmental impact of flying'. This may apply to en route charges or terminal air navigation charges, the latter often being wrapped up in the airport's wider charges to airlines.

Guidance on NOx emissions-related charges

As for noise, emissions-related charges are one of several types of airport charge for which adequate consultation preceding any change is required.

24 Directive 2009/12/EC of the European Parliament and of the Council of 11 March 2009 on airport charges

ICAO Doc 9082 provides guidance on emissions-related aircraft charges to address local air quality (LAQ) problems at or around airports. Costs incurred in mitigating or preventing the problem may be attributed to airports and recovered from the users. States have the flexibility to decide on the method of cost recovery and charging to be used in the light of local circumstances.

In the event that emissions-related charges are to be levied, section II.9 of Doc 9082 states that the charges:

- should be levied only at airports with a defined existing or projected LAQ problem and should be designed to recover no more than the costs of measures applied to the mitigation or prevention of the damage caused by the aircraft;
- should be established in a transparent manner, and the share directly attributable to aircraft should be properly assessed;
- should be designed to address the LAQ problem in a cost-effective way;
- should be designed to recover the costs of addressing the LAQ problem at airports from the users in a fair and equitable manner;
- should be non-discriminatory between users; and
- should not be established at such levels as to be prohibitively high for the operation of certain aircraft.

In addition, it is recommended that:

- in levying LAQ emissions-related charges, special consideration be given to the need to reduce the potential impact on the developing world;
- emissions-related charges could be associated with the landing charges, possibly by means of surcharges or rebates, or in the form of separate charges but should be subject to the proper identification of costs;
- the aircraft emissions charges scheme be based on data that most accurately reflect the actual operations of aircraft. In the absence of such data, ICAO standardized landing/take off (LTO) cycle times-in-mode should be used (Annex 16 – Environmental Protection to the Convention on International Civil Aviation, Volume II – Aircraft Engine Emissions); and
- any State imposing LAQ emissions-related charges on aircraft that are in international operation should annually report the existence of such charging schemes to ICAO. The charging authority should maintain records regarding the fees collected and the use of funds to be made available to all users.

Charging parameters

Ascertained NOx Emission

An aircraft's Ascertained NOx Emission means the product of the Engine NOx Emission as set out in an Airport's Emission Database and the number of engines on the aircraft. NOx charges, in practice, are based on absolute NOx emitted, not by reference to applicable ICAO standards as is the case for noise. This appears to be more in accordance with the 'polluter pays' principle, but is less aligned with the 'best in class' approach adopted by noise-charging.

SECTION 6

Emission-related charging in practice

Charging elements and values (as applied in 2013/14)

At Heathrow and Gatwick airports, there is an emission-based charge which is payable on the basis of the Aircraft's Ascertained NOx Emission[25].

At Heathrow, a NOx emissions charge of £7.76 per kilogram of NOx applies to all aircraft over 8,618 kg.

At Gatwick, a NOx emissions charge of £5.26 per kilogram of NOx applies to all aircraft over 8,618 kg.

For example, considering common narrow-body twin aircraft types at Heathrow, the charge per-rotation for an Airbus A319 with IAE-V2522 engines would be around £150 at Heathrow and £100 at Gatwick.

Considering a common wide-body twin operating at Heathrow, the charge per-rotation for a Boeing 777-200ER with Rolls-Royce Trent 895 engines is £870 at Heathrow, and £590 at Gatwick.

Considering common wide-body quad aircraft types at Heathrow, the charge for a Boeing 747-400 with Rolls-Royce RB211-524G-T engines would be around £780 at Heathrow and £530 at Gatwick. By comparison, the charge for an Airbus A380 with Rolls-Royce Trent 970 engines would be around £1,030 at Heathrow and £700 at Gatwick.

The above illustrative calculations are based on the publically-accessible EASA Aircraft Engine Emissions Databank. They use the 'LTO total mass of oxides of nitrogen'[26] parameter in light of not having access to the BAA Emission Database.

For Heathrow and Gatwick, the charges increase proportionally with the ascertained NOx emission level, so logic would dictate that the incentive is for airlines to minimise emissions rather than strive for best-in-class performance. For example, an Airbus A380 pays a higher NOx charge than a Boeing 747-400 because despite having a greater NOx margin, it is a larger aircraft which emits more total NOx.

25 Aircraft's Ascertained NOx Emission means the product of the Engine NOx Emission as set out in the BAA Emission Database and the number of engines on the aircraft

26 The total mass of oxides of nitrogen emitted during the LTO cycle (sum of time in mode x fuel flow x average EI at each of the four power settings).

Another distinction between this and the noise charging is that there are discrete charging categories in use for noise charging, whereas emissions are rated for charging purposes on a linear scale. In light of this, where there is a tendency for the distinction between noise-related and demand-related landing charges to blur, this is not the case for NOx emissions charges which are clearly and separately defined. This is beneficial to transparency.

No emissions charge is levied at Stansted, Manchester, Birmingham and East Midlands. ICAO Doc 9082 states that emissions-related charges should be levied only at airports with a defined existing or projected LAQ problem. Due to the locations of these airports with respect to populated areas and/or their level of activity, these airports may not have a defined existing or projected LAQ problem, hence they do not levy a NOx charge.

Historical emissions standards

The ICAO Committee on Aircraft Environmental Protection (CAEP) standards exist to ensure, in the most part, comprehensive uptake of the new technology by certain dates as described below. They also put some pressure on the aviation industry to design and manufacture less polluting aircraft engines.

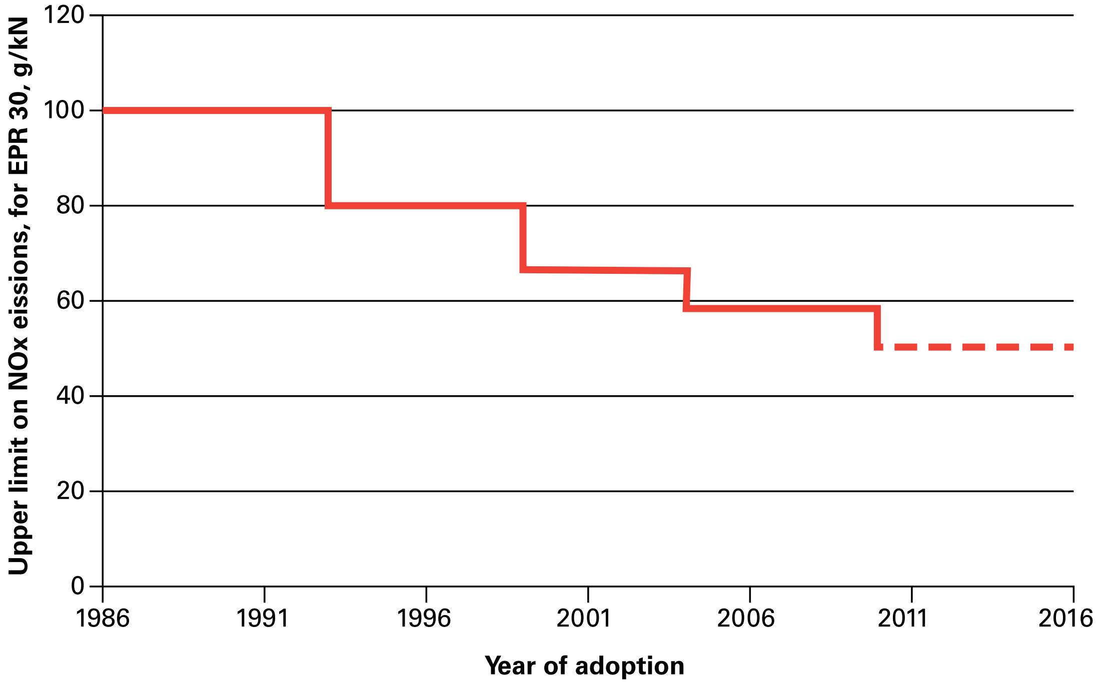
The development of the CAEP NOx standards is summarised below, and illustrated in Figure 8.

- The CAEP/1 NOx standard was adopted in 1981 which applied to newly manufactured engines from 1986. It established an upper limit on NOx emissions at 100 g/kN of rated engine thrust for Engine Pressure Ratio (EPR) 30.
- The CAEP/2 NOx standard was adopted by ICAO in 1993. This reduced emission limits by 20% to 80 g/kN for EPR 30. This standard applied to newly certified engines from 1996 and to already-certified newly manufactured engines from 2000.
- The CAEP/4 NOx standard was adopted by ICAO in 1999. This applied to newly certified engines and reduced emission limits by an additional 16% to 67 g/kN for EPR 30 and smaller percentage reductions for EPR greater than 30 beginning in 2004. This standard does not apply to newly-manufactured engines from old designs to offer protection of asset values of existing fleets.
- The CAEP/6 NOx standard was adopted by ICAO in 2004 and introduced in 2008. Again this applies to newly certified aircraft jet engines and is 12% more stringent than the previous standard.

- The CAEP/8 NOx standard was adopted by ICAO in 2010 and will be introduced in 2014. This will be a further 15% more stringent than the CAEP/6 standard for newly certified large jet engines.

Figure 8

Development of CAEP NOx standards



Since most engines in production already meet the standard by the date the standards are adopted, the NOx standards are broadly 'technology-following' as intended. As previously mentioned, this is the declared ICAO policy for all environmental standards, i.e. they should be technology-following, not technology-forcing. Considering the lead time between adoption and introduction, they also put pressure on the aviation industry to design and manufacture less polluting aircraft engines.

Historical charges

At both Heathrow and Gatwick, the emissions-related NOx charge remained steady at £1 per kilogram of NOx from their introduction in around 2004 until around 2007 when the charge began to rise. The charges rose to £6.69 at Heathrow, and £4.80 at Gatwick, in 2012/13. Taking account of inflation over the period from 2006/7 to 2012/13 at a rate of 3.4%, this corresponds to increases in charges in real terms of 448% and 293% at Heathrow and Gatwick respectively.

Considering the changes in the emissions-related charges in the context of the changing standards, the charges were introduced around the time of the application of the CAEP/4 standard and the rises in charge anticipated the introduction of the CAEP/6 standard. Without a significant lag between the introduction of the new standards and the rise in charge, which would otherwise allow for market penetration of the new complying technology, there may be some evidence for the charging systems driving improvements on this basis alone.

It could also be argued that the charges were long-overdue, and should have been introduced in the 1980's when the first ICAO NOx standard was introduced.

SECTION 7

Possible effects of emissions-related charges

To put emissions charges into context, Heathrow forecasts receiving about £47m from emissions charges for 2013/4. Total revenue from airport charges is expected to be £1.5bn, i.e. emissions constitute about 3% of total airport charges. In 2011/12 revenue from airport charges was about 57% of Heathrow's total revenue[27].

Section 6, page 40 identified that emissions-related charges scale linearly with LTO emissions. Therefore, if there is a significant difference between the emissions of two different aircraft (airframe/engine configurations) within a class, the charges will be correspondingly different. The examples given for a Boeing 747-400 and A380 illustrate how the latter, despite being newer, is larger with a greater passenger capacity than the former, emits more NOx leading to a 32% higher charge.

A specific example of where improvements in emissions performance has occurred by modifying aircraft engines on in-service aircraft is the Rolls Royce modification on the RB211-524G and -524H engines. By fitting a Trent 700 combustor, their NOx emissions were substantially lowered. Re-designated RB211-524G-T and -524H-T, NOx emissions were reduced by over 40%. The engines on 60% of British Airways' fleet of Boeing 747-400s were modified, possibly as a consequence of the NOx charge.

In other instances, where engine improvements have been made available as part of continuous product development, airlines have selected these improved variants of the same engine to fulfil remaining orders.

However, section 4 highlighted that airport charges are typically a small proportion of an airline's total costs, so the associated incentives for airlines to use aircraft with increasingly lower NOx emissions may be small.

27 Calculated from Heathrow Airport Charges Consultation Document 2013/14, p.48

SECTION 8

Issues for consideration

Absolute vs relative noise levels

The ICAO noise limits are proportional to maximum take-off mass between 35 and 280-400 tonnes. The cumulative margin discussed above is relative to the noise limit, so a large aircraft with a large margin can still produce more noise than a smaller aircraft with a smaller margin. For example:

- An A320 with a margin of around -8 dB is QC/1
- An A380 with a margin of around -27 dB is QC/2 (i.e. noisier than QC/1)

The A380 is noisier, in absolute terms, than the A320 even though the A380 performs better in relative terms having almost 20 dB more margin than the A320.

Historically, a view has been taken that using the cumulative noise margin as a basis for setting charges encourages best-in-class aircraft to be used. There is a risk, however, that higher charges and/or greater charge differentials could incentivise a smaller aircraft to be replaced by a larger aircraft that is noisier despite having a greater margin.

Linear vs stepped charging categories

As previously mentioned, ICAO Doc 9562 clarifies that 'the sophistication or complexity in the design of the scale would vary according to local circumstances and requirements' and that the 'scale could be linear or in steps'.

Noise-related charges are calculated on a stepped scale according to their ICAO chapter / ACI noise rating category where each step is 5 dB wide. In theory, to achieve incentives through charge differentials, wider categories means fewer categories, hence greater charge differentials between them. This may result in inequity between charges for aircraft with similar noise performance just above and just below a category boundary.

It may also result in potentially unfair application of charges in certain cases where an airline operates an aircraft below the take-off weight to which the noise certification results apply. As mentioned in section 2, the noise category is directly informed by certification noise levels. Reducing the take-off weight usually reduces noise emissions, which could put the aircraft in the quieter/cheaper noise category than that which the certification levels dictate.

Adding more categories reduces their width, and reduces the charge differential between categories. In the limiting case where the width of the categories tends to zero, the stepped scale becomes a linear (continuous) charging scale. This avoids the inequity at category boundaries, but is more complicated to administrate.

A linear scale such as this would most likely be based on the cumulative margin of the aircraft type (or even individual airframe). This would add complexity to the administration of the scheme, which may be difficult to justify under current practice. Sections 3 and 4 show that the highest charges are for prohibited and a relatively small number of the noisiest aircraft types, whereas the charge differentials between Chapter 3 Minus and Chapter 4 categories are small if not zero.

Where noise-related charge differentials are applied, it might be desirable to consider narrower categories or a linear scale to reduce or remove the inequity and potential unfairness at category boundaries.

NOx charges are already calculated on a linear scale for aircraft over 8,618 kg at Heathrow and Gatwick. The system is sophisticated in that the charge is proportional to NOx emissions. There is no scope for inequity in charges for aircraft categorised close to a category boundary, in the same way as exists for noise charging. The system has operated this way for the past decade, so by implication, the level of sophistication is not unduly onerous to administrators.

Potential trade-offs

Noise, emissions and any CO_2-related charges should be set such that they provide the correct relative incentives according to the Government's policies. The APF states that 'Government expects that at the local level, individual airports working with the appropriate air traffic service providers should give particular weight to the management and mitigation of noise, as opposed to other environmental impacts, in the immediate vicinity of airports, where this does not conflict with the Government's obligations to meet mandatory EU air quality targets'.

Disincentivising night operations may reduce choice to passengers if such services were to be ceased, and potentially worsen the passenger experience if, as a result, passengers are required to depart or arrive in the middle of the night at the non-UK airport. Reducing services may also cause price escalation hence reducing value for money for passengers.

Also relating to time-of-day incentives, some charging structures attempt to incentivise off-peak operations at times of day when demand is lower. If the aim was changed to encourage operations during the day when sensitivity to noise is generally lower, this may have an impact on commercial aspects of the airport's operation. A balance should be struck between the various aims of the incentives which are likely to be different between airports, but as previously mentioned, there should be a clear distinction between demand-related and noise-related differential landing charges.

Approach

Cap and Trade

Using a similar concept to the 'cap and trade' approach which forms the basis of the CO_2 European Union Emissions Trading Scheme (EU-ETS), a noise and/ or NOx emissions trading scheme could be adopted. As with other 'cap and trade' systems, the benefit of such an approach is that it would lead the aircraft operators to internalise some of the costs of the impacts of their commercial activity on local communities.

Such economic instruments would be complex to implement in practice and further work would be required to establish the feasibility of such approaches. For the purposes of illustration, a stylised example of how such a system might work for noise control was provided in our Aviation Policy for the Environment[28] document and is reproduced here:

- The primary capacity cap at airports would be expressed in terms of noise emissions, rather than aircraft movements as at present;
- A 'noise emissions envelope' or quota would be set for each airport level, for example based on modelled estimations of the population affected at a given noise level;
- Initial 'noise allocations' would be given to airlines operating at each airport. These allocations would be made on the basis of past performance;

The size of the overall cap would be reduced over time, for example in line with the long-term trend of technological improvement. This ensures residents get continued benefit from technological improvements.

As capacity caps are no longer expressed in terms of aircraft movements, aircraft operators who outperform the cap can potentially benefit from increased throughput at an airport, subject to satisfying safety requirements. Airlines are therefore incentivised to address fleet noise performance in order to generate additional flights, subject to infrastructure and operational constraints. Alternatively, noise-efficient airlines can sell surplus quotas to other operators.

28 CAA Insight Note 2: Aviation Policy for the Environment, Page 34

Although it is not a landing charge as such, the current Night Noise Quota scheme in operation at the designated airports is already a cap and trade scheme, albeit with limited trade capability, especially at Heathrow, because of the movement constraints.

Polluter Pays

A suggestion has been made at European Parliament, under the 'polluter pays' principle, that noise-related landing charges could be based not solely on certified aircraft noise levels, but on noise impact, i.e. noise contour areas and the populations enclosed by it. This goes some way to address ECAC/24-1 Article 3 (see section 2, page 14 above) and exhibits some fairness towards local residents.

The proposal would not, however, be equitable at Heathrow where noise impact is clearly dependent on runway mode. Because the average population density to the east of the airport is significantly greater than that to the west, the Stage 1 Consultation for the current Night Noise Restrictions showed up to twelve times more people living within the arrival noise footprints for a generic QC/4 aircraft to the east of the airport compared with those to the west[29].

Whether the operations are easterly or westerly depends principally on the wind direction, which is outside the airlines' control. If noise-related charges are based on noise impact, differentials may be very significant and due more to population distribution than the noisiness of the aircraft.

As an aim of the noise-related charges is to incentivise the airlines' use of quieter aircraft, a system which incorporates price differentials which are not directly related to aircraft types does not meet the aim.

Value of intervention

In light of the majority of current aircraft fleets meeting Chapter 4, the most meaningful charge differentials are therefore between the quieter Chapter 4 categories. Effective charging systems based on noise categories require there to be charge differentials between the Chapter 4 categories. Charging systems could introduce greater incentives by further differentiating the charges for aircraft with higher cumulative margins.

More effective charging schemes could be developed which drive improvements by earlier introduction of the higher charges for categories of aircraft that exhibit

29 Arrival SEL footprints for Heathrow in Section 3 of Annex C of the Night Flying Restrictions at Heathrow, Gatwick and Stansted Stage 1 of Consultation on Restrictions to apply from 30 October 2005

poor noise and NOx performance relative to emerging standards. Providing clearer time-bound foresight on how charging will change in the future may be a means for achieving this, within the bounds of the principle that ICAO standards are technology-following.

Under the CAA's current price regulation of Heathrow, Gatwick and Stansted, increases in environmental landing charges could be accommodated but would have to be counter-balanced by decreases in other charges. As noise-related landing charges are relatively low compared to per-passenger charges, and emissions-related landing charges are even lower, there could be scope to do this.

Any higher charging levels would need to be chosen carefully, however, as an environmental charge which is so high as to make the operation non-profitable could be considered to be an operating restriction if the service is consequently withdrawn. This outcome would be in violation of the guidance of ICAO Doc. 9082. In line with current practice, charge increases would need to be announced prior to their introduction so as to provide sufficient notice to airlines to take any necessary action.

However, there is every possibility that, due to the difference in timeframes between setting charges (short-term) and fleet replacement (long-term), increasing charges significantly above current rates would become operating restrictions before driving fleet changes. Options to increase incentives may therefore be restricted to increasing differentials rather than absolute charges, while addressing the adverse effects of the trade-offs (e.g. time-of-day charge differentials which encourage night operations).

Consideration should also be given to potential trade-offs with other environmental factors (namely emissions affecting local air quality and CO_2 emissions), economic factors and factors relating to consumer choice and experience.

Airlines endeavour to minimise fuel-burn to reduce their fuel costs, which are a significant proportion of their operating costs. As emissions and fuel-burn are broadly proportional to each other, a strong incentive already exists for airlines to reduce emissions, even if indirectly. Conversely, reducing the noisiness of aircraft is often accompanied by slight increases in fuel-burn, which in isolation may result in a disincentive. It should, however, be emphasised that although noise charging may not offer such a strong short-term incentive, airports should plan future charges that will bite in the longer-term to put pressure on airlines to plan accordingly.

Harmonisation

Owing to the legislative framework and international guidance which sets common principles for the setting of charges, there is a potential desirability for harmonising charging systems amongst airports. This has been highlighted in previous studies on environmental charging.

There could be merit in harmonising charging schemes at airports within the UK. It would simplify the process, potentially reduce an administrative burden on airlines, aid transparency and hopefully build stakeholder support. Ideally, aircraft should be treated similarly from one airport to another, even if the charges at each airport are different.

SECTION 9
Conclusions

The key conclusions and messages for policy makers and airport authorities in developing charging policy are as follows.

Noise

The monetary incentives designed to encourage airlines to use the quietest aircraft vary from airport to airport. The designated airports levy landing charges in the strict sense of the ICAO guidance, whereas the non-designated airports tend to levy other surcharges and penalties which, although do serve a noise-management role, do not meet the criteria for noise-related landing charges.

The designated airports levy significantly higher runway charges on the noisier aircraft types (compared to the charges on the quieter types), but these aircraft tend to comprise a small proportion of the active fleet. The most meaningful charge differentials are between the quieter Chapter 4 noise categories which account for the majority of aircraft in service. At Heathrow, the Chapter 4 category charges approximately follow the relative loudness of the categories and offer better noise value for money than charges for Chapter 2 and 3 aircraft. At Gatwick and Stansted, there are no charge differentials between the Chapter 4 categories. Furthermore, charges for Chapter 4 aircraft offer worse noise value for money than charges for Chapter 3 aircraft, potentially disincentivising the use of the quieter aircraft.

Currently there is limited means to incentivise the very quietest types. The system could introduce greater incentives by increasing the charges for lower margins, and reducing the charges for higher margins. More generally, a charging system should cover the full range of aircraft in operation at the airport and comprise charging differentials throughout the range.

The charging differentials appear to be relatively small compared to the overall airport charges met by airlines. This may reduce the effect of any intended incentives to operate quieter aircraft. They may, however, influence decisions such as when to replace ageing aircraft and what aircraft type to use for a new service, and should be set at appropriate levels to enable this wherever possible.

Furthermore, the charging differentials may contribute to a basket of measures, including noise and track-keeping penalties, that collectively has a beneficial effect in the shorter-term. The 'non-landing charge' noise penalties imposed by some of the non-designated airports may offer incentives to use quieter aircraft.

Noise-related charges have changed over time, and any resulting incentives have followed improvements in aircraft technology rather than driven them. This is the declared ICAO policy for all environmental standards. The improvements in quiet aircraft technology appear to have been driven more by factors such as tightening international noise standards, meeting other noise restrictions and pressure from local communities. However, an expectation that charges on noisy aircraft will increase may have contributed to the improvements.

Some airports implement charge differentials between operations occurring, or scheduled to occur, at certain times of day, providing a means for the airlines to internalise some of the costs of night-time noise disturbance. Such charges generally relate to noise management, though are not noise-related landing charges per se. Some airports offer disincentives for night-time operations, reflecting a general heightened sensitivity to aircraft noise occurring during the night as oppose to day, while others disincentivise operations at other times for other reasons such as demand. In some cases of the latter, an incentive to operate at night is inadvertently provided. There should be a clear distinction between demand-related and noise-related differential landing charges.

Historically, a view has been taken that using the cumulative noise margin as a basis for setting charges encourages best-in-class aircraft to be used. There is a risk, however, that higher charges could incentivise a smaller aircraft to be replaced by a larger aircraft that is noisier despite having a greater margin.

It might be desirable to consider narrower categories or a linear (continuous) scale to reduce or remove the inequity at category boundaries. In making any such decision, the increase in fairness would need to be balanced against the added complexity in administrating the system. Categories of equal width would aid transparency and avoid unnecessary complexity. Adopting this approach and using the margin to Chapter 3 as a basis for the system means reference no longer needs to be made to the ICAO chapter definitions. This avoids the complication of accommodating the new Chapter 14 standard which is 7 EPNdB below the Chapter 4 standard and does not lend itself to equal width categories (typically 5 EPNdB). Ultimately, since this approach is still takes into account the noise certification provisions of ICAO Annex 16 in respect of aircraft noise levels, ICAO guidance on setting noise-related charges is clearly met in this regard.

Emissions

Of the airports considered in this review, only Heathrow and Gatwick provided some incentives to use best-in-class aircraft in terms of levels of NOx emissions.

Emissions-related charges scale linearly with NOx emissions which may vary significantly between different aircraft within the same class. In these cases, the charges will be correspondingly different.

Where there is a tendency for the distinction between noise-related and demand-related landing charges to blur, this is not the case for NOx emissions charges which are clearly and separately defined. This is beneficial to transparency.

However, airport charges are typically a small proportion of an airline's total costs, so the associated incentives for airlines to use aircraft with best-in-class NOx-performance may be small compared to other drivers.

Common to noise and emissions

Differential environmental landing charges may have some incentivising effects but they are unlikely to be the main financial driver for using quieter and less-polluting aircraft. More effective charging schemes could be developed which drive improvements by earlier introduction of the higher charges for categories of aircraft that exhibit poor noise and NOx performance relative to emerging standards. Providing clearer time-bound foresight on how charging will change in the future may be a means for achieving this.

Under the CAA's current price regulation of Heathrow, Gatwick and Stansted, increases in environmental landing charges could be accommodated but would have to be counter-balanced by decreases in other charges. As noise-related landing charges are relatively low compared to per-passenger charges, and emissions-related landing charges are even lower, there could be scope to do this.

However, there is every possibility that, due to the difference in timeframes between setting charges (short-term) and fleet replacement (long-term), increasing charges significantly above current rates would become operating restrictions before driving fleet changes. Options to increase incentives may therefore be restricted to increasing differentials rather than absolute charges, while addressing the adverse effects of the trade-offs.

Any policy interventions would need to consider potential trade-offs with other environmental factors (namely emissions affecting local air quality and CO_2 emissions), economic factors and factors relating to consumer choice and experience.

There could be merit in harmonising charging schemes at airports within the UK. This would simplify the process, potentially reduce an administrative burden on airlines, aid transparency and hopefully build stakeholder support.

Good practice principles

This study has highlighted a number of principles which we consider to constitute good practice in the setting of airport noise and emissions charges:

a) Noise charging categories should be based on ICAO certification data, namely the margin to Chapter 3, to incentivise best-in-class.

b) Noise charging categories should of equal width, typically 5 EPNdB, or narrower, to ensure adequate differentiation of noise performance.

c) The noise charging categories used at a given airport should cover the full range of aircraft in operation at the airport. This range should be reviewed periodically and modified as appropriate.

d) Noise charges for operations occurring at night should be greater than those that occur during the day.

e) Where noise-related charge differentials occur depending on the time of day of an operation, the scheduled time of the operation should be used as oppose to the actual time. Penalties may be used to disincentivise operations scheduled to occur on the cusp of the night period that regularly fall into the night period.

f) There should be a clear distinction between noise-related landing charges and any non-noise-related charges, e.g. demand-related charges.

g) Charging schemes should ideally be harmonised across airports within the UK. Aircraft should be treated similarly from one airport to another, even if the charges at each airport are different.

APPENDIX A

Previous studies

Öko-Institut e.V., Report into noise-related landing charges

In May 2004, the Öko-Institut e.V. published a report titled Economic measures for the reduction of the environmental impact of air transport: noise related landing charges[30]. This was commissioned by the Federal Environmental Agency in Germany.

This study examines, with an LTO-charging (Landing and Take-off) model differentiated according to aircraft-noise emissions and incentives for air transport companies for the use of less-noisy aircraft. The results of the study are based on a comprehensive status-quo analysis of European LTO-charging models; they demonstrate the need for harmonised development of this kind of instrument as an incentive, in order to be able to obtain transparency and comprehensibility.

The study concludes with a set of guidelines for the development of a harmonised system of noise-related charges that it suggests must be considered in future. In the opinion of the project team, the perspectives and principles of the further development of the economic instrument of noise-related LTO charges can be summarised as follows:

'Standardization and harmonization of structure, systematics and bases for assessment is necessary, in order to place greater emphasis on the objective of noise mitigation and to make the levying and effectiveness of charges more transparent, without competition between airports at the cost of noise mitigation. Differentiation of landing and take-off as well as of the timing of flight movements through the spread and level of charges in absolute terms, as well as the time-related dynamization of the system and consideration of the nuisance effect in the vicinity of an airport, are necessary in order to define the specific circumstances at individual airports. Effective monitoring and reporting, as well as the strengthening of the financing function, can encourage the transparency and effectiveness of the instrument in the medium and long term.'

30 Economic measures for the reduction of the environmental impact of air transport: noise related landing charges (FKZ 201 96 107), Oko-Institut e.V., May 2004

Jacobs Consultancy, Review of Airport Charges

This report sets out to identify all of the charges which are used to recover or contribute to the infrastructure and environmental costs associated with the arrival at, and departure from, an airport by a sample of eight different aircraft types, carrying a typical passenger load on an international flight. In order to ensure consistency in the comparisons made, the results do not necessarily represent actual amounts paid directly or indirectly by passengers.

The Review contains comments on the Index of charges, provides a description of the charges and of the specific effects of security charges, and discusses a number of issues which influence the level at which charges are set and the system employed in the US where airport charging systems differ from those in the rest of the world. It provides a review of pricing formulae at a number of airports around the world but does not include ground handling charges in the analysis.

LeighFisher, Review of Airport Charges 2011

For more than 20 years, LeighFisher has produced an annual report which sets out to help airport management teams, investors, finance sector analysts, and airlines gain a better understanding of how airports worldwide stack up in terms of relative operational and financial efficiency.

The report compares the sum of aeronautical arrival and departure charges at 50 of the world's busiest airports for a sample of eight aircraft that are most predominant in airline fleets. The report also provides an extensive historical background of aeronautical charging systems and methods of airport price regulation. In addition to being a benchmarking resource, the report can be used to inform pricing discussions between airports, regulators, and airline users.

APPENDIX B

Sources of information

The systems of charges at airports are, in general, published annually. Records to the current financial year (2013/14) have been obtained for Heathrow, Gatwick and Stansted since 2001/2, and Manchester, East Midlands and Birmingham since 2002/3.

At the designated airports, the airport charges are set out in the Conditions of Use (CoU) documents. Data has been obtained from consultation documents relating to the subsequent year’s scheme.

Manchester Airport publishes a Schedule of Charges and Terms, and Conditions of Use document, and Birmingham Airport publishes a Fees and Charges document. Both of these apply from 1 April for the given publication year. East Midlands Airport publishes a Scale of Fees and Charges plus Standard Conditions of Use document which applies from 1 May for the given publication year.

These documents contain a comprehensive schedule of the Airport Charges, i.e. the charges imposed on airlines by airports. Charging elements include the following: passenger/cargo aircraft runway charges, General Aviation (GA) charges, charges on landing, charges on passengers (departing, facilities, security, disabled, persons of reduced mobility), noise penalties, Air Traffic Services charge, baggage handling and ground handling charges, and aircraft parking charges.

There are differences in the charging structures for airports, some reflecting differences in their shares of the market. For example, Birmingham and East Midlands Airport make provision for training flights, and Manchester for military operations.

CAPITA SYMONDS

CPRE~~Regular Music~~

Kent International Airport - Manston
~~2~~

Aircraft Noise Assessment

Draft

Technical Report

~~**Regular Music**~~

CPRE~~Gig on~~
Kent International Airport - Manston
Noise Assessment
June 2005~~2~~

Appendix A **Glossary of Acoustic Terms**
Figure 1 **Location of Noise Measurement Positions 1 and 2**
Figure 2 **Location of Noise Measurement Positions 3**
Appendix B **Photograph of Kent International Airport noise monitoring station and noise monitoring equipment used on behalf of the CPRE**

Capita Symonds Ltd		
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1. INTRODUCTION

Capita Symonds has been appointed by the CPRE to carry out a noise assessment of aircraft using Kent International Airport at Manston in Thanet, Kent.

Thanet District Council presently has a Section 106 agreement with Planestation, the operators of Kent International Airport. At the end of 2004 the airline operator EU Jet began operating short haul flights to various European destinations. The introduction of the services by EU Jet has brought a rapid increase in the amount of air traffic passing through the airport with further substantial increases anticipated in the coming years ahead. To take account of the recent increase of air traffic at the airport and future proposals the operators are working with Thanet District Council to review the Section 106 Agreement. Public consultation is being made as part of this exercise.

The following tasks have been undertaken as part of the noise assessment:

- Measure noise levels of a sample of aircraft passing overhead at locations in both the rural environment to the west of the airport and the urban environment of Ramsgate to the east.
- Carry out a frequency analysis of aircraft at the same locations in 1/3 octave bands
- Comment upon the likely impact of the noise levels upon these areas

2. NOISE SURVEYS

An aircraft noise survey was carried out during the late afternoon and early evening period of Friday 29th April 2005 between 15.00 and 20.00.

A background noise survey was carried out during the evening of Wednesday 15th June 2005 during periods when there was no aircraft activity.

Both surveys were carried out in accordance with British Standard BS 7445.

A type 1 Larson Davis 593 sound level meter was used during the aircraft noise survey, a type 1 Larson Davis 820 was used for the background noise survey. Both sound level meters hold a cuurent accredited calibration certificate. Additionally, a calibration check was made immediately prior to and on completion of both noise surveys and was found to be within tolerance for both meters.

Description of locations:

Noise measurements were made from 3 positions during the survey. Position 1 and 2 were to the west of the main runway in a rural environment. Position 3 was to the east of the main runway in the urban environment of the built-up area of Ramsgate. A more detailed description of each position follows:

Position 1 – Position 1 is approximately 3.5Km from the western end of the runway and approximately 300m north of the flight path of aircraft approaching the main runway from the west. It lies just off the St. Nicholas roundabout at a Council road maintenance storage area. The stockpiled road chipping provided screening from vehicles approaching the roundabout.

Position 2 – Position 2 is at the roadside at the junction between Seamark Road and Plumstone Road. This location is approximately 2.2Km from the western end of the runway

Position 3 – Position 3 is in the built-up area of Ramsgate at the junction between Elms Avenue and George Street next to Clarendon House Grammar School. This position is approximately 2.8Km from the eastern end of the main runway.

3. AIRCRAFT NOISE SURVEY

Weather conditions:

During the survey the weather was mild for the time of year, dry with sunny conditions. Measurements were made periodically during the survey using an anemometer. The wind was determined to be from a south south west direction with gusts reaching a maximum of 3.5 m/s.
A shift in the wind direction towards the end of the survey resulted in the last flight of the survey shown in table 6.5 approaching the runway from the opposite direction from aircraft landing earlier during the survey

Initially measurements were recorded from positions 1 and 2 to the west of the main runway. Owing to the wind direction aircraft were taking off in a westerly direction heading towards measuring positions 1 and 2. These positions are shown in Figure 1.

Later during the survey measurements were taken at position 3 to the east of the main runway. Again, due to the wind direction aircraft were on the landing approach to the airport at this location.

4. BACKGROUND NOISE SURVEY

Weather Conditions

During the background survey the weather remained dry warm with clear skies. There was a strong wind from the south of approximately 7m/s.

5. BACKGROUND NOISE MEASUREMENTS

Table 5.1 Background Noise Levels

Location	Date	Start Time	Duration mins	Leq	Lmax	Lmin	L(10)	L(90)
1	15-Jun	17:30:00	15	66.2	78.5	61	67.8	63.7
1	15-Jun	19:15:00	15	63.2	73.8	55.5	65.6	59.1
1	15-Jun	20:45:00	15	61.8	76.7	53	64.2	57.4
2	15-Jun	18:15:00	15	59.8	81.5	47	57.1	49
2	15-Jun	19:45:00	15	58.4	77.8	44.9	55.4	46.5
2	15-Jun	21:15:00	15	54.1	76	42.4	53	46.1
3	15-Jun	18:45:00	546.1sec*	60.2	71.4	44.4	64.8	47.4
3	15-Jun	20:15:00	15	53.4	67.3	38.8	55.9	41.5
3	15-Jun	21:45:00	15	51	65.9	38	51.2	39.4

* measurement stopped short of 15 min run due to approaching EU Jet Fokker F100

6. SITE SURVEY NOISE MEASUREMENTS OF AIRCRAFT

Table 6.1 – Measurement 1 from Position 1 of Fokker F100 , E U Jet on landing approach heading south east, 25 second duration

Start Time 15.03.02	dB L	dB A	Background Level 15.06.05
SPL Max	75.5	68.4	
Leq	71.4	63.1	57 – 64 LA90 15 min
SEL	85.6	79.8	
LIN Peak	85.7	80.2	

Table 6.2 – Measurement 2 from Position 1 of Fokker F100 , E U Jet on landing approach heading south east, 31 second duration

Start Time 15.14.01	dB L	dB A	Background Level 15.06.05
SPL Max	81.6	74.9	
Leq	76.6	70.9	57 – 64 LA90 15 min
SEL	91.6	85.3	
LIN Peak	90.7		

Table 6.3 – Measurement 4 from Position 2 of Fokker F100 , E U Jet just after take-off heading north west, 31 second duration

Start Time 16.23.38	dB L	dB A	Background Level 15.06.05
SPL Max	86.9	81.9	
Leq	82.0	75.3	46 – 49 LA90 15 min
SEL	96.9	90.2	
LIN Peak	99.6		

Table 6.4 – Measurement 5 from Position 2 of Fokker F100 , E U Jet just after take-off heading north west, 30 second duration

Start Time 16.43.50	dB L	dB A	Background Level 15.06.05
SPL Max	89.8	84.3	
Leq	83.7	77.7	46 – 49 LA90 15 min
SEL	98.6	92.5	
LIN Peak	102.2		

Table 6.5 – Measurement 6 from Position 3 of Fokker F100 , E U Jet on landing approach heading north west, 30 second duration

Start Time 19.46.00	dB L	dB A	Background Level 15.06.05
SPL Max	83.3	79.2	
Leq	77.4	72.2	39 – 47 LA90 15 min
SEL	92.3	87	
LIN Peak	93.8		

Position 1 was selected as a location from which to take measurements as this is the site of the airport's own noise measuring location, refer to photograph 1 in appendix B. It should be emphasised that background noise levels at this location are significantly higher than most other locations to the west of the runway owing to the close proximity of the airport's noise monitoring equipment to the busy dual carriageway road A299.

An increase in aircraft traffic will lead to an increase in vehicle traffic on the A299 leading to the airport. Consequently an increase in aircraft traffic causing increased road traffic will also raise background noise levels at location 1.

At location 1, just (**10 metres – could this be confirmed please**) away from the dual carriageway aircraft noise levels are not significantly higher than the high background noise levels dominated by vehicle traffic. During the background noise survey the strong wind from the direction of the road resulted in a worst case background noise level.

At the rural position 2 a location that is more typical of the general area road noise from the A299 was still the dominant noise. Reduced background noise levels could therefore be anticipated in the substantial area further from the A299 that is still close to the western end of the runway. From tables 6.3 and 6.4 it can be seen that passing aircraft produce noise levels subtantially above background noise levels.

In the urban environment of Ramsgate centre at location 3 the greatest difference between background noise levels and noise levels from passing aircraft is shown in table 6.5. This difference will have a significant impact upon people's enjoyment of using the town's amenities, have an impact upon speech intelligibility and a detrimental effect upon the learning environment.

It can be seen when comparing background noise levels with the L_{eqT} overflying aircraft noise measurements noise levels are increased by up to 30dB A. To quantify this further an increase of 10dB A is the equivalent of a doubling of noise perceived by the human ear.

Since aircraft on flightpaths to the east of the runway either land or taking off generally take a route across the centre of Ramsgate much of the town will experience noise levels similar to those measured. Although there are various methods of assessing disturbance from aircraft in the vicinity of airports the measured noise levels at position 3 would indicate that a large number of residents are likely to be affected by noise from aircraft using the airport.

To the west of the airport in the rural environment background noise levels are generally lower than those within Ramsgate. Those enjoying the rural amenities such as the public footpaths and nature reserve are likely to be disturbed by aircraft in an otherwise tranquil setting.

1. Frequency Analysis

Chart 1 shows the third octave frequency spectra of a Fokker F100 , E U Jet passing overhead immediately after take-off heading north west when measured from position 2.

Chart 2 shows the third octave frequency spectra of a Fokker F100 , E U Jet passing overhead on the landing approach heading north west when measured from position 3.

A prominent tonal component can be identified in the third octave spectra if the level of a one-third octave exceeds the level of the adjacent bands by 5dB or more.

Chart 2 suggests that there is a prominent tonal component in the low frequency spectra at 32Hz. Whilst no other tonal components can be identified in the third octave spectra a distinct low whine can be heard from these aircraft which may be evident in a more detailed narrow band analysis.

The two charts show there is some variation in the shaping of the frequency spectrum between the measurements taken for the aircraft shortly after take-off and the aircraft on the landing approach. Common to both sets of analysis is the fall off in frequency levels only at the higher end of the spectrum somewhere in the range of 4,000Hz and 8,000Hz. Speech generally occurs within the range of 250Hz and 4,000Hz so it can be seen that speech intelligibility will be disrupted at the recorded levels without people raising their voices. In turn this is likely to spoil peoples enjoyment of the local amenities and is likely to have a detrimental effect upon those in a learning environment as discussed further on in this report.

Chart 1 – Third octave frequency spectra recorded at position 2 whilst E U Jet passes overhead

Immediately after take-off dB

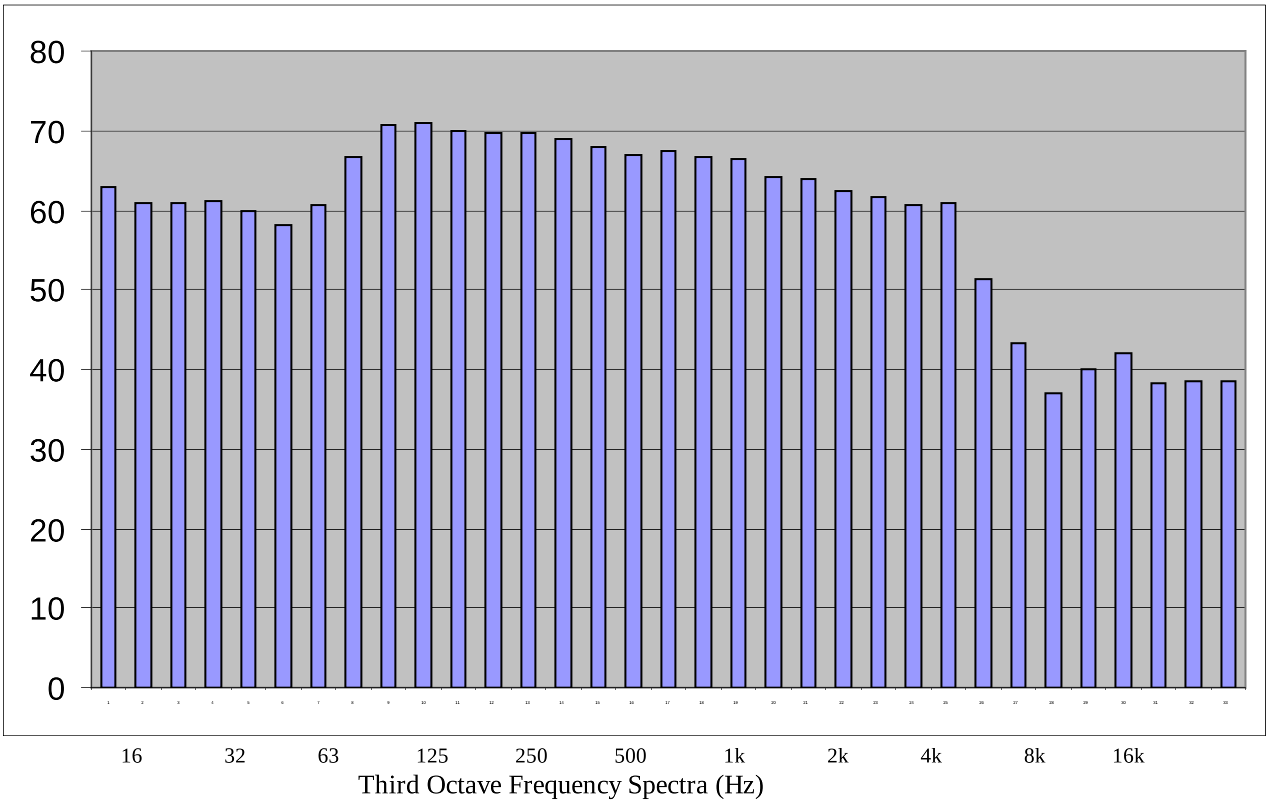
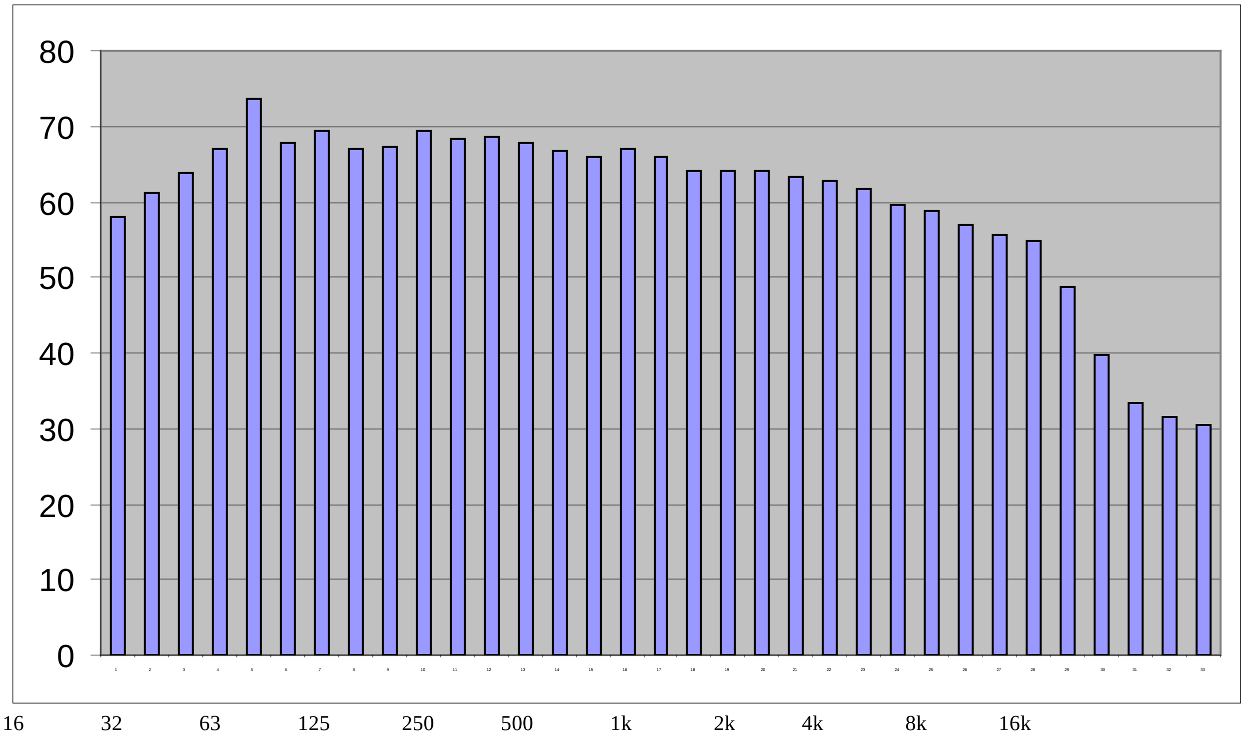


Chart 2 – Third octave frequency spectra recorded at position 3 whilst E U Jet passes overhead

on approach to landing dB



2. Effect upon the Rural Environment

The area immediately to the west of he main runway is predominantly rural which provides a more peaceful environment for the nearby inhabitants of Broadstairs, Margate and Ramsgate wishing to enjoy the countryside. There are public footpaths in this area including the Saxon Shore Way which is strongly promoted by Thanet District Council. There are dedicated cycle routes in the area close to the runway including the Viking cycle route. During the background noise survey a local cycle race was taking place with many participants using the public roads in the vicinity of the airport.

Monkton Nature Reserve is located just 2.7 Km from the western end of the main runway. The reserve provides a recreational facility in this locality for those wishing to visit and enjoy its tranquil environment. The reserve provides a home to a rich array of natural British wildlife including mammals, reptiles, rare plants and bats. The reserve acts as a field study centre with an extensive library available to visiting parties including groups of school children. The effects of noise upon children's education is covered further on in this report. Additionally, the reserve has a large telescope which is available to groups of people interested in astronomy on suitable nights. It is likely that this leisure activity could be severely disrupted by night flights at Kent International Airport.

The beaches around the Thanet coast are an important recreational facility to local residents and are important in attracting tourists. The beaches along the north coast of Thanet are significantly affected by noise from aircraft using Kent International Airport whilst Ramsgate beach, which attracts large numbers of visitors during the summer is severely affected with aircraft passing directly overhead.

Effect upon the Urban Community of Ramsgate

Ramsgate is a densely populated town of approximately 42,000 inhabitants most of which are living in close proximity to the flightpath and are likely therefore to be disturbed by aircraft noise.

Ramsgate Schools

The Department of Health has carried out research with the assistance of Prof. Shield and Prof. Dockrell into the effect of noise upon children's learning. Their research was based upon three boroughs selected to be representative of the urban environment of London.

The report contains many relevant findings however some of the most significant findings of their report relevant to the situation of schools in Ramsgate are as follows:

Noise measurements taken were found to exceed those recommended by the W.H.O. and also those recommended in the guidance for building new school buildings Building Bulletin 87* (now superseded).

During the course of the investigations children reported that they were sometimes annoyed by external noise.

The predominant external noise source was from road traffic with air transport also being a significant factor.

Conducted experiments found that noise was not only annoying to pupils in some instances but also had a negative impact upon some learning tasks.

It is clear from the research carried out by the W.H.O, the Department of Health, and many other research establishments, that there is a general consensus that intrusive noise levels can disrupt and hinder learning and the problem is widespread in schools throughout the United Kingdom.

Recent changes in legislation have been introduced in an attempt to combat the disruption to children's education caused by noise disturbance. These include increased standards demanded by the Building Regulations and the introduction of Building Bulletin 93 providing advice on construction details. This legislation only applies to the construction of new school buildings. 16 schools have been identified in Ramsgate that are in close proximity to the flight path of aircraft using Kent International Airport. These schools have not been constructed recently and will not have been constructed to the higher acoustic standards recently introduced.

7. CONCLUSION

A noise survey of a sample of E U Jet aircraft using Kent International Airport – Manston was carried out on Friday 29th April 2005.

The noise levels measured suggest that people enjoying the amenities such as public footpaths and Monkton Nature Reserve in the relatively tranquil rural area to the west of the airport runway are likely to be disturbed by the increase in background noise levels caused by aircraft.

From position 3 close to the centre of Ramsgate the measured noise levels of aircraft passing overhead suggest that a large number of people may be disturbed by aircraft using the airport when considering the usual flightpath aircraft take over the town.

An analysis of third octave frequency spectra suggests some low frequency tonality to the noise of aircraft passing overhead which may become more apparent on more detailed analysis.

Previous research carried out by various bodies have concluded that both road and aircraft noise have a detrimental effect on children's concentration and learning ability. As a consequence of this new legislation requires a higher standard of new school buildings. 16 schools have been identified in Ramsgate which will not have been subject to the new higher design standards but are likely to experience disturbance from aircraft using Kent International Airport.

Bibliography

Research carried out by Prof. Shield and Prof. Dockrell on behalf of the Department of Health into the effect of noise upon children's learning.

APPENDIX A

GLOSSARY OF TERMS

A1. DEFINITIONS AND UNITS

A1.1 Noise is defined as unwanted sound. The range of audible sound is from 0dB to 140dB, which is taken to be the threshold of pain. The sound pressure detected by the human ear covers an extremely wide range. The decibel (dB) is used to condense this range into a manageable scale by taking the logarithm of the ratio of the sound pressure and a reference sound pressure.

A1.2 The unit of frequency is Hz. 1 Hz is one pressure fluctuation in one second. The frequency response of the ear is usually taken to be about 16Hz (number of oscillations per second) to 18,000Hz. The ear does not respond equally to different frequencies at the same level. It is more sensitive in the mid-frequency range than at the lower and higher frequencies, and because of this, the low and high frequency component of a sound are reduced in importance by applying a weighting (filtering) circuit to the noise measuring instrument. The weighting which is most used and which correlates best with the subjective response to noise is the dB(A) weighting. This electronic filter matches the variation in the frequency sensitivity of the meter to that of the human ear. This is an internationally accepted standard for noise measurements.

A1.3 The ear can just distinguish a difference in loudness between two noise sources when there is a 3dB(A) difference between them. Also when two sound sources of the same noise level are combined the resultant level is 3dB(A) higher than the single source. When two sounds differ by 10dB(A) one is said to be twice as loud as the other.

A1.4 A few examples of noise of various levels are given below:

Sound Level, dB(A)	Environmental Condition
0 – 10	Threshold of hearing
10 - 20	Broadcasting Studio
20 – 30	Bedroom at night
30 – 40	Library
40 – 50	Living room urban area
50 – 60	Typical Business Offices
60 – 70	Conversation Speech
70 – 80	Average traffic on street corner
80 – 90	Inside bus
100 – 110	Alarm Clock (1m away)
110 – 120	Loud car horn (1m away)
120 – 130	Pneumatic drill (1m away)
130 - 140	Threshold of pain

A1.5 The subjective response to a noise is dependent not only upon the sound pressure level and its frequency, but also its intermittency. Various statistical indices have been developed to try and correlate annoyances with the noise level and its fluctuations in a changing noise environment. The indices and parameters used in this report are defined below:

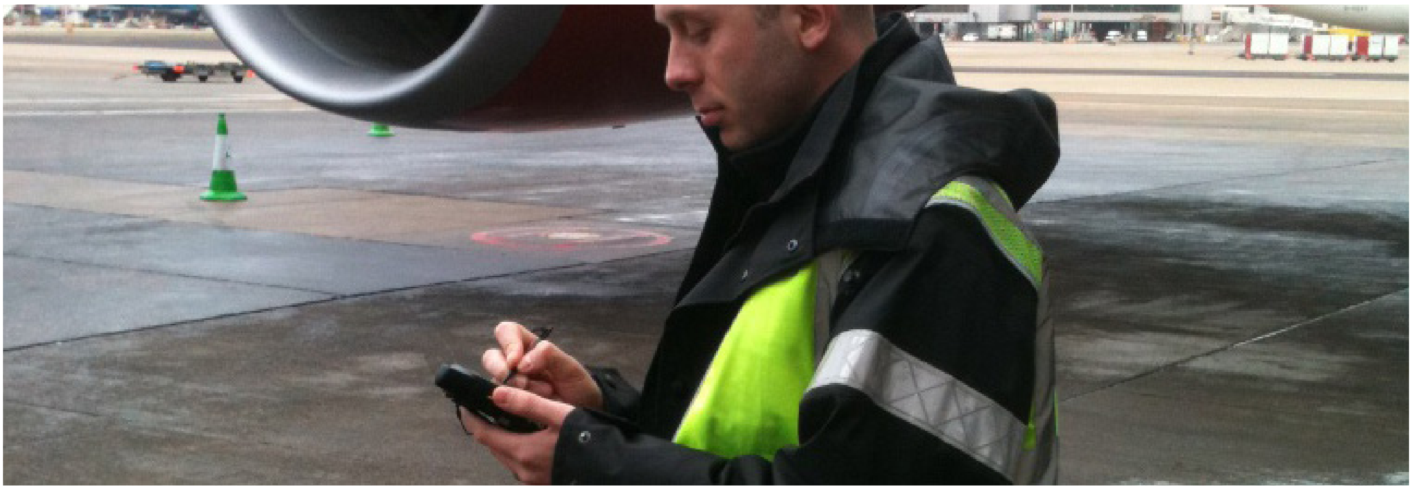
A1.6 L_{Aeq}: Equivalent Continuous Sound Pressure Level The A-weighted sound pressure level of a steady sound that has, over a given period, the same energy as the fluctuating sound under investigation. It is in effect the energy average level over the specified measurement period (T) and is the most widely used indicator for environmental noise.

A1.7 L_{AN}: the A-weighted sound level exceeded for N% of the measurement period. In BS7445 the L_{A90} is used to define the background noise level, i.e. the noise that would remain once all local noise sources were removed. The L_{A10} gives an indication of the upper limit of fluctuating noise and is used in the assessment of road traffic noise.

A1.8 L_{AMAX}: The maximum 'A' weighted noise level recorded during the measurement period.

IMPROVING AIRCRAFT TURNAROUND TIMES

VIRGIN ATLANTIC DEPLOYS AVTURA'S REAL-TIME AIRCRAFT TURNAROUND TOOL (RATT™) TO LEAD ON PUNCTUALITY



VIRGIN ATLANTIC

Virgin Atlantic is one of the world's most instantly recognizable brands. Flying to North America, the Caribbean, the Middle East, Asia and Australia from London Heathrow, London Gatwick, Manchester and Glasgow airports it's the second-largest long-haul carrier operating from the UK.

Virgin Atlantic is renowned for pioneering new services and technology to improve performance. This drive was behind its desire to improve the way aircraft are turned around. When a plane lands, a complex array of services must come together quickly to ensure an on-schedule departure. Traditionally, the industry has relied on paper-based processes to manage turnarounds. But this caused inefficiencies, with the dispatcher often having to leave the aircraft side – where he or she really needs to be – to send important messages from a PC at the gate. In addition, central dispatch teams had no real-time view of aircraft status.

Virgin Atlantic has transformed the way it manages turnarounds by deploying Avtura's real-time turnaround system. Its dispatchers access the software via handheld computers for pro-active coordination of turnaround services and provide a real-time view of status to central teams. The easy-to-use technology is improving productivity by allowing dispatchers to be at the heart of the action and contributing to enhanced on-time performance (OTP) and lower delay costs: Over the last 24 months, Virgin Atlantic has achieved a 30% reduction in the proportion of flights delayed by over 15 minutes. As a result Virgin Atlantic's OTP is routinely ahead of its key competitors, making it the most punctual Heathrow-based airline.

CUSTOMER PROFILE

Organisation
Virgin Atlantic

Location
The UK

Industry
Airlines

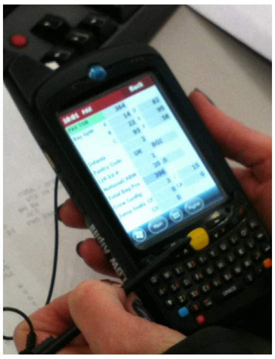
Partner
Avtura

Motorola Solutions' products
- 18 MC65 rugged handheld computers
- 3 ES400 rugged handheld computers

Applications
The pro-active coordination of aircraft turnaround services with time alerts if any service is running behind schedule. The system also provides messaging and reporting functionality to provide a real-time view on an turnaround status

"On-time performance is a key metric for any airline. Research tells us that customers' top priority is to depart and arrive on time and get their bags quickly. This is why we deployed Avtura's real-time automated turnaround software as part of our drive for improved punctuality. Working with Avtura we reviewed the critical elements in our turnaround process and mapped these to its RATT software. The technology, which converts a complex set of tasks into an intuitive application for dispatchers, has helped us embed a step-change in our on-time performance, improving our service to customers and having a knock-on benefit on costs."

Joe Thompson, General Manager, Airport Operations, Virgin Atlantic



CHALLENGE

Managing the turnaround of a wide-bodied passenger jet requires the complex and timely synchronization of an array of tasks and services. Traditionally, airlines have used paper-based processes to manage turnarounds. But this caused inefficiencies. The sending of key messages required dispatchers to leave the aircraft and run to the gate – losing valuable time. Also, the central dispatch team could not see a real-time status of their turnaround operation. With these issues in mind, Virgin Atlantic looked to deploy a new mobile computing system to coordinate turnaround. It also wanted to ensure that, with airport authorities looking to better share information between air traffic controllers, airlines, and the airport management, it was in a position to provide real-time status information to these partners.

SOLUTION

Virgin Atlantic was part of a trial of Avtura's RATT undertaken by the Heathrow Airport Limited (HAL). Its favorable impression of the solution led it to deploy the technology to manage its turnaround operations. RATT is a Software-as-a-Service solution, with a series of pre-configured applications available to customers. These were customized to Virgin Atlantic's requirements with new features also added.

The dispatchers are the focal point of the turnaround operation at the main base airport. RATT provides them with details of each service that their incoming aircraft needs, together with a precision "critical time path" of when each has to be completed. If a service is running behind, RATT prompts them. They can then use their handheld computer to call suppliers without leaving the aircraft. They can also use their computer to message controllers – e.g. sending important load information to the team that calculates take-off parameters – and confirm in real time when each service, from cleaning to refueling, catering, and more, is completed. The system also provides details on incoming aircraft – e.g. the location of cargo and the baggage of premium passengers to prioritize unloading. And dispatchers can use the computer's camera to record images such as damage to the aircraft interior, exterior, or cargo to attach to safety reports.

Users visited Motorola Solutions' Training Center to trial the handheld computers recommended by Avtura. The key criteria for the computers were that they should be rugged and durable, provide a simple interface, integrate a phone, and offer accessories so that individuals could select the best way for them to carry the device. Dispatchers chose Motorola Solutions' MC65 and Duty Managers chose Motorola's ES400 rugged PDA.

BENEFITS

As RATT is a SaaS solution it requires no integration with the back office and was rolled out quickly. It enables proactive management of the turnaround process. Dispatchers spend more time with the aircraft, with live prompts on their computer alerting them to potentially late services. All data captured by dispatchers on their handheld computer is available to the business in real time so dispatch can view a live dashboard showing the status of all operations – offering assistance if any red flags are showing.

RATT put Virgin Atlantic ahead of the game at London Heathrow when it came to sharing its turnaround status with airport authorities, as part of a wider drive to improve airport performance. It's similarly ready – ahead of peers – to provide the same information at London Gatwick when their new system rolls out this year.

But the key benefit lies in the fact that, over the last two years, Virgin Atlantic has embedded a step-change in its punctuality, reducing the number of flights delayed by more than 15 minutes by over 30%. This is a huge gain when perceptions of customer service are so tied to punctuality. It also reduces costs – improving punctuality means that the cost of delayed baggage and, accommodating delayed passengers, is cut significantly. Virgin Atlantic expects that there's more to come too: it will use data captured by RATT to identify performance trends and drive further improvements.

Benefits

- **Improved On-Time Performance (OTP):** Virgin Atlantic is the leading base carrier for OTP from London Heathrow (based on Feb12-Jan13)
- **Reduced costs:** Delay costs such as baggage delivery and overnight accommodation for mis-connected passengers are falling
- **Real-time view:** Dispatchers can intervene and provide assistance if red flags are indicating problems with a turnaround
- **Ongoing efficiencies:** Data collated by RATT can be analyzed to identify process improvements

For more information on how Motorola Solutions' rugged handheld computers can improve the efficiency of your turnaround operations please visit us on the web at www.motorola.com/Business/XU EN/Business+Solutions/Industry+Solutions/Transportation or access our global contact directory at www.motorolasolutions.com/contactus

MOTOROLA

www.theguardian.com/environment/2018/dec/05/sea-levels-may-rise-more-rapidly-due-to-greenland-ice-melt

Sea levels may rise more rapidly due to Greenland ice melt

Run-off from vast ice sheet is increasing due to manmade global warming, says study

Jonathan Watts Global environment editor

Wed 5 Dec 2018 18.19 GMT First published on Wed 5 Dec 2018 18.17 GMT

Rising sea levels could become overwhelming sooner than previously believed, according to the authors of the most comprehensive study yet of the accelerating ice melt in Greenland.

Run-off from this vast northern ice sheet – currently the biggest single source of meltwater adding to the volume of the world's oceans – is 50% higher than pre-industrial levels and increasing exponentially as a result of manmade global warming, says the paper, published in Nature on Wednesday.

Almost all of the increase has occurred in the past two decades – a jolt upwards after several centuries of relative stability. This suggests the ice sheet becomes more sensitive as temperatures go up.

"Greenland ice is melting more in recent decades than at any point in at least the last four centuries, and probably more than at any time in the last seven to eight millennia," said the lead author Luke Trusel, of Rowan University.

"We demonstrate that Greenland ice is more sensitive to warming today than in the past – it responds non-linearly due to positive feedbacks inherent to the system. Warming means more today than it did even just a few decades ago."

The researchers used ice core data from three locations to build the first multi-century record of temperature, surface melt and run-off in Greenland. Going back 339 years, they found the first sign of meltwater increase began along with the industrial revolution in the mid-1800s. The trend remained within the natural variation until the 1990s, since when it has spiked far outside of the usual nine- to 13-year cycles.

Greenland currently contributes about 20% of global sea-level rise, which is running at 4mm per year. This pace will probably double by the end of the century, according to the most recent models used by the UN Intergovernmental Panel on Climate Change. How the new study affects those projections will be the subjects of future study by the authors. **If all the ice in Greenland melted, it would raise sea levels by seven metres.** At the current pace that would take thousands of years, but the ongoing acceleration could bring this forward rapidly.

"At some point, sea-level rise will be too fast for us to adapt to, so we really have to avoid this situation by reducing emissions," said the study's co-author Michiel van den Broeke of Utrecht University. "I think this is one of the many wake-up calls that we have had in the last few decades. It clearly links manmade global warming to sea-level rise."

The research comes out as policymakers from around the world are attending UN climate talks in Katowice, Poland, where governments are trying to set new rules to keep global warming to between 1.5C and 2C. The authors said the paper underlined the dangers of exceeding even the lower figure.

"On a personal level it is worrying to see this – along with the vast array of other scientific evidence showing that we've entered unprecedented or exceptional times," said Trusel.

"The ice has no political agenda – it either grows or melts. Today it is melting as humans have warmed the planet. The ice sheets have tipping points, and how quickly they impact our livelihoods through sea level rise depends on what we do now and in the very near future."

Other academics, uninvolved in the paper, said the new study was an important confirmation of what scientists have long suspected: that the recent increase in ice melt is ominously unusual.

"The Greenland ice sheet is like a sleeping giant who is slowly but surely awakening to ongoing global warming, and there are surprises in its response. However, the response may be more rapid than previously believed," said Edward Hanna, professor of climate science and meteorology at the University of Lincoln.

Article

Travel trends: 2017

Annual estimates of travel and tourism visits to the UK and associated earnings and expenditure between the UK and the rest of the world.

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Notice

17 August 2018

We published Travel trends 2017 on 20 July 2018, containing the main tables for the publication. Not all the tables were published on 20 July: some were delayed due to the work ongoing to modernise the data collection approach underpinning Travel trends.

The following tables have now been added:
Section 2: Overseas residents' visits to the UK, 2013 to 2017
Section 3: UK residents' visits abroad, 2013 to 2017
Section 6: Overseas travel and tourism, Quarter 4 (Oct to Dec) 2017

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1 . Main points

- There was a record number of visits to the UK in 2017 and a record number of visits abroad by UK residents.
- There were 39.2 million visits by overseas residents to the UK in 2017, 4% more than in 2016.
- There were 72.8 million visits overseas by UK residents in 2017, an increase of 3% when compared with 2016.
- Overseas residents spent £24.5 billion on visits to the UK in 2017, an increase of 9% compared with 2016.
- UK residents spent £44.8 billion on visits overseas in 2017, which was 2% more than in 2016.
- The most frequent reason for visits was for holidays, both for UK residents visiting abroad and overseas residents visiting the UK.
- Business visits decreased in 2017, both for UK residents visiting abroad and overseas residents visiting the UK.
- This version of Travel trends publishes the full set of tables, along with the associated Travelpac publication; the previous version (published on 20 July 2018) included the main travel and tourism results, the full set of tables have been published later due to work ongoing to modernise the data collection approach underpinning Travel trends.

2 . Things you need to know about this release

Travel trends is an annual report that provides estimates and profiles of travel and tourism visits (those of less than 12 months' duration) and associated earnings and expenditure between the UK and the rest of the world.

The International Passenger Survey (IPS) has been providing the source data for travel and tourism since 1961. The IPS is in the process of modernising its data collection approach from data collected on paper forms to an improved method using tablet computers. Tablet data collection was phased in gradually from September 2017 to April 2018 and this transition has required extensive additional data processing and quality assurance.

For this reason the edition of Travel trends originally published (on 20 July 2018) included the main results, but not the full suite of tables. This edition of Travel trends includes the full suite of tables. The tables added for this edition are:

- Section 2: Overseas residents' visits to the UK, 2013 to 2017
- Section 3: UK residents' visits abroad, 2013 to 2017
- Section 6: Overseas travel and tourism, Quarter 4 (Oct to Dec) 2017

The information provided in this report is used in a number of ways, including:

- to track earnings and expenditure, as an important input to measuring balance of payments
- to understand how the volume of visits and earnings to the UK develops, which can be compared with statistics from other countries to assess how effective the UK is in attracting visits from main parts of the world, for different purposes and among different demographic groups
- to help understand how particular events held in the UK (for example, the London 2012 Olympic Games and Paralympics and Royal Weddings) link to visits and spending, which can aid future decision-making
- to provide insights into how effective different parts of the UK are in attracting visits and earnings, in total and from different parts of the world and for different purposes
- to provide profiles of UK residents travelling to different parts of the world, to aid government and industry in developing policy and strategy

Estimates contained in this bulletin are produced from responses provided by international passengers arriving in and departing from the UK, sampled on our International Passenger Survey (IPS).

Responses to the survey are scaled up to represent all passengers using information on total international passenger traffic for the reporting period.

The reported spend for visits include any spending associated (excluding fares) with the visit, which may occur before, during or after the trip.

Parts of the bulletin refer to countries visited abroad. It should be noted that if a UK resident visited more than one country on a trip abroad, the country recorded as visited in this publication is the country that was visited for the longest period.

Estimates are subject to sampling error and confidence intervals are provided to help you interpret the estimates (see Section 5 Quality and methodology).

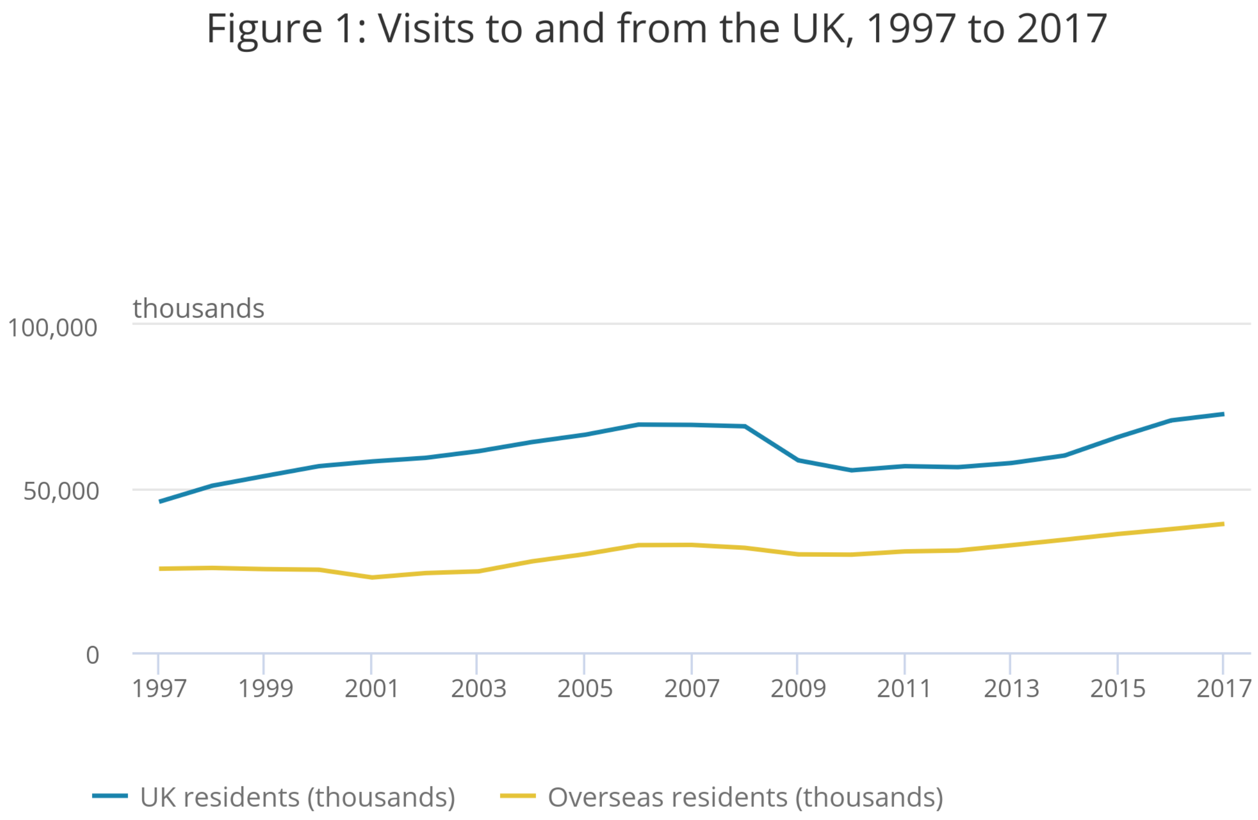
Overseas travel and tourism monthly estimates are revised during the processing of the quarterly dataset and again during the processing of the annual dataset. This bulletin contains final estimates for 2017.

3 . UK trips abroad and visits to the UK continue to rise

There were 72.8 million visits overseas by UK residents in 2017 (see Figure 1), an increase of 3% compared with 2016 and the highest figure recorded. The number of visits has increased each year since 2012.

There were 39.2 million visits by overseas residents to the UK in 2017 (see Figure 1), 4% more than in 2016 and the highest figure recorded. The number of visits has increased each year since 2010. Over a longer period there has been a general upward trend in the number of visits to the UK. In 1997 there were 25.5 million visits.

Figure 1: Visits to and from the UK, 1997 to 2017



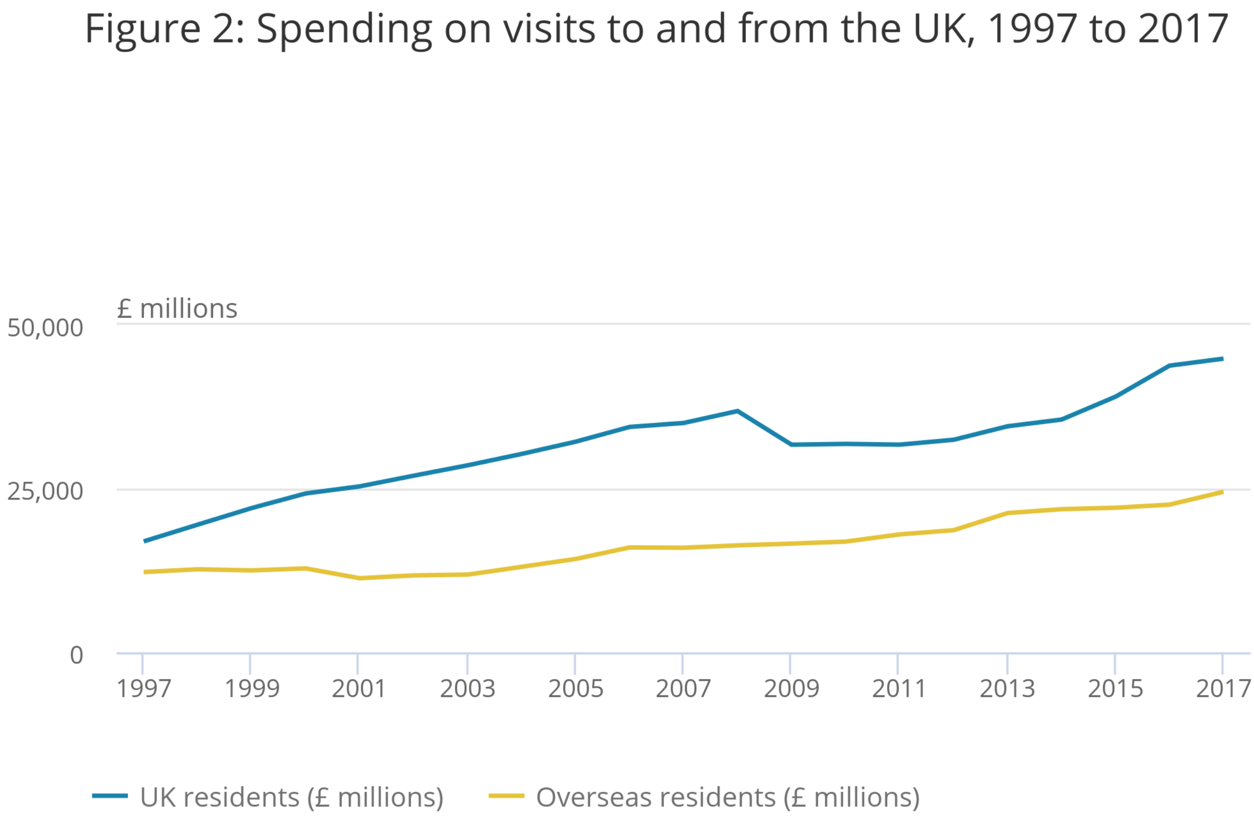
Source: Office for National Statistics

UK residents spent £44.8 billion on visits abroad in 2017, which was 2% more than in 2016 (see Figure 2). The increase in spending was similar to the increase in the number of visits (3%).

Overseas residents spent £24.5 billion on visits to the UK in 2017, an increase of 9% compared with 2016 (see Figure 2). The increase in spending was larger than the increase in the number of visits (4%).

The trends in spending by UK visitors abroad and overseas visitors to the UK broadly reflect the trends in visits.

Figure 2: Spending on visits to and from the UK, 1997 to 2017



Source: Office for National Statistics

Holidays are still the most common reason for visiting the UK

There were 15.4 million holiday visits to the UK in 2017, an increase of 11% and accounting for 39% of the total visits. This makes holidays the most common reason for visiting the UK. The number of holiday visits in 2017 was 1.5 million more than in 2016. Visits to friends and family (12.0 million) and miscellaneous visits (3.1 million) increased in 2017. The number of business visits fell from 9.2 million in 2016 to 8.8 million in 2017, a decrease of 4%.

Overall, there have been increases in visits to the UK since 1997 for all these reasons for visits. This is despite falls in some years, notably in 2001 (due to Foot and Mouth disease as well as the events of 11 September that year) and 2009 (following the start of the economic downturn).

UK residents' visits abroad continued to increase into 2017

There were 72.8 million visits overseas by UK residents in 2017, the highest figure recorded by the International Passenger Survey (IPS). The most common reason for travelling abroad was for holidays. There were 46.6 million holiday visits abroad by UK residents, 4% more than in 2016 and accounting for almost two-thirds (64%) of visits. By comparison, there were 29.1 million holiday visits abroad in 1997.

There were 17.6 million visits overseas to visit friends and family in 2017 (6% more than in 2016) and 6.8 million business visits in 2017 (5% fewer than in 2016). Consequently, there was a fall in business visits both by UK residents abroad and by overseas residents visiting the UK.

4 . What's changed in this release?

This edition of Travel trends is the first to include data collected by tablet, rather than the previous paper-based collection. Rollout of tablet data collection started in September 2017 and completed in April 2018 when Heathrow Airport moved to tablets. The proportion of data collected by tablet in 2017 is therefore relatively low. More information can be found in a separate note on changes to data collection and planned methodological changes.

5 . Quality and methodology

The International Passenger Survey (IPS) Quality and Methodology Information report contains important information on:

- the strengths and limitations of the data and how it compares with related data
- uses and users of the data
- how the output was created
- the quality of the output including the accuracy of the data

The estimates contained in Travel trends (as well as our other Overseas Travel and Tourism statistics) are subject to sampling errors, which are driven by the fact that IPS is a survey. It is important to understand the factors that dictate the quality of the estimates. Confidence intervals relating to a wide range of estimates are provided under the Accuracy of overseas travel and tourism estimates section.

The collection of the IPS data

The key to producing reliable results from the IPS lies initially in the way the data are collected. Great emphasis is therefore placed upon the IPS interviewers to ensure they are able to capture data efficiently and accurately.

Nationally, IPS data are collected by a team of over 200 interviewers who are recruited and trained specifically to work on the IPS. Interviews are carried out on all days of the year, apart from Christmas Eve, Christmas Day, Boxing Day and New Year's Day.

IPS interviews take place on a face-to-face basis. Until recently, responses were initially recorded on paper forms. In September 2017, data collection on tablets started to be phased in and this implementation was completed in April 2018. Now data are keyed directly into the collection program, which includes a series of electronic checks. Most of the data presented in this report, however, were collected on paper. For these cases, shortly after the interview has taken place, the data are transferred to a computer system in which electronic checks are made of the data input. The data are then transmitted to ONS headquarters where a series of further quality and accuracy checks are made on the data before processing and analysis.

Due to the layout and facilities at some seaports it is not always possible to interview passengers as they arrive. In such cases, IPS staff interview on board vessels leaving or returning to the UK, or on board the Eurotunnel Trains.

More information about the collection of IPS data can be found in the IPS Overseas Travel and Tourism User Guide (Volume 1): Background and Methodology (PDF, 423KB).

IPS response rates

Sample surveys such as the IPS depend on achieving high levels of response from the public. Non-respondents often have different characteristics of travel and expenditure compared with those who do respond and this can lead to biases being introduced into the results.

The response rates for the air, sea and the Channel Tunnel samples are shown in Table D.1. These response rates relate to complete and partial interviews. The overall response rate in 2017 was 74.1%. Information about the construction of the IPS overseas travel and tourism response rates can be found in the IPS Overseas Travel and Tourism User Guide (Volume 1): Background and Methodology (PDF, 423KB). For information about the 2017 response rates contact socialsurveys@ons.gov.uk.

Table 1: IPS Response Rates for 2016 and 2017 estimates: % Of complete or partial responses

		2016 Q1	2017 Q1	2016 Q2	2017 Q2	2016 Q3	2017 Q3	2016 Q4	2017 Q4	2016	2017
Total IPS Response Rate	Arrivals	78.9	68.7	78.3	71.2	74.0	70.1	76.7	74.7	76.8	69.3
	Departures	80.5	75.8	80.8	76.4	78.0	73.9	79.7	76.6	79.7	77.4
	Total	79.8	72.9	79.7	74.3	76.3	72.3	78.4	75.9	78.4	74.1
IPS Response Rate (Air)	Arrivals	78.4	66.7	77.7	68.3	73.0	68.2	76.2	72.6	76.1	68.3
	Departures	80.0	74.7	80.3	74.9	77.4	72.2	79.7	75.2	79.3	76.1
	Total	79.3	71.5	79.2	72.3	75.5	70.5	78.3	74.2	77.9	73.0
IPS Response Rate (Sea)	Arrivals	84.0	84.0	88.8	89.6	82.1	86.3	84.6	88.7	84.7	88.0
	Departures	84.0	88.0	87.2	89.4	79.6	86.0	78.0	88.8	81.9	88.4
	Total	84.0	86.0	87.9	89.5	80.7	86.0	80.7	88.8	83.2	88.2
IPS Response Rate (Tunnel)	Arrivals	79.8	80.0	74.3	83.9	74.6	71.6	75.8	83.3	76.0	63.8
	Departures	85.3	85.8	79.2	90.6	84.2	88.4	80.8	89.2	82.3	89.5
	Total	82.4	82.4	76.7	86.4	79.3	79.8	78.1	86.3	79.0	74.9

Source: Office for National Statistics

Accuracy of overseas travel and tourism estimates

Annual figures shown in this publication are final estimates, previous estimates provided in the monthly and quarterly publications are provisional and subject to revision in light of additional passenger data obtained at the end of each year.

IPS estimates are revised in line with the IPS revisions policy. The revisions policy is available in the IPS Quality and Methodology Information report to assist users in the understanding of the cycle and frequency of data revisions. Users of this report are strongly advised to read this policy before using this data for research or policy-related purposes.

Planned revisions usually arise from either the receipt of revised passenger traffic data or the correction of errors to existing data identified later in the annual processing cycle. Those of significant magnitude will be highlighted and explained.

Revisions to published quarterly IPS estimates for 2017 can be expected in the publication of the annual overseas travel and tourism report (Travel trends).

All other revisions will be regarded as unplanned and will be dealt with by non-standard releases. All revisions will be released in compliance with the same principles as other new information. Please refer to the ONS guide to statistical revisions.

Some of the series presented are seasonally adjusted. This aids interpretation by identifying seasonal patterns and calendar effects and removing them from the unadjusted data. The resulting figures give a more accurate indication of underlying movements in the series.

The estimates produced from the IPS are subject to sampling errors that result because not every traveller to or from the UK is interviewed on the survey. Sampling errors are determined both by the sample design and by the sample size – generally speaking, the larger the sample supporting a particular estimate, the proportionately smaller is its sampling error. The survey sample size is approximately 70,000 per quarter for travel and tourism interviews.

Table E1 shows the 95% confidence intervals for the 2017 estimates of the total number of visits, nights and expenditure for both overseas residents visiting the UK and UK residents going abroad. These represent the interval into which there are 19 chances out of 20 that the true figure (had all travellers been surveyed) would lie.

If, for example, the relative 95% confidence interval relating to an estimate of 10,000 was 5.0% there would be 19 chances out of 20 that the true figure (if all travellers had been surveyed) would lie in the range 9,500 to 10,500.

Table E1: IPS confidence intervals for 2017 estimates

	Estimate	**Relative 95% confidence interval (+/- % of the estimate)**
Overseas visitors to the UK		
Number of visits ('000s)	39,214	2.3%
Total earnings (£million)	24,507	3.3%
Number of visitor nights ('000s)	284,781	3.0%
UK residents going abroad		
Number of visits ('000s)	72,772	1.8%
Total expenditure (£million)	44,840	2.5%
Number of visitor nights ('000s)	743,469	2.5%

Source: Office for National Statistics

The confidence intervals dataset for 2017 shows estimates relating to various purposes for visit and region of the world, together with regions of the UK visited. Relative confidence intervals are also shown for estimates relating to individual country of visit to and from the UK.

Further guidance for readers is provided about the quality of overseas travel and tourism estimates.

One indication of the reliability of the main indicators in this release can be obtained by monitoring the size of revisions. The monthly statistical bulletin provides information about the size and pattern of revisions to the quarterly IPS data that have occurred over the last five years to the following main seasonally adjusted estimates:

- the number of visits by overseas residents to the UK (GMAT)
- the number of visits abroad by UK residents (GMAX)
- earnings made from overseas residents in the UK (GMAZ) and
- expenditure abroad by UK residents (GMBB)

Access to IPS data and analysis

IPS results published by ONS

In addition to Travel trends, we also publish provisional monthly and quarterly results from the IPS that are available free of charge from our website. The most recent monthly results currently available are for December 2017, due to delays for processing and additional quality assurance.

The website also provides more information about the International Passenger Survey methodology including the current IPS questionnaire and interviewer instructions.

Accessing datasets

1. To enable easier examination of the IPS data, a simplified version of the IPS dataset called Travelpac, comprising 14 of the most widely used variables, is available. Data are available online for each year from 1993 onwards, in both SPSS and Excel formats. Travelpac data for 2017 were added on 17 August 2018 due to delays for processing and additional quality assurance.
2. Larger IPS datasets are available through the Data Archive at Essex University. Contact details are as follows:

Telephone: +44 (0) 1206 872143

Web: Data Archive Homepage

Table TSGB0211 (AVI0203)
Worldwide employment by UK registered airlines: 2007 to 2017

Number

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Pilots and co-pilots	11,259	11,631	10,690	10,237	10,188	10,232	10,159	10,416	10,889	12,354	12,354
Other cockpit personnel	152	111	125	97	27	33	33	11	4	0	0
Cabin attendants	34,369	35,457	31,592	29,463	30,782	31,554	31,375	31,644	32,569	33,271	34,286
Maintenance and overhaul personnel	9,075	8,681	8,325	7,949	8,223	8,699	8,836	9,034	8,780	8,503	8,009
Tickets and sales personnel	6,258	6,314	5,997	5,477	4,704	5,030	4,975	4,986	5,229	4,861	4,794
All other personnel	24,571	25,266	22,551	20,861	21,553	21,521	20,456	14,296	20,632	21,162	20,021
Total	**85,684**	**87,460**	**79,280**	**74,084**	**75,477**	**77,069**	**75,834**	**70,387**	**78,103**	**80,151**	**79,464**

1. Personnel related to staff in full and part time employment.
2. Personnel figures represent employment as at the end of each calendar year.

Source: Civil Aviation Authority
Last updated: November 2018
Next update: November 2019
Telephone: 020 7944 4847
Email: aviation.stats@dft.gov.uk
The figures in this table are outside the scope of National Statistics

Airport jobs: false hopes, cruel hoax

Brendon Sewill

Brendon Sewill has an economics degree from Cambridge. He has been an adviser in the Treasury, and to the British Bankers Association, a member of the Council of the National Trust, a member of the CPRE national executive, and a vice president of the British Trust for Conservation Volunteers. Having lived all his life near Gatwick he developed an interest in the impact of aviation on the environment, and is chairman of the Gatwick Area Conservation Campaign.

In 2003, on behalf of a number of environmental groups, he persuaded the government to rerun their computer forecasts on the assumption that by 2030 air travel would be paying the same rate of tax as car travel. The dramatic results of this exercise were set out in *The Hidden Cost of Flying* (AEF, 2003), in which he also calculated the value of the tax concessions for aviation at £9 billion a year, a figure that has gained wide acceptance.

In *Fly now, grieve later* (AEF, 2005) he summarised the concerns about the impact of air travel on climate change, and explored the political and practical problems in making airlines pay sensible rates of tax.

Colleagues from other environmental groups have encouraged him to write this booklet, and he would like to thank all those who have contributed much helpful information.

AEF gratefully acknowledges the contributions of WWF-UK, HACAN Clearskies, and Stop Bristol Airport Expansion towards the costs of printing and distributing this publication.

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CONTENTS

EXECUTIVE SUMMARY

1. **With the current recession, when thousands are losing their jobs, any promise of more jobs is welcome. Airports and airlines for their own commercial reasons tend, however, to exaggerate the number of jobs that will be created by airport expansion.**

2. **Claims that airports create 'indirect', 'induced' and 'catalytic' jobs are based on dubious statistical concepts.**

3. **Between 1998 and 2004, despite a 30% rise in air passengers, the total employment attributed to airports and airlines actually went down.**

4. **Master Plans produced by each airport are inconsistent, and their employment forecasts are little better than guesses – designed to influence local councillors and planners.**

5. **The Airport Operators Association has forecast that by 2030 an increase of 104 % in the number of passengers passing through UK airports will produce a 21% increase in jobs at airports.**

6. **UK residents took 41.5 million more return flights for leisure in 2005 than foreigners came here for leisure. The aviation tourism deficit is costing the UK about 900,000 jobs as a result of people spending their money abroad instead of here.**

7. **Aviation – direct employment at airports and by airlines – provides under 200,000 jobs in the UK. Thus at present air travel is costing the UK roughly a net 700,000 jobs.**

8. **That is not a moral judgement that people ought to spend their holidays in Britain, merely a statistical fact that flying abroad creates jobs elsewhere, not in this country.**

9. **As a result of the Government's plans for the growth in aviation, the situation is due to get worse. By 2030 the UK tourism deficit in terms of return trips by air passengers is forecast to double, to 88.5 million.**

10. **The growth in air travel is likely to lead to a net loss of a further 860,000 UK jobs by 2030. This loss of jobs will affect every part of the UK.**

INTRODUCTION

Like ‘sex’, the word ‘jobs’ makes an excellent tabloid headline: short, sharp and emotive. It stirs deep folk memories of the poor law and the workhouse, and of the mass unemployment of the 1920’s and 1930’s. Being without a job, with a prospect of hardship, anxiety and loss of self-respect, is still the dread of almost every family of working age. With the current recession, when thousands are losing their jobs, and millions fear that they may do so, any promise of more jobs is welcome.

Thus the suggestion that a new or expanded airport will create more jobs is a sure way to attract support from the public and a fair wind from the planners. Naturally airport companies and airlines make the most of this. Yet because they have a commercial interest in magnifying the number of new jobs, their figures need careful examination. False hopes can prove a cruel hoax.

TOTAL EMPLOYMENT IN AVIATION

There are no official statistics showing the number of people employed in the aviation industry. Undeterred by the lack of hard facts, the Air Transport White Paper (2003) supported the Government’s plans for airport expansion with the claim: “The aviation industry itself makes an important contribution to our economy. It directly supports around 200,000 jobs, and indirectly up to three times as many.” These figures were based on a report commissioned and paid for by the aviation industry from a consultancy firm, Oxford Economic Forecasting (OEF).[1]

The definition of aviation used by OEF included airline and airport operations, passengers and freight services, aircraft maintenance, air traffic control, and on-site retail and catering, but excluded aircraft manufacture. Since there are no official statistics, OEF stated that they ‘put together these statistics from a number of sources.’ Their conclusion was that in 1998 the aviation industry in the UK generated around 180,000 jobs (full-time equivalents).

The Department for Transport (DfT) produced a Progress Report in December 2006, and made a similar claim. ‘The aviation industry makes a significant contribution to employment and investment in the UK economy. It is itself a substantial employer, providing around 200,000 jobs directly and [somewhat more cautiously] many more indirectly.’

This statement was based on a further report by OEF produced in October 2006.[2] Using figures supplied by the Airport Operators Association, OEF found that the aviation industry directly employed 186,000 people in 2004.[3] That is the latest figure which is available.

EMPLOYMENT CATEGORIES

Discussion about employment in aviation is usually carried out in terms of different categories. The exact definitions vary from one study to another but are broadly as follows:

Direct on-airport: All jobs within the airport boundary, including hotels, catering and retail.

Direct off-airport: Employees outside the airport working directly for airport and airline companies; for example, airline offices where these are located outside the airport.

Indirect: Jobs in firms which supply goods and services to the aviation industry. OEF quote jobs in the energy sector generated because of airline purchases of aircraft fuel; in the aerospace industry because of airline purchases of aircraft equipment; construction workers at airports; and the workers required to manufacture the goods sold in airport retail outlets.[4]

Induced: Jobs created when aviation employees (direct and indirect) spend their income. For example, when an airline pilot buys a loaf of bread he is helping to create employment for bakers.

Travel agents: OEF (but not other studies) also added employment in travel agents on the grounds that travel agents mainly sell holidays by air.

Catalytic: Jobs in firms attracted to the area as a result of the transport links created by the airport. Since these firms will normally be relocating from other parts of the UK, there is little effect on total national employment.

The two OEF studies gave the figures for each category (excluding catalytic) in 1998 and 2004 as follows:

	1998	**2004**
Direct airport jobs	180,000	186,000
Indirect jobs	200,000	167,000
Induced jobs	94,000	88,000
Travel agents	75,000	82,000
Total	549,000	523,000

The significant thing about this table is that it shows that in six years when the number of passengers passing through UK airports rose by 30%, the number of direct jobs at airports only went up 3%. Moreover during these years, **the total level of employment attributed to aviation actually went down.**

In every document produced by the aviation industry, or by the Department for Transport on their behalf, these categories of employment are trotted out as if they are indisputable truths. They are used to back up claims that airport expansion creates many jobs 'in the wider area.' Yet each of the concepts is distinctly dubious.

Mini-hoax?

The figures for 1998 above appeared to be the basis for the White Paper statement "The aviation industry ... directly supports around 200,000 jobs, and indirectly up to three times as many"*.* At first sight that sentence seems to suggest that the number employed indirectly is *three* times the number employed directly. But the table above shows that the number employed indirectly, including induced and travel agents, is actually *twice* the number employed directly.

The phrase would be true if it is construed as meaning that the total number employed, directly *and* indirectly, is three times the number employed directly. Let us hope that the civil servants who drafted the White Paper were deficient in their grammar, not in their mathematical honesty.

Direct employment includes a substantial number of jobs in airport shops. Airport shops do not provide much extra employment; they mainly take business away from the High Street. Indeed buying goods at an airport is basically illogical: it is cumbersome to carry shopping on and off an aircraft. The only reason why most people shop is that, due to possible delays in reaching the airport, and long check-in times, many people arrive several hours before their flight and are corralled with little else to do; and because of the lure of duty and tax free goods - an unjustified subsidy for aviation. It could be argued that jobs in airport shops should be included in the statistics of retail employment, not under aviation.

Indirect employment has a certain validity as a statistical concept but has the fatal flaw that it means double-counting people employed in other industries. For example, it is stated that it includes jobs in producing aircraft fuel: thus it may include some workers on the North Sea oil rigs. Since these people are also included in the statistics of workers in the oil industry, there is obvious double-counting.

The inclusion of construction workers is incorrect: Government guidance says that they should be classified under 'construction', and not be included in the industry for which they may be undertaking a project.[5]

If every other industry used the same technique the number of people employed in British industry would far exceed the total population.

The definition of indirect employment also leads to some rather far-fetched results. It is said to include the workers who produce the goods sold in airport shops: thus it includes, for example, the Scottish distillery workers who produce the whisky sold in airport duty-free shops.

Travel agents do depend largely on selling holidays by air. But with the increasing trend to buy flights and book hotels on the internet, travel agent employment is likely to decline. Again there is double counting: travel agents are also included in the statistics of employment in the tourist industry.

Induced employment could be a valid concept if applied to public works designed to relieve serious unemployment. John Maynard Keynes in 1936 used the concept of the multiplier to explain how providing extra employment could trickle down through the economy. Yet as he acknowledged, this theory was mainly applicable to a situation of mass unemployment. "It is obvious that the employment of a given number of men on public works will ... have a much larger effect on aggregate employment at a time when there is severe unemployment, than it will have later on when full employment is approached."[6]

Moreover, many of the induced jobs are not created in the local area: the baker who bakes the pilot's loaf may be local but the man on the oil rig certainly is not. To the extent that a sizeable proportion of expenditure by every family these days is on goods produced abroad, the induced jobs will not even be created in the UK.

According to OEF and other airport studies, induced employment includes jobs due to purchases by both direct and indirect airport employees, again leading to some far-fetched results. Thus it includes not only the bakers who provide the bread for the airline pilots but also the bakers who provide bread for the oil rig workers and the distillery workers. When the man on the oil rig takes a holiday in Cornwall, the hotel staff (or at least a proportion of them) are counted as part of aviation employment. When the distillery worker buys some kippers for his family supper, some of the fishermen who caught the herrings are counted as being employed in aviation!

There is no reason why the process should not go on indefinitely. Why not also take into account that when the fishermen spends some of their income on cabbages that creates jobs for farmers, and when the farmers buy newspapers that helps to create jobs for journalists, and when the journalists fly abroad that creates jobs in aviation, and so on ad infinitum.

FORECASTS OF FUTURE EMPLOYMENT

The DfT forecast that the number of passengers passing through UK airports will increase from 228 million in 2005 to 450 million in 2030.[7] There are, however, no official forecasts of what this might mean in terms of employment.

Perhaps that is not surprising. The future of aviation is almost impossible to predict. Even the passenger figures are subject to huge uncertainties.[8] They depend on the assumptions that:

- after the current recession, growth returns to its previous trend;
- the price of oil remains below $78 per barrel in real terms until 2030;
- there is no increase in tax on air travel to raise revenue;
- any tax imposed for climate change reasons (or the cost of emissions trading permits) will be exceptionally low;
- the growth in aviation is not affected by the recent decision to aim for an 80% cut in CO2 emissions by 2050.

Taking the next step, to translate the number of passengers into the number of employees is fraught with further uncertainty.

For many years there was a rough rule of thumb that every million passengers per annum require a thousand airport and airline (direct) employees. That rule roughly held good for the level of employment at the time of the Air Transport White Paper. In 2003 there were roughly 200 million passengers and 200,000 employees.

It would be rash, however, to predict that every *extra* million passengers will require an *extra* thousand employees. In 2005 the Airport Operators Association commissioned York Aviation to study future employment trends.[9] Their conclusion was that direct airport employment would increase from 185,900 in 2004 to 225,200 in 2030 assuming full expansion of all airports as in the Air Transport White Paper. A forecast increase of 237 million passengers (104 %) in the number of passengers was only expected to produce a 39,300 (21%) increase in jobs. The ratio of extra jobs to extra passengers is only 166, far below 1,000.

Even that may be over optimistic. It has not happened in the past. As previously noted, a 30% rise in UK passenger numbers only produced a 3% rise in employment. The same is true abroad. At Frankfurt airport, flight movements increased 78% between 1978 and 1996, yet employment only rose by 0.6% over the same period.[10]

Promises by airports and airlines that expansion will mean more jobs may not be borne out in the real world. There are a number of changes which will tend to reduce the number of people employed at airports. The low cost airlines have shown how it is possible to make drastic cuts in

Treasury hoaxed

Explaining why he had dropped his proposal to replace air passenger duty by a tax per plane, the Chancellor in his Pre-Budget Report in November 2008 stated that: '*The Government recognises the contribution that the aviation industry makes to the UK economy: providing around 200,000 jobs directly in the industry, employing up to 500,000 people in the supply chain, …'* A footnote explained that this statement was based on the 2006 OEF report.

When it was pointed out to the Treasury that the OEF report showed that the number of jobs 'in the supply train' (i.e. indirect jobs) was 167,000 not 'up to 500,000', their only reply was to put the blame onto the Department for Transport for supplying the information.

staff, with fewer staff at the airport, fewer staff on board and a higher proportion of aircraft seats filled. Although the figures may not be exactly comparable, Ryanair handles over 10,000 passengers for each member of staff whereas British Airways handle under 800.[11] If competition forces the traditional airlines to adopt the low cost model there will be a fall in airport employment.

What is not so generally realised is that there is a parallel move to 'low cost airports' with tickets bought on the internet; check-in done electronically, and baggage handling increasingly automated, so that the same number of airport staff can handle far more passengers. Heathrow Terminal 5 was designed as a self-service terminal - with as many as nine out of ten passengers having no need to contact members of staff until they reach boarding gates.

NEW RUNWAYS 'VITAL FOR JOBS'

by Vincent Moss, Political Editor

Sunday Mirror, 11 January 2009

Airline bosses have warned that 500,000 new jobs would be lost unless the Government backs a major expansion of Britain's airports...

The future may see a move to an even more simplified type of airport. Baggage will be checked-in at the car park, passengers will go straight to the gate room with the security checks carried out just before boarding. That is the Ryanair model, and it is the reason why they complain that at Stansted BAA are planning to build a 'Taj Mahal' terminal.

ARE MORE JOBS A GOOD THING?

Since 'jobs' is such an emotive headline, it seems almost like sacrilege to ask if more jobs in aviation actually benefit the nation. In a recession, more jobs in almost any industry, even jobs digging useless holes in the ground, are welcome.

In more normal times, however, when there is reasonably full employment, if the public have a fixed amount of money to spend, then more jobs in aviation will mean fewer jobs in other industries. This was the point made in a study by Berkeley Hanover Consulting.[12] It has also been acknowledged (sotto voce) by OEF.[13] So more pilots and more air hostesses, more baggage handlers and more air traffic controllers would mean fewer doctors, fewer nurses, fewer teachers, fewer waste collectors, fewer shop assistants, fewer people behind the bar in the pub. That is fine, and good economics, if it reflects real consumer preferences about how they wish to spend their money. And if the prices of the various services reflect their true cost, without any subsidy.

Economic growth, or real wealth per head, is created by increasing efficiency. This means reducing the number of jobs for a given output, not increasing them. More jobs in aviation will only add to economic growth if they replace less productive jobs elsewhere. But many jobs in aviation, such as baggage handling or aircraft cleaning, are relatively unskilled. And they are all subsidised.

Aviation pays no fuel tax and no VAT. It benefits from duty-free sales at airports and from artificially low landing fees. Although it pays air passenger duty this is comparatively low compared to the fuel tax and VAT reliefs. The net tax subsidy received by air travel as compared to car travel is around £9 billion a year.[14]

This means that, on average, the tax subsidy per (direct) job in the aviation industry is £50,000 a year; or £1,000 a week; or £25 an hour.

Any industry could promise to provide more jobs if it received that level of subsidy.

Once upon a time jobs in aviation seemed romantic: brave pilots; seductive air hostesses; far-flung destinations; all the buzz of being at the forefront of technological innovation. Now we have learned how polluting the industry is, however, employment in aviation seems less glamorous. In 2005 UK aviation produced 37.9 million tons of CO_2, forecast to rise to 59.9 million tons in 2030 even after taking into account more efficient aircraft.[15] On average at present each aviation worker is responsible for over 200 tons of CO_2 per year, or the equivalent of around 400 tons if radiative forcing is taken into account.

Each job in aviation is thus about twenty times more damaging to the climate than the average job in the rest of industry (energy supply, business and transport).[16]

MORE LOCAL JOBS?

It is now time to switch from the national to the local picture. Again there are no official statistics for the number of people employed at each airport. The Airport Operators Association and OEF have produced the following table, albeit by now somewhat out-of -date.[17]

Employment in the Aviation Industry, 2004

Airport	Passengers (Million)	Direct employment
Aberdeen	2.64	2,716
Belfast City	2.13	807
Birmingham	8.86	9,071
Bristol	4.65	4,747
Cardiff	1.89	1,932
East Midlands	4.38	4,512
Edinburgh	8.02	2,300
Gatwick	31.47	23,761
Glasgow	8.58	5,442
Heathrow	67.34	68,427
Luton	7.54	7,756
Manchester	21.25	18,000
Newcastle	4.72	4,855
Stansted	20.91	10,592
Other Airports	20.63	21,116
Total	**214.98**	**185,900**

Funny thing is that some of the figures in this table appear to be too high. One might think that the Airport Operators Association would know how many people are employed at each airport, but not so. The Bristol Airport Master Plan compiled by Bristol Airport shows that the number directly employed in 2005 as 2,284, not 4,747. The Birmingham Master Plan shows the total, including some indirect employment, as 7,500 in 2006, not 9,071.

On other occasions airports exaggerate the number of jobs they provide. For example, the East Midlands Airport employee survey claimed 7,089 employees in 2004, compared to the figure of 4,512 shown in the above table. The explanation is thought to lie in the inclusion of non-airport companies located in the airport business park.

Whenever a new airport is proposed, or when plans are announced for the expansion of an existing airport, the airport company invariably claims that it will create more jobs for the local area. These forecasts tend to be optimistic and should be treated with caution.

When Manchester Airport announced in 1991 that it wanted to build a second runway, the Chairman of the Airport company claimed that this would create 50,000 new jobs.[18] A subsequent report, presented by the Airport to the public inquiry, revised the figure to 18,000 new jobs. This figure included indirect and induced employment, and employment in firms which would be attracted to the Manchester area. It also included jobs created by inward tourism - without taking account of outward tourism. The media continued to use the 50,000 figure, and indeed it was repeated by the airport chief executive in 1997 after planning permission was granted.[19]

In the real world, the runway was built, and opened in 2001. The total number of jobs at the airport in 2006 was 4,000 more than ten years previously. Even adding indirect and induced employment at the usually quoted ratios, the increase would be around 6,400. It is obvious that the figure of 50,000 extra jobs was a flight of fancy.

The Air Transport White Paper encouraged the growth of most airports in the UK. It also indicated that each airport should produce a master plan. The Department for Transport has, however, now admitted that Master Plans tend to be over optimistic about future passenger numbers. They explain that their forecasts for total UK passenger numbers are lower than the sum total of all the master plans because each airport tends to be over optimistic.[20]

Master Plans do not last forever. Luton Airport published their draft master plan in October 2005, and withdrew it in July 2007, cancelling the previously planned new runway.

Master Plan psychology

Master plans are produced by the airport owners, and are an expression of their hopes for the future. If they were called 'What We Would Like To Happen In Order To Maximise Our Profits' they would be treated with appropriate scepticism. In normal parlance they would be called 'airport plans'. But the addition of the word 'master' implies that all else must be subservient to them. And the fact that they are usually written in capital letters, like God, subtly implies that they are omnipotent and omniscient. Local planning authorities bow. When the Master Plans also contain forecasts of more jobs, the planners genuflect.

Indeed the Government has made master plan genuflection compulsory by amending the planning system so that regional plans and local plans have to take 'Master Plans' into account.

Forecasting the future number of passengers, and the future number of jobs, at each airport is largely guesswork. Individual circumstances, the balance of scheduled versus charter flights, the importance of low cost airlines and the scope for creating jobs well away from the region (e.g. British Airways engine maintenance in Cardiff and software support in Bangalore, India) all make these numbers unreliable.

The ratio of 1,000 extra jobs per 1 million extra passengers is sometimes too low, sometimes much too high At Exeter in 2005 there were 1,359 jobs per million passengers, predicted to fall to 1,029 in 2030. At Bristol the ratio was 439 jobs per million passengers, predicted to rise (yes, rise) to 454 by 2030; at Edinburgh the ratio is forecast to rise from 376 at present to 391 in 2030. All three airports look to be in the running for awards for inefficiency!

At Luton some councillors were quoting the 1,000 jobs per million passengers until it was pointed out to them that the growth in jobs at the airport in the ten years to 2006, based on the local council's annual employment survey, had been around 100 jobs per million passengers.

> Announcing the go-ahead for the third runway at Heathrow, Transport Secretary Geoffrey Hoon said**:** *"Heathrow airport supports over 100,000 British jobs. A third runway is forecast to create up to 8,000 new on-site jobs by 2030 and will provide further employment benefits to the surrounding area."* (January 2009)

The explanation for variations in employment forecasts may be that the forecasts are tailored to what will best impress the public and the planners. For example, the Heathrow 2005 Interim Master Plan[21] recorded 68,400 direct on-airport jobs, a ratio of 1,021 jobs per million passengers. However, the Terminal 5 Inspector had concluded that the maximum the area could support was 61,500 jobs. So the Master Plan predicted that, even if by 2015 passenger numbers grew by 40%, the number of jobs would fall by 10%. Very convenient!

The fear that increasing efficiency will lead to a loss of jobs is a potent weapon in the hands of airport proponents. When existing jobs are at risk, all the airport workers must inevitably vote for expansion. The Government consultation document *Adding Capacity at Heathrow Airport* suggested that by 2030, with the airport operating as at present the number employed at the airport would have fallen to 52,400 but that - if a new runway and new terminal were to be built - the number would be 60,400.

Fear of a loss of jobs through new technology is not a good reason to promote otherwise unjustified expansion. If it were, we would now have a large number of people employed as charcoal-burners, fletchers, wheelwrights, ostlers and postillions.

There appears to be a tendency for airport owners to pitch their guesses high in areas where they reckon that extra jobs would be welcome to the local population and to the local councils; and to pitch their guesses low where extra jobs would be less popular. At Gatwick, which has for fifty years had a high level of employment, extra jobs are seen as causing problems for local firms. There is strong opposition to the in-migration of labour which creates a demand for additional housing in an area where the protection of the countryside has a high priority. Surprise, surprise, the Gatwick Interim Master Plan (October 2006) showed no extra jobs being created between 1997 and 2015 despite a forecast increase in passengers from 25 to 40 million. [22]

The Gatwick Master Plan contains details of a possible additional runway designed to double the size of the airport, making it larger than

Heathrow today. Yet it contains none of the usual hyperbole about the extra employment that would be created. BAA know only too well that local councillors would be appalled at the prospect of building still more houses, more offices and more factories in the Surrey and Sussex countryside.

Every Master Plan, except Gatwick's, contains high flown rhetoric about the number of jobs created in the wider community, by indirect, induced or catalytic employment. The Aberdeen Master Plan claims that 2,800 jobs at the airport support 9,000 other jobs across Scotland. Birmingham claims that 'Taking account of additional indirect and induced impacts, in 2006, it is estimated that the Airport supported around 10,490 full time equivalent jobs in the West Midlands Region.' Heathrow, with 70,000 employees, 'supports over 100,000 further jobs right across the UK.'

As we have seen, the concepts of indirect and induced employment are distinctly dubious at national level; they become even more dubious at a local level.

Local indirect employment

To recap, indirect employment is defined as jobs in firms which supply services to the airport. Clearly there will be some local firms connected to the airport, for example local hotels or off-airport car parking. Airport construction workers may be local but temporary. Many indirect jobs will, however, be in other parts of the UK, or abroad, although in respectable job statistics these are not included. Aircraft fuel will provide jobs in the North Sea or in Saudi Arabia; and purchases of aircraft equipment may come from Airbus in Toulouse or from Boeing in Seattle. Airport shops are not noted for selling local produce.

In the SERAS studies conducted for the Department for Transport in the run-up to the 2003 White Paper, consultants Halcrow listed various previous studies which had worked out indirect employment ratios, that is the number of local indirect jobs for each direct airport job. The figures varied between 0.2 for Newcastle and 0.45 for Stansted. The average was 0.3.[23] But all these studies had been commissioned by aviation lobbying organisations.

It is true that investment creates employment. But jobs are used to justify anything and everything. If recession strikes, the political value of any scheme which boosts them will rise. Projects which in more prosperous times might have been rejected by planners or ministers will suddenly find favour. Anyone who stands in their way - however daft the schemes may be - will be walloped as an antisocial Luddite.

But the big question is asked very rarely in the press: how reliable are these promises? Whenever a new defence contract or superstore or road or airport is announced, newspapers and broadcasters repeat the employment figures without questioning them. They rarely return to the story to discover whether the claims were true.

George Monbiot, *The Guardian*, 1 April 2008

Local induced employment

We have seen already that induced employment is a concept which leads to some far-fetched results. That is even more so on a local level. When the airline pilot buys his bread there is a fair chance that the baker to whom he gives employment will be situated in the local area. But practically everything else he buys in the supermarket will have come from all over the UK, indeed all over the world. When he buys a banana he will be providing induced aviation employment in the West Indies.

In 1995 the Treasury suggested a figure of 0.2 for the regional induced employment ratio.[24] The Halcrow study for SERAS found a range of values, varying from 0.2 at Birmingham Airport to 0.5 at Stansted, the variation being due to the use of different definitions. The average was 0.3 although this calculation was not included in the final version of the SERAS consultation paper as even the DfT admitted that the number was difficult to calculate accurately.

DO AIRPORTS ATTRACT FIRMS TO THE AREA?

Airport companies love to talk about catalytic employment. It is a long, arcane and erudite word - and therefore must be true. It means that airports act as a catalyst (as in a chemical reaction) and attract firms to the vicinity. Catalytic employment is a beggar-my-neighbour concept. Any firms attracted to the area will have come from some other area, which will thus lose jobs. It is also somewhat old-fashioned: electronic communications and teleconferencing mean that air travel is less vital for business operations.

A key academic study of this subject, although applying mainly to road transport, was carried out for the Department for Transport by Professor Ronald W. McQuaid and colleagues at the Transport Research Institute at Napier University, Edinburgh.[25] They found that:

"There is a wide body of knowledge stretching back to the 19th Century outlining the theoretical transport-related drivers of business location, …. This initial review indicates that transport is a factor in business location decisions but is neither the only, nor the most important factor. There are cases where the linkages between transport investment in isolation and industrial location appear to be weak, or indirect. …."

"The evidence suggests that transport is a necessary, but not sufficient condition in determining business location. Other factors such as a skilled and/or cost of workforce, the quality of the local environment and cost of premises have been shown to be equally, if not more important when considered in isolation. Research has also shown that climate, business environment and government assistance may be magnets for business location…. transportation costs are typically found to be only a very small proportion of firms' total costs - usually less than 5%. As such, any improvements to the transport infrastructure is likely to yield small cost savings and gains to firms."

The South West Regional Development Agency commissioned the consultants EKOS to undertake an economic assessment of South West Regional Airports. Their report, published in December 2007, found that "The relationship between high growth sectors in the region and air travel appears to be weak. Air travel may not necessarily be a prerequisite for economic growth"

A 1998 survey of Economic Development Officers in local authorities concluded that the availability of workforce skills and suitable development sites were of equal or greater importance than transport in terms of attracting inward investment. [26]

Aviation proponents quote a number of business surveys which put good communications, or proximity to an airport, as an important reason for their choice of location. One of the most often quoted is the 'European Cities Monitor' conducted annually by the commercial real estate agents Cushman & Wakefield.[27] For example, the DfT in their consultation on the expansion of Heathrow stated: *A survey of 500 of*

Nearly ten times as many UK businesses support the idea of a fast rail link from London to the North than support expanding Heathrow.

Only 4% of British businesses polled believe they will benefit from expanding Heathrow. 95% said it would make little or no difference. In contrast, 23% of businesses believe they will be helped by a new high-speed rail line to the North, as proposed by David Cameron.

Woodnewton Associates. 5 December 2008.
www.woodnewtonassociates.co.uk

Europe's top companies found that 52% of companies considered transport links a vital factor in deciding where to locate their business; and 58% identified good access to markets, customer or clients as essential. A footnote shows this to be a quote from a BAA document: 'The Economic Benefit of Heathrow' which in turn quoted the European Cities Monitor.

This was based on a survey of 500 senior executives across Europe. 53 % (52 % in 2007) did indeed include 'transport links with other cities and internationally among the factors they considered essential in choosing a location. But it was only fourth in the list of important factors, and closer examination shows that 'links with other cities' included trains and motorways!

Looking at UK companies only, a Cushman and Wakefield survey of 200 executives (presumably part of the same survey) asked what factors were most important in deciding their choice of location. 'Transport links internationally' was only mentioned by 30 % (22% in 2007).[28] Seven other factors were considered more important. This survey is not quoted by the aviation proponents.

OMIS is a leading independent consultancy specialising in business location and corporate relocation, which has for over a decade conducted surveys of CEOs and senior executives of major companies located in the biggest cities across the country. The latest survey of over 5,000 business leaders was carried out between August and November 2005 and the results released in March 2006. It showed little correlation between major cities' air services and their attractiveness to business. Manchester, Glasgow and Leeds were all put higher than London. The previous survey, in 2003, put Leeds (with only a small airport) as the most attractive location for business.[29]

The major Japanese investments in the UK, in car assembly plants at Sunderland, Swindon and Derby, and in electronic and electrical consumer goods in South Wales, prove that the quality of airport facilities/air links are not the most important consideration in relation to inward investment decisions. None of these locations (with the possible exception of Swindon) is anywhere near an airport which offers services to Japan.

The aviation industry, and indeed the Air Transport White Paper, make a great play with the importance of inward investment. The point has been answered by Professor John Whitelegg:

Data for the UK as a whole show that the amounts of money invested by UK companies abroad is higher than that invested by overseas businesses in the UK. If there is a link between the enhanced accessibility provided by international air services (as the aviation industry claim) then it works to the disadvantage of the UK and supports a net outflow of resources. Put very simply potential jobs in the UK are sacrificed for the benefits of investing abroad. Whilst we would not wish to claim that this job loss and net outflow of funds should be "laid at the door" of aviation we also wish to question the logic of the opposite assertion from the industry itself. Inward *investment cannot be claimed as a benefit of airports or aviation. If it is claimed then equal weight has to be given to the debit side of the balance sheet.*

The balance sheet shows a substantial net deficit ... approximately £38 billion each year.[30]

This net deficit has a direct equivalence in job losses. If we accept that the cost of creating a job in the UK is approximately £23,000 (National Audit Office, 1999) then this outflow represents a job loss of 1.65 million each year for 5 years.... This job loss is facilitated by the development of air services and the aviation industry.[31]

BOGUS SURVEYS

The Department for Transport, in their 2006 Progress Report on the Air Transport White Paper, stated that: 'According to the latest research by Oxford Economic Forecasting, access to air services is an important factor for 25 per cent of companies across the whole economy in influencing where they locate their operations within the UK. Access to these services also affects the decisions by 10 per cent of companies as to whether to invest in the UK at all.'

According to the OEF report, "Questionnaires were sent out by OEF to around 6,000 companies and 165 replies were received."[32] Any respectable polling organisation would regard this 2.75% rate of response as exceptionally low and wide open to bias. The poor response means that where OEF and DfT refer to 10% of companies, they are relying on the forms returned - a mere 10% of 165. 16 companies out of 6,000.

The letter sent out to the 6,000 firms explained that: "Oxford Economic Forecasting is conducting this survey on behalf of the CBI, the Department for Transport, a consortium of airlines and airports, and VisitBritain in order to assess the contribution of air services to the UK economy and the competitiveness of UK business. The results of the survey will be presented to the Government to inform the 2006 Progress Report on its White Paper on airports policy." With that powerful introduction it is extremely significant that 5,835 companies did not bother to reply. The conclusion could well be the opposite to that drawn by OEF and the DfT – that over 97% of companies do not consider that air services are sufficiently important to spend ten minutes filling in a questionnaire.

Another bogus survey was contained in a report by York Aviation commissioned by the City of London Corporation in 2008. Based on a survey of London businesses the report argued that air travel is important to the City. But in fact only 44 firms responded, accounting for 38,000 business journeys a year. That is, about 0.1 per cent of Heathrow business journeys.

At Prestwick, SQW Consulting recently produced a study[33] for the South Ayrshire Council and Scottish Enterprise that claimed that 66% of companies used the airport for business trips. Over 1,000 questionnaires had been posted and the survey was sent by email to all members of the Chamber of Commerce. Only 174 replies were received. But, of course, they were the ones most likely to return the questionnaire. If it were to be assumed that all the firms who did not bother to respond were not interested in the airport, then the proportion of firms who used the airport was well under 10%.

THE TWO WAY ROAD

In 1999 the Government Special Advisory Committee on Trunk Road Assessment (SACTRA) reported that: "There is no guarantee that transport improvements will benefit the local or regional economy at only one end of the route - roads operate in two directions, and in some circumstances the benefits will accrue to other, competing, regions."[34]

Sally Cairns of the University of Oxford Environmental Change Institute has commented: "It seems plausible that the two-way road argument could also prove to be relevant for an expansion of UK air capacity."[35] Thus a local firm may be happily supplying goods to a local area but when a local airport is developed it may become possible to supply the area more cheaply by air from somewhere where they can be mass produced.

The argument for airport expansion is, however, usually made in terms of improving communications for businessmen. But that is also a two-way road. The expansion of UK airports with an increased range of destinations is likely to facilitate UK businessmen travelling abroad to set up factories or call centres in countries such as China and India, thus leading to a loss of UK jobs.

It is easy for the managers of, let us say, a biscuit-making business in Furthershire, to believe that the opening of a new airport or the expansion of an existing airport will enable them more easily to travel the world extolling the virtues of Furthershire Biscuits. And make it easier for buyers from abroad to travel to Furthershire, sample the delights of its climate and cuisine, and place large orders for Furthershire Biscuits. The local councillors who all their lives have eaten little but Furthershire Biscuits are, of course, delighted to grant any necessary planning permissions.

What is less easy to envisage, but in the real world just as likely, is that the airport will enable marketing executives from biscuit making companies in France, Germany, Italy or wherever, to fly in, size up the market, and run the old established Furthershire Biscuits Ltd out of business. Like roads, flights go in both directions.

Where an airport only serves a small town it is unlikely to be able to support a wide range of routes. Doncaster Council thought that the creation of the new Robin Hood Airport would bring prosperity and jobs to Doncaster. But in fact it offers scheduled services to 16 destinations, only two of which are daily (to Belfast and Dublin). Eight are to obvious tourist resorts (such as Tenerife) which are unlikely to be used for business purposes. Four of the routes are to Poland, and it is not difficult to guess that these are mainly catering for migrant workers, the exact opposite of the intention of creating jobs for local residents.

Thus it is possible to have a long runway, and to give the local airport a grand name, but still have few flights which are any use to business people. Another example is Manston aerodrome, now re-named Kent International Airport, which apart from charter flights only has a service to Majorca which departs every Friday during the summer, a service to Jersey every Saturday in the summer, and a service to Gran Canaria which departs every Tuesday but only in August. But hope springs eternal. The Manston Master Plan, published in October 2008 predicts a throughput of 6 million passengers a year by 2033 (sic) with employment rising to 7,500.

THE TOURISM EMPLOYMENT DEFICIT

The fact that so many more Brits fly abroad for their holidays than foreigners come here, means a huge loss of jobs in this country. Every part of the country is adversely affected. The UK currently runs a tourism deficit of £19 billion a year.[36] That includes tourists arriving or departing by train or ferry: the tourism deficit due to aviation is around £17 billion a year.

The average pay of people employed in the UK tourist industry is £19,000 a year.[37] It can thus be deduced that the **aviation tourism deficit is equivalent to a loss of roughly 900,000 jobs in the UK.**

A practical businessman might argue that creating a new job involves not only paying the worker concerned but also a roughly similar sum in overheads, such as premises and equipment. Yet providing the premises and the equipment can also be translated into extra jobs, so we come back to the loss of approximately 900,000 jobs. That is on the assumption – a statistical concept, not a likely situation – that if people did not fly abroad, they would spend the same amount taking holidays in the UK.

To repeat, this is a statistical exercise, not a moral judgement. It is not necessary to say that people 'ought' to take holidays in this country. Nor would it be correct to say that environmentalists are kill-joys who want no-one to have a holiday in the sun. But if the jobs created by aviation are to be counted, then the jobs lost by aviation must also be included.

If, to use a different example, people want to eat more bananas and fewer English apples, there is nothing wrong in that. It merely means a slight change in the exchange rate so the UK has to sell more widgets or financial derivatives in order to pay for the extra bananas. In terms of jobs it is merely a statistical issue of how many jobs are lost in the apple orchards here and how many are created in the banana plantations abroad. The banana merchants, unlike the aviation lobbyists, do not try to argue that buying more bananas creates more jobs in the UK.

Two 'moral' issues do arise. One is in relation to the impact of the ever increasing number of tourist flights on climate change. The other is that the number of Brits going abroad, and the trend towards short breaks abroad, is largely caused by the large fiscal subsidy given to aviation by the exemption from fuel duty and VAT (only partially balanced by the air passenger duty). But these issues are not relevant to a discussion of jobs.

The official forecast of the number of tourists coming in and going out, now and in future years, is given in the official air passenger forecasts published in January 2009.[38] Data from the key table is reproduced on the following page. It is assumed that new runways will be built at Heathrow and at Stansted, but 'constrained' means that airport growth is limited to the proposals in the Air Transport White Paper. These figures show the number of passengers passing through airports, so it is necessary to divide by two to get the number of return trips.

A number of points emerge from this table:

- The right hand column shows that in 2005 there were 83 million more UK leisure flights than foreign leisure flights. Thus Brits had 41.5 million more holidays abroad than foreigners came here for pleasure.
- As a result of the Government's plans for the growth in aviation, the situation is due to get worse. In 2015 the UK tourism deficit in terms of numbers of return air passengers is forecast to be 60 million, and by 2030 it will have grown to 88.5 million. (These figures are significantly worse than forecast in November 2007).
- At Heathrow, leisure passengers at present outnumber business passengers by 30 million to 19 million. By 2030, with another runway, the number of business passengers is forecast to rise to 40 million but the number of leisure passengers is forecast to rise to 59 million, with outward bound British tourists outnumbering incoming tourists almost three to one.
- Gatwick maintains its reputation as a bucket-and-spade airport, with six times as many leisure passengers as business passengers. Brits going abroad outnumber foreign tourists coming in by four to one.
- Stansted is also mainly leisure, not business. At present the Stansted tourism deficit in terms of the number of return air passengers is 3 million. Building a second runway would increase the forecast deficit to 8.5 million return passengers. Stansted expansion would, on the same basis of calculation as above, cause the loss of 120,000 UK jobs as a result of people spending their money abroad instead of in the UK[39]: far, far more than any growth in aviation jobs at an enlarged airport.

CONSTRAINED TERMINAL PASSENGERS BY JOURNEY PURPOSE AND YEAR								
2005	**Heathrow**		**Gatwick**		**Stansted**		**National**	
UK Business	12	24%	3	11%	3	14%	40	20%
UK Leisure	19	40%	20	68%	11	55%	116	57%
Foreign Business	7	15%	1	4%	1	7%	15	7%
Foreign Leisure	11	22%	5	17%	5	25%	33	16%
International-International Transfer	18		3		1		22	
Total	66		33		10		225	
2015	**Heathrow**		**Gatwick**		**Stansted**		**National**	
UK Business	15	26%	4	11%	5	14%	57	20%
UK Leisure	24	43%	22	66%	19	55%	162	58%
Foreign Business	8	14%	2	5%	2	7%	20	7%
Foreign Leisure	10	17%	6	18%	8	25%	42	15%
International-International Transfer	21		3		2		26	
Total	78		37		36		308	
2030	**Heathrow**		**Gatwick**		**Stansted**		**National**	
UK Business	26	26%	4	11%	7	13%	91	22%
UK Leisure	44	44%	26	68%	30	56%	234	56%
Foreign Business	14	15%	2	4%	3	6%	32	8%
Foreign Leisure	15	15%	7	17%	13	25%	57	14%
International-International Transfer	34		2		3		39	
Total	133		40		56		452	

DOUBLING THE EMPLOYMENT DEFICIT

The Government's policy of encouraging the doubling of air travel by 2030, will double the aviation tourism deficit, and could mean the loss of a further 900,000 UK jobs in leisure and recreation.

Against this would need to be set any increase in aviation employment. As mentioned earlier, the Airport Operators Association commissioned a study by York Aviation which found that doubling the number of passengers by 2030 could be achieved with a 39,000 increase in direct airport employment.

Thus the Government policy is likely to lead to a net loss of a further 860,000 UK jobs by 2030, as a result of people spending their money abroad rather than in this country. That is an average loss of 3,500 jobs per month - every month - year in and year out.

Air travel may be a great benefit to the UK in that it enables the British public to travel the world, and to enjoy the sun. Or it may be a great disaster in that it is causing ever increasing climate change damage. But what it does not do is to provide more jobs in this country.

More jobs in Alicante, Antigua and Athens; more jobs in Bangkok, Cancun and Corfu; more jobs in Faro, Ibiza, Larnaca and Orlando; more jobs in Palma, Phuket, and Prague. But fewer jobs in Britain.

HOAX BY THE AVIATION LOBBY

The aviation lobby group Flying Matters put out a press release on 3 December 2008, clearly designed to influence the decision on Heathrow expansion.

It was headed: "***Stopping new runways would cost half a million new jobs".*** The text stated that: "*International visitors to the UK from around the world are set to more than double from 32 million last year to 82 million by 2030... The forecast growth in international visitors ... is expected to generate an additional half a million jobs by 2030."*

These figures appear exaggerated, partly because they include visits by train and ferry. The Department for Transport official forecast (as shown in the table on page 19) is that international business and leisure visits by air will increase from 24 million in 2005 to 44.5 million in 2030.

More important, to count incoming tourists without counting outgoing tourists must be statistical rubbish. The correct procedure should be to look at the net tourist deficit.

By admitting the connection between air travel, tourism and jobs the aviation industry has vindicated the approach taken in this study.

ANNEX: THE REGIONAL IMPACT

The seminal work on the cost of regional tourism deficits was done by Friends of the Earth, and published in August 2005.[40] Their conclusions are shown in column A of the table below.

NET LOSS OF JOBS DUE TO TOURISM DEFICIT

Region	Tourism deficit 2005 (£ million)	Tourism jobs lost 2005	Jobs at airports 2004	Net loss of jobs, rounded
	A	B	C	D
North East	- 761	40,000	4,100	36,000
North West	- 2,212	116,000	21,800	94,000
York/ Humber	- 1,610	85,000	2,100	83,000
East Midlands	- 1,339	70,000	6,500	64,000
West Midlands	- 1,680	88,000	7,200	81,000
East of England	- 1,913	101,000	20,000	81,000
London and South East	- 2,335	124,000	96,800	27,000
South West	- 1,240	65,000	6,800	58,000
Wales	- 756	40,000	1,800	38,000
Scotland	- 1,291	68,000	12,400	56,000
N. Ireland	- 114	6,000	5,300	1,000
TOTAL	- 15,251	803,000	184,800	620,000

On the same basis that the average pay in the UK tourist industry is £19,000, column B shows the number of tourism jobs which are at present lost to each region as a result of air travel.

The column C shows the direct employment at UK airports in each region, as reported by the Airport Operators Association.[41] Indirect, induced and catalytic employment are excluded: if they were to be included for airports, they would also need to be included for the UK tourist industry (and the UK tourist industry, if it had a lobby anything like as powerful as the aviation industry, would be busy totting up the number of indirect and induced jobs it provides).

Column D (B minus C) shows the net loss of jobs which is suffered at present by each region as a result of aviation. The totals are lower than the figures given on previous pages as this table applies to earlier years.

For every region the aviation tourism deficit causes a substantial net loss of jobs. Far more jobs are created in the hotels, cafes, golf courses etc in Spain, Italy, Greece, Florida etc - and thus lost here - than are provided by UK airports and airlines.

If the Government were to succeed in its aim of more than doubling air traffic by 2030, the situation would get worse. As shown earlier, the aviation tourism deficit would double. Assuming the increase in air travel were to be spread equally over all regions, the number of jobs lost in each region would double.

Column E in the table overleaf shows the extra leisure and recreation jobs that would be lost as a result of the doubling of air travel by 2030. Since doubling means adding the same again, column E is the same as column B above.

It is then necessary to estimate the extra airport jobs that would be created in each region by a doubling of air traffic. If it is assumed that the 21% increase in direct airport employment, as suggested by the Airport Operators Association, occurs proportionately in each region, it is simple to derive column F as 21% of the figures in column C.

Thus we reach column G, a rough estimate of the net loss of jobs in each region that can be expected as a result of the policy of doubling the amount of air travel.

FUTURE NET LOSS OF JOBS DUE TO INCREASED TOURISM DEFICIT

Region	Extra tourism jobs lost to region by 2030	Extra direct airport jobs created by 2030	Net loss of jobs by 2030, rounded
	E	F	G
North East	40,000	860	39,000
North West	116,000	4,580	111,000
York/Humber	85,000	440	85,000
East Midlands	70,000	1,370	69,000
West Midlands	88,000	1,510	86,000
East of England	101,000	4,200	97,000
London and South East	124,000	20,330	104,000
South West	65,000	1,430	64,000
Wales	40,000	380	40,000
Scotland	68,000	2,600	65,000
N. Ireland	6,000	1,110	5,000

NOTES

[1] *The Contribution of the Aviation Industry to the UK Economy*. Oxford Economic Forecasting, November 1999. For an analysis of how far the DfT relied on this report see *Alexander's Ragtime Band*. AirportWatch, 2007

[2] *The Economic Contribution of the Aviation Industry in the UK*. Oxford Economic Forecasting, 2006 www.aoa.org.uk/publications/OEF_Report.pdf

[3] The AOA figures were based on a report by York Aviation on the Economic and Social Impact of Airports, September 2005. www.aoa.org.uk/publications/Economic_Impact_Report.doc

[4] As note 1.

[5] EGRUP guidance www.webtag.org.uk/archive/msapart1/11.htm

[6] *The General Theory of Employment, Interest and Money*. John Maynard Keynes, 1936

[7] *UK Air Passenger Demand and CO2 Forecasts.* DfT, January 2009. The figure of 450 million is after taking into account the higher rates of air passenger duty announced in November 2008. www.dft.gov.uk/pgr/aviation/atf/co2forecasts09/co2forecasts09.pdf

[8] *Fallible Forecasts.* AirportWatch, 2008

[9] *Economic and Social Impact of Airports*. September 2005. www.aoa.org.uk/publications/Economic_Impact_Report.doc

[10] Birmingham Friends of the Earth

[11] Derived from figures given in their annual reports

[12] *The Impacts of Future Aviation Growth in the UK*. Berkeley Hanover Consulting, 2000

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[14] *The Hidden Cost of Flying*. Sewill, 2003. The Treasury have accepted that the absence of fuel tax and VAT amount to £10 billion a year. Response to Emissions Cost Assessment Consultation. www.dft.gov.uk/pgr/aviation/environmentalissues/aviationemissionscostassess/costassesssresponconsul.pdf

[15] As note 7.

[16] www.defra.gov.uk/environment/statistics/globatmos/gagccukem.htm

[17] As note 2.

[18] www.gmpte.com/upload/library/met_south.pdf

[19] Press report 16 January 1997

[20] As note 7. See page 55.

[21] www.baa.com/assets//B2CPortal/Static%20Files/LHRInterimMasterPlan.pdf

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[26] *Transport Links and the Economy*. Automobile Association and Confederation of British Industry, 1998

[27] *European Cities Monitor*. Cushman and Wakefield, 2008. www.cushwake.com/cwglobal/jsp/kcRegisterLogin.jsp?documentURL=/cwglobal/docviewer/2008_European_Cities_Monitor.pdf?id=c20100017p&repositoryKey=CoreRepository&itemDesc=document&cid=c17500010p&crep=Core&cdesc=binaryPubContent&Country=GLOBAL&Language=EN

[28] UK Cities Monitor 2008 (see note 27)

[29] OMIS, 2006. Britain's Best Cities 2005-2006.

[30] United Nations Conference on Trade and Development (UNCTAD), World Investment 2002, Transnational Corporations and Export Competitiveness. September 2002.

[31] *The Economics of Aviation: a North West England perspective*. John Whitelegg, April 2003

[32] As note 1.

[33] www.sqw.co.uk/file_download/129

[34] Stationery Office.

[35] Predict and Decide. 2006

[36] www.tourismalliance.com/attach.pl/204/240/TA%20Aviation%20Duty%20Submission.pdf

[37] Gross pay of employees in hotels, restaurants, recreational, cultural and sporting. ONS. 2008

[38] UK Air Passenger Demand and CO2 Forecasts. Page 134. DfT. January 2009. www.dft.gov.uk/pgr/aviation/atf/co2forecasts09/co2forecasts09.pdf

[39] 5.5 million divided by 41.5 million multiplied by 900,000.

[40] *Why airport expansion is bad for regional economies*. Friends of the Earth, 2005 www.foe.co.uk/resource/briefings/regional_tourism_deficit.pdf

[41] As note 9.

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Summary

Introduction

Over the years there have been numerous debates on the expansion of London's airports. The Davies Commission is currently examining 'the scale and timing of any requirement for additional capacity to maintain the UK's position as Europe's most important aviation hub'. The RSPB, WWF-UK and HACAN want to engage in the process, ensuring that a proper methodological framework is used for assessing the different options.

They have asked CE Delft to propose a general framework for assessing airport expansion and new airport development projects, based on best practices and academic research. Special attention is paid to one of the least understood elements in such a framework: connectivity.

Social cost benefit framework

A social cost benefit analysis (SCBA) is the most appropriate way to evaluate airport investment plans. It provides an overview of current and future pros and cons of a particular project for society as a whole (public, private sector and government) as objectively as possible. SCBA therefore differs fundamentally from a financial analysis or business case, which identifies the costs and benefits solely for a particular party.

The use of SCBAs is common practice in the UK and many other countries. The *Transport Assessment Guideline (TAG)* specifies how an SCBA of an airport investment project should be conducted. The main items are transport efficiency, time savings, investment costs and noise. Most of the effects are direct (i.e. accruing to the providers and users of airport infrastructure) or external (i.e. not included in the cost price of airports). In well-functioning markets, indirect effects (e.g. effects on suppliers of airports) should not be counted, as they are passed through by either the producers or the consumers as part of their costs and benefits.

Although economically incorrect, indirect costs are often included in commonly used frameworks, which inevitably leads to double counting by adding direct, indirect, induced and catalytic effects of aviation.

SCBAs should take into account any risks and uncertainties that might occur. A major source of uncertainty in airport projects is the forecast of future demand for aviation. Past experience has shown that these forecasts have been systematically too high, their use consequently leading to overestimation of the main benefits of aviation (transport efficiency and time savings).

The benefits of connectivity

Among the wider economic benefits of airport expansion are the impacts on productivity: agglomeration effects, output change, changes in labour market supply and the move to more or less productive jobs. These are often captured under the term 'benefits of connectivity'. They provide one of the main arguments employed in the public debate on airport expansion, and studies have been published which claim the benefits of expanding London's airports will be very large for the capital as well as for the country as a whole.

Connectivity is defined as the degree to which a country or city is linked to other destinations and the ease or speed with which those destinations can be reached. All modes of transport are relevant in this regard, as well as transport replacement options.

A comparative analysis of the aviation network of the main European hubs (Heathrow, Paris, Frankfurt, Amsterdam) reveals that Heathrow has fewer destinations than other hubs and that the number of destinations is not rising as fast as at other airports. However, Heathrow offers a high frequency of flights to the destinations it serves. It appears that Heathrow's network is much more specialised on the most profitable routes.

The relationship between connectivity and GDP has not been studied in much detail in the academic literature. Even less is known about the possible existence of a causal relation between connectivity and economic growth, trade or other relevant economic parameters. The available empirical evidence suggests there is a weak correlation, mostly for less developed economies, but there is no evidence of causation.

The relation between aviation activity and economic performance has attracted more attention. A review of the academic literature suggests there is a two-way causal relation between aviation activity and regional economic performance, with an increase in aviation activity causing an increase in GDP, and vice versa. This relation appears to be stronger for remote regions and stronger for poorer regions and countries than for well-developed ones. When reviewing this evidence, one should be aware that the method used to establish a causal relation cannot establish whether airports cause additional economic activity per se, or whether regions with airports grow at the expense or surrounding regions without airports.

Conclusion

This study provides a transparent framework for (social) cost benefit analysis of airport expansion and new airport development projects. It is extremely important that all types of effects are included in the CBA and to avoid any double counting by including indirect effects. This means that considerable effort is needed to evaluate the type of effects that can be expected to occur and to appropriately include them in the CBA.

Many studies find a positive correlation between aviation and economic growth, but no causal relationship between connectivity and economic growth was found. The positive effect of aviation on economic growth appears to be stronger for remote and poor regions than for central, well-developed ones. It is not clear whether this effect is truly additional, or whether regions with airports grow at the expense of other regions.

1 Introduction

1.1 Background

For many years there has been discussion on the capacity and expansion of London's airports. The current debate is on whether or not capacity should be increased at these airports, and if so, where this additional capacity should be placed. The main options for expansion are to build a third runway at Heathrow airport, an additional runway at another London airport or a new airport in the Thames Estuary. Proponents of airport expansion claim that current capacity is insufficient and that expansion is needed for economic growth. Opponents, on the other hand, question the lack of capacity and the presumed large benefits to the economy. They argue that expansion is unnecessary, will lead to major costs and result in more noise and environmental pollution.

The UK government has therefore established an Airport Commission to "examine the scale and timing of any requirement for additional capacity to maintain the UK's position as Europe's most important aviation hub". The Commission is to report in two stages. By the end of 2013 it will report on the steps needed to maintain the UK's hub status and how to improve use of existing capacity over the next five years, and by 2015 it will report on its assessment of the options for meeting the UK's international connectivity needs. For its work, the commission will seek stakeholder input.

The RSPB, WWF-UK and HACAN want to engage with the Commission, ensuring that a proper methodological framework is used for assessing the different options. Based on best practices and academic research, this report proposes such a framework. Furthermore, it investigates the relationship between expansion, connectivity and economic growth.

1.2 Objective

The aim of the study is to propose a general framework for assessing airport expansion and new airport development projects, and to propose a methodology to analyse the impact of one of the least understood and often neglected elements of such a framework: connectivity.

1.3 Research question

The two main questions that this study aims to answer are as follows:

1. What framework should be used to assess the economic impacts of airport investment projects?
   - Which of the costs and benefits that are included in current cost benefit analysis (CBA) frameworks should be taken into account in airport investment projects?
   - What are the likely differences in costs and benefits between airport expansion and new airport development?

2. Does airport expansion lead to increased capacity, more connectivity and more economic growth?
   - What is the relationship between capacity and connectivity?
   - What is the relationship between connectivity and economic growth?

1.4 Scope

This study focuses on potential airport investment projects in South-East England, considering two types of airport project: expansion of existing airports and new airport development. This report is not an investment analysis, but rather an analysis of the costs and benefits that need to be taken into account to estimate the impact of airport expansion or new airport development for society as a whole.

The research carried out for this study is based primarily on existing literature and includes little new data analysis. An analysis of optimisation of airport capacity is therefore beyond the scope of the present project. Nevertheless, the report contains many elements that could be useful for such an analysis.

1.5 Outline

Chapter 2 provides an answer to the question of what framework should be used to conduct a proper CBA of airport investment projects. Chapter 3 studies the relation between airport capacity, connectivity and growth. Chapter 4 concludes with the findings of the study.

2 Assessment of the economic impacts of airport investments

2.1 Introduction

This chapter analyses how the impacts of airport investment projects can be assessed. A (social) cost benefit analysis (CBA) is the most appropriate way to do so and is common practice in the UK and many other countries. We compare the UK guidelines for CBAs with two other guidelines and apply the methodology to airport expansion and new airport development projects.

2.2 Assessing economic impacts of airport investments: cost benefit analysis

A CBA is defined as 'an evaluation method that can be used to consider the impact of policy decisions'. It provides an overview of current and future pros and cons of a particular investment or policy project for society as a whole as objectively as possible. It is based on a broad definition of the term welfare and includes public, private and government benefits and costs[1]. CBA therefore differs fundamentally from a financial analysis (business case), which reveals the costs and benefits solely for a particular party.

A CBA typically comprises of four steps:

1. The project and the baseline scenarios are defined. If project alternatives exist, all relevant alternatives are defined.
2. The effects of the project are identified.
3. Each effect is quantified.
4. Where possible, effects are monetised.

Monetised CBA

Whereas some effects, like increased employment, are usually expressed in monetary terms, others are not. Impacts such as: noise, biodiversity or regional inequality are more difficult to express in monetary values because they are not commonly traded in markets. In a monetised CBA, only monetised effects are included – meaning non-monetised impacts have an implied price of zero. In order to correct for bias against non-market goods, and because non-monetised effects are certainly of importance, several accepted methodologies have been developed to monetise these effects.

Role of CBA in the decision making process

A CBA is an important tool in the decision making process in order to prioritise the allocation of public spending. CBA is used regularly for national and regional policy making, for example in the fields of infrastructural investments (such as rail, road or aviation), river basin management, flood risk management and spatial development.

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[1] Besides goods and services, CBA takes into account intangible effects and expresses them in monetary terms. These include effects on the environment, landscape, nature and spatial quality.

The method of CBA is widely used in transport investment appraisals and other ex-ante policy evaluations both in the UK and in many other countries. They are recommended by the European Union for appraisal of infrastructure investments. In the UK, they are recommended by the UK Department for Transport (DfT) for transport appraisal.[2] Apart form CBA, there are also other inputs that play a role in the decision making process, such as distributional effects, legal aspects, public opinion, equity, fairness, employment effects.

2.3 CBA: Which costs and benefits are included?

CBA in UK has to be carried out according to the 'Transport Analysis Guidance', abbreviated TAG, which is published by the DfT. TAG has a separate unit for aviation appraisal (TAG Unit 3.18), which is developed for government interventions especially in the aviation industry. It sets out how aviation policies can impact national welfare and how these impacts can be appraised (DfT, 2012). This section will study the aviation appraisal in more detail and investigate which elements should be included in CBA.

Table 1 gives an overview of the different impacts that are included in the CBA for aviation investment projects by TAG. Also, a comparison is made with two other CBA guidelines that are often used abroad for (aviation) investment projects:
- OEI manual (CBP and NEI, 2000);
- Guide to CBA of the European Commission (EC, 2008).

Table 1 Impacts included in cost benefit analysis for aviation appraisal (TAG)

	Economic impacts	Social impacts	Environmental impacts	Other
TAG	– Transport economic efficiency – Time savings from delay reduction – Wider economic impacts* – Surface access impacts – Costs • Investment • Maintenance • Operational	– Accidents – Security* – Accessibility* – Integration*	– Noise – Air quality – GHG emissions *Non-monetised impacts:* – Biodiversity* – Landscape* – Water* – Historic heritage*	Impact on public accounts
Additional effects in other CBA (but excluded from TAG)				
Other CBA guidelines	– Impact on property and land values – Impact on other transport modalities – Indirect effects on other markets – Strategic effects	– Regional inequality – Congestion		

Source: DfT (2012).

Costs and benefits marked by * are not included in monetised CBA. These impacts are regularly not expressed in monetary terms and are included in the Appraisal Summary Table (Annex C).

2 http://www.dft.gov.uk/webtag/documents/overview/unit1.1.php.

For a more detailed comparison of the CBA guidelines, see Annex B.

The impacts of investment in aviation projects that are distinguished are economic, social, environmental, and public account. In general, the rule is to include only direct effects in CBA, unless market failures exist. In perfect markets indirect effects are internalised in the market prices and included in producer and consumer surplus. Indirect effects, catalytic and induced effects should therefore not be included in CBA. Nevertheless, these effects are often important in the public debate. More about these effects and why they should not be included in CBA will be further discussed in Section 2.7. In Annex A an overview is presented of the direct, indirect and external effects.

In the following sections, the cost benefit impacts from Table 1 are explained in more detail.

2.4 Economic impact

The economic impact of an airport project consists of many aspects. The CBA for aviation appraisal of TAG includes the effects on transport economic efficiency, time savings, wider economic impacts and surface access impacts. These impacts are further explained in detail below.

Transport economic efficiency

Transport economic efficiency includes the costs and benefits to passengers, airports and airlines, such as changes in business and non-business travellers' journey time, impacts on private sector providers' revenues and costs, changes in fares and other changes in revenues. It is the change in welfare for passengers due to decreased travel time and for operators and airports due to higher net revenues from more flights.

Transport economic efficiency only changes when there is unmet demand for airport capacity[3]. Estimating unmet demand is by no means straightforward, what also appears from UK aviation forecasts of DfT, which have been continuously downgraded. Apart from uncertainty in determinants such as economic growth, oil prices and carbon prices, demand for flights and value of time varies between business and leisure travellers. It is therefore important to estimate the change in transport economic efficiency for different groups of users.[4] The topic of unmet demand is a key point in CBA for aviation investment projects, and will be further discussed in Chapter 3.

Time savings

Expansion of an airport and hence more capacity offers more possibilities to divert to another runway when there are sudden changes in the flight schedules thereby avoiding delays. Expansion can therefore lead to time savings from delay reductions (in travelling journey time).

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[3] In case of unmet demand (demand for air travel is larger than supply), additional capacity will lead to more profits and increased welfare. In case of no unmet demand (demand is equal or lower than supply), additional capacity will nit lead to additional welfare.

[4] About 75% of passengers at Heathrow are leisure travellers yet expansion proposals are being driven by perceived business demand.

TAG prescribes the inclusion of the effects of better transport interchange on traveller journey times in monetised CBA, but excludes other transport interchange quality factors (such as waiting environment, level of facilities, level of information, etc.). Furthermore, it currently excludes reliability impacts, as the method for calculating these is still undergoing further study.

Wider economic impacts

Wider economic impacts include the impact on agglomeration, output change, labour market supply and the move to more or less productive jobs. They are not estimated as part of the direct effects (transport user benefit) but are estimated separately. Since these effects are often large compared to other effects, but very difficult to quantify and monetise, they require careful attention.

TAG excludes wider economic impacts in the analysis of monetised CBA. The reason for this is that in perfect markets, all costs are internalised in market prices and only direct effects should be included in CBA. Indirect economic benefits (but also catalytic and induced effects) should therefore not be included in CBA, unless market failures exist.

Wider Economic Impacts

Agglomeration impact
Agglomeration refers to the concentration of economic activity in an area. Transport investments can improve the accessibility of an area for firms and workers, which affects the level of agglomeration. A higher agglomeration level affects the productivity of firms and workers in an area. Through its impact on productivity, agglomeration has an impact on welfare and Gross Domestic Product (GDP).

Output change
In imperfect competitive markets, production can be lower and prices can be higher compared to a competitive market. A reduction in transport costs (to business and/or freight) allows for an increase in production or output in the goods or service markets that use transport. Better transport provision may result in less congestion and enable a firm to carry out more deliveries in a day (i.e. increase output). A transport intervention that leads to an expansion of output will deliver a welfare gain as consumers of the goods and services will value any increases in production by more than the cost of the additional units of production.

Impact on labour market supply
Transport costs are likely to affect the overall costs and benefits to an individual from working. In deciding whether or not to work, an individual will weigh travel costs against the wage rate of the job travelled to. A change in transport costs is therefore likely to affect the incentives of individuals to work and hence the overall level of labour supplied in the economy. The level of labour supply can impact on welfare through GDP but also through benefits and disbenefits to individuals depending upon whether they like or dislike working.

Move to more or less productive jobs
Investment in transportation projects, such as building a new airport, can affect the incentives for firms and workers to locate and work in different locations. Employment growth or decline in different areas is likely to have implications for productivity, as workers are often more or less productive in different locations. This may have implications for UK productivity which, in turn, will impact on UK welfare.

Surface access impacts

Surface access impacts are the effects of an investment project on new levels of traffic on contingent surface access schemes as well as the existing network. When an airport is increasing its capacity by building a new runway, it is likely that the increased capacity will lead to more flights and more passengers who need to reach the airport. This will also increase pressure on the capacity of public transportation and existing road infrastructure. This could lead to more emissions, more congestion and more accidents. Any airport development which would impact on surface access would be likely to require an appraisal. So far, however, only a surface access impact for housing development has been developed, not for aviation investment projects

Treatment of benefits to non-UK residents

Some benefits of expansion will accrue to non-UK residents. For example, a reduction in travel costs to a foreign businessman travelling to the UK may benefit the businessman and/or his employer. Regarding the treatment of benefits to non-UK residents, TAG follows the HM Treasury's green book guidance (2003), which states that appraisals should take account of all benefits to both UK and non-UK residents[5]. It states that proposals should not proceed if, despite a net overall benefit, there is a net cost to the UK.

Additional economic impacts included in other CBA guidelines

In contrast to other CBA guidelines, TAG does not mention the impacts on property and land values (EC DG Regional Policy, 2012). They can be positive, e.g. because office space near an airport commands a higher rent, or negative, e.g. because zoning laws prohibit using certain areas for residential buildings. Since the impact on property and land values can be substantial it would be informative to include them.

Furthermore, it appears that TAG does not include indirect effects on other markets, such as the costs and benefits to businesses in the supply chain (backward linkages), or the effects on other transport modalities (effect on rail and road transport). Other (indirect) effects which are not included are strategic effects (locational/settling factors). The welfare gain of these effects is, however, difficult to determine, and should only be included when they result in additional welfare (CBP and NEI, 2000) Including these effects requires careful attention, since there is substantial risk of double counting and overestimation of the positive effects.

2.4.1 Project costs

Aviation investment projects usually involve large costs. The costs that are included in CBA are investment costs, maintenance costs and operating costs:

- *Investment costs* (often referred to as capital costs) include construction costs, land and property costs and compensation, preparation and administration costs, and on-site supervision and testing.
- *Maintenance costs* are traffic related costs and include costs for reconstruction, resurfacing, surface dressing, etcetera.
- *Operating costs* are non-traffic related costs and include for example landside costs or airside costs. Landside costs are those incurred by processing passengers and cargo through terminals. Airside costs are those attributable to processing aircraft through aprons, taxiways and runways.

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[5] An exception is made for international transfer passengers who simply changes planes at a UK airport.

Other costs that are included in the CBA are for risk adjustments and optimism bias. The former implies costs for risks that might occur during a project and the latter reflects the bias for estimated costs that are often too low and delivery times that are too short. See Section 2.6 for more details of how TAG copes with risk and uncertainties.

2.4.2 Social effects

Social impacts invoked by the introduction of a transport intervention includes the effects on communities such as cohesion, stability and services, people's way of life (how they live, work and play). TAG mentions several social effects such as accidents, security, accessibility and integration. In monetised CBA, TAG only includes the changes in numbers of accidents, excludes impacts on (personal and freight) security and integration, and subsumes the accessibility impacts to the extent that the cost benefit analysis takes account of all significant behavioural responses. These impacts appear in the Appraisal Summary Table (included in Annex C).

Accidents

TAG provides guidance on appraisal of accident impacts of transport interventions, since they may alter the risk of individuals being killed or injured as a result of accidents. It prescribes for monetised CBA to include changes in the numbers of accidents, but to exclude impacts on personal and freight security.

Security

Investment projects may affect the level of security for road users, public transport passengers and freight (all modes). The changes in security and the likely numbers of users affected are taken into account. Security indicators that are used for public transport passengers are site perimeters, entrances and exits, surveillance, lighting and visibility. However, these effects are not included in monetised CBA.

Accessibility

With a new airport being developed, accessibility is an important factor. The accessibility objective in TAG however, is focused on accessibility of public transportation and does not address accessibility benefits or costs from airport expansion or new airport development.

Integration

TAG considers the interchange of transport (modal transfers for passengers and freight from air to road, rail or sea). Furthermore, it takes into account how the investment proposal is integrated with land use proposals and policies and with proposals and policies concerning other transport modes.

Additional social impacts included in other CBA guidelines (but not in TAG)

Other CBA guidelines explicitly mention the impacts of airport projects on regional inequality and congestion.

The construction of a new airport may increase or decrease *regional inequality*, depending on the location of the new airport (remote region or core region). For example, airport development in a remote region may reduce the inequality gap between remote and core regions. Since the impact on regional inequality only affects redistribution of total wealth, it should be mentioned, but not included in CBA analysis (CBP and NEI, 2000).

The impact of investments in transport development on *congestion* can be direct (in terms of reduction in delays) and indirect (with respect to increased/decreased congestion in other modalities). Although in other CBA, congestion is treated as a separate category, TAG includes the direct effect of congestion within the economic effect of 'time savings' and includes the indirect effect within the category of 'surface access impacts'. Remarkably, congestion effects during the construction phase of the investment project (detour, leaving and approaching trucks, roadblocks, etc.) are not mentioned in any of the CBA guidelines.

While regional inequality is probably very hard to establish, congestion can be important, especially if the airport is accessed through landside infrastructure that is also used for other purposes.

2.4.3 Environmental effects

In monetised CBA, TAG includes environmental impacts on noise, greenhouse gases and local air quality. Although these environmental effects are indirect, they should be included since the costs of negative externalities are not included in market price due to market failures. Since they are not traded in markets their costs are not incurred by anyone, leading to over- or under-production, otherwise known as market failure.

TAG currently excludes impacts on the landscape, townscape, heritage of historic resources, biodiversity, and water environment and so some market failure exists within the CBA as well. These impacts are excluded in monetised CBA, as no monetary values for these have yet been established by the Department.

Noise

Noise can be defined as the unwanted sound or sounds of duration, intensity, or other quality that causes physiological or psychological harm to humans (CE, 2008). In general, two types of negative impacts of transport noise can be distinguished, namely health effects and annoyance effects:

- Annoyance effects reflect the cost of the disturbance which individuals experience when exposed to noise, ranging from sleep disturbance to discomfort, inconvenience and restrictions on enjoyment of desired leisure activities.
- Health effects relate to the long term exposure to noise and are often stress related, such as hypertension and myocardial infarction. Hearing damage can be caused by noise levels above 85 dB(A). The negative impact of noise on human health results in various types of costs - medical, the impact of lost productivity, and the costs of increased mortality. TAG does not take the impact of noise on health into account, but only investigates the annoyance effects (up to 81 dB).

The UK has well established procedures for assessing noise annoyance effects to people caused by road and rail traffic-related noise and vibration. But, there is no specific procedure for aviation related noise annoyance. The noise impact assessment in TAG involves two methods. The first, based on the concept of noise annoyance, involves calculating the difference in the estimated population who would be annoyed by noise from alternative sources, comparing the do-minimum and do-something scenarios. The second is based on the effect of noise on house prices and involves calculating the present value of households' willingness to pay to avoid transport related noise over the whole appraisal period for each scenario.

For road and rail, monetary valuation of noise is established by determining annoyance response relationships (which percentage is annoyed at certain levels of dB ranging from 45 to 81 dB) and then determining the £ per household per dB change (DfT, 2012: TAG Unit 3.2) However, in the case of aviation, noise impacts are more severe than compared to road or rail traffic. TAG does not include noise impacts from aviation, nor does it include impacts above 81 dB. A recent study by the World Health Organisation (2011) on noise effects points out that there is much uncertainty about valuation of noise from aviation at night time. Furthermore, it must be noted that there is no mention in the any of the CBA guidelines about noise impacts during the construction phase of the transport development. This is likely to result in a significant underestimate of the disbenefits to the local population, since noise nuisance during construction is likely to take place.

Air quality (local and regional)

TAG provides guidance on assessing the impact of transport options on local and regional air quality. It focuses mainly on transportation by road and rail, and not on air transport. Emissions that are included in TAG are NO_x, CO, VOCs, and fine particulate matter (such as PM_{10}). The impact of CO_2 and other greenhouse gas emissions are included in the category 'Greenhouse gases/Emissions' (below). Monetary valuation of changes in air quality is carried out by calculating the marginal abatement costs (MAC) or damage cost values. The damage cost values reflect the cost of health impacts associated with exposure to air pollution. In the guideline for CBA of the European Commission, health impacts are measured by life expectancy or quality of life (quality-adjusted-life year, QALY) or by the willingness to pay for prevention of fatalities/injuries (EC, 2008).

Emissions (CO_2 and other GHG)

TAG takes into account the impact of CO_2 and other greenhouse gas (GHG) emissions. These emissions are not only limited to emissions from fuel consumption and electricity generation, but can also include those resulting from the production of materials used in any infrastructure as well as those resulting from changes to the use of transport fuels. All changes in greenhouse gas emissions are prescribed to be presented in tonnes of carbon dioxide equivalent (CO_2e).

In TAG, assumptions are made that the majority of the embedded emissions would be covered by the EU ETS and would therefore already be internalised. TAG's analysis is therefore limited to emissions from fuel consumption and electricity generation only. However, since aviation ETS is temporarily halted for non-EU flights, a different method should be applied to include emissions in a proper way in CBA.

The monetary value of a change in CO_2 emissions is calculated by converting the estimated total number of litres of fuel burnt or the number of kWh of electricity used, to CO_2 emissions per litre fuel burnt or per kWh electricity used. Then, multiplied by CO_2 prices gives the CO_2 emissions in monetary terms.

Biodiversity, landscape and water (non-monetised effects)
The costs and benefits of transport project investment on biodiversity, landscape, water, townscape and heritage of historic resources are difficult to estimate and express in monetary values. The development of a new airport in the Thames Estuary, for example, is likely to have a large impact on the landscape and local flora and fauna, but the question is how to express the loss of biodiversity in monetary terms. In the last decade, the valuation and monetisation of nature has become popular, and as a result the valuation methods are now more developed.

Regarding the aviation appraisal of TAG, these environmental effects are excluded in the monetised CBA, but included in the Appraisal Summary Table (included in Annex C). The reason for this is that no monetary values for these have been established yet by the Department for Transport (DfT, 2012: TAG Unit 3.5.4). When these effects are not taken into consideration, it could lead to a large under-estimation of the costs of an airport investment project. Environmental values should not be underestimated. Costs can add up to a large scale, as was the case with the Exxon Valdez oil spill (1989, Alaska).

In addition to CBA, there also exists an Environmental Impact Assessment (EIA), For large infrastructural investment projects, developers must carry out an EIA, which assesses all possible positive and negative impacts that a proposed project may have on the environment (EC, 2012).

2.4.4 Public account
An aviation intervention can affect the public account directly, by changing the tax receipts from taxes directly levied on aviation, such as the air passenger duty (APD). It can also affect the public accounts indirectly, by altering indirect taxation receipts from goods consumed across the rest of the economy. However, in a first order approach the effect on the public account should not be included in cost benefit analysis since it concerns transfers to the government and subsidies and pure transfers should not be included according to the CBA of the European Commission (EC, 2008).

2.5 CBA: Airport expansion versus new airport development

Differences in costs and benefits between expansion and new airport development will appear in the costs for construction, infrastructure, land values and travel time:
- Costs for construction are expected to be higher for new airport development than for expansion, since new runways and terminals have to be built.
- Costs for infrastructure are expected to be higher for new airport development since a new infrastructure network (roads, public transport) has to be built.
- Land value: in the case of new airport development, the former land on which the airport was built can be sold. However, new land also has to be bought, which might include compensation for people who have to leave their houses in the area where the new airport will be built.
- Travelling time or time savings for employees working at the airport might increase or decrease with the establishment of a new airport. Usually, airports relocate due to capacity constraints and/or noise issues. They therefore relocate to more remote places with enough space to expand and less noise annoyance to local residents. Therefore, travel time is likely to increase for employees at the airport.

- Effects on biodiversity (although not included in monetised CBA) are likely to be more severe in the case of development of a new airport since these take place in remote areas often with more natural value, landscape and biodiversity.
- Noise effects are likely to be more severe in the case of expansion of an airport, since existing airports are often located in a built environment, while new airport development often takes place in a more remote location.
- Closure costs of the existing airport and associated compensation costs to airlines, equity investors, bondholders and air traffic control could lead to significant increase in total costs for a new airport development. For Heathrow these costs are estimated at £ 20 billion (Oxera, 2013).

2.6 Risk and uncertainties

In order to estimate the costs and benefits of the different effects, many uncertainties may arise, such as uncertainty regarding:
- physical effects;
- statistical analysis;
- and future projections.

Each will be explained in more detail below.

Physical effects
Risk and uncertainty about project costs may turn into risks when, for example, investment or operational costs overrun due to unexpected circumstances. Other project risks might occur due to uncertainty surrounding planning and land issues as well as timing and delivery. In TAG, for transport projects with a cost greater than £ 5m a Quantified Risk Assessment (QRA) is required. Furthermore, risks around project costs are taken into account by adjusting the baseline costs for risk and optimism bias:
- Risk: identifiable future situations that could cause an overspend or underspend to occur.
- Optimism bias: demonstrated systematic tendency to be overly optimistic (underestimation of costs).

Statistical analysis
Regarding statistical analysis, uncertainties may arise due to model specification and measurement errors. These can be taken into account by means of probability analysis and standard error.
- Probability analysis measures the probability that an event may occur.
- Standard errors are a common statistical measure of risk and measure the accuracy with which a sample represents a population. The smaller the standard error the higher the accuracy. If the standard deviation is greater, the variability and thus risk is also greater.

TAG does not require specific measures for standard errors, but only requires sensitivity tests and alternative scenarios.

Future projections and model forecasting

In order to estimate future costs and benefits, uncertainty arises about future parameters such as future transport demand, economic growth, oil prices, environmental policies and regulations. These future demand projections play a large role since the economic benefits rely heavily on the number of flights and flight tickets sold. In case future projections are not carried out well and demand is overestimated, it might lead to the risk that a ghost airport is built, like the airport Ciudad Real in Madrid. Here, investments of £ 1.1 billion were made for the development of an overflow airport that wasn't needed (Daily Mail, 2012).

TAG (DfT, 2012: Unit 3.15.5) provides a systematic analysis method for dealing with uncertainty in model forecasting by developing scenarios and sensitivity tests. Scenarios are used to combine the impact of different variables and to show the different outcomes under different assumptions. It often includes three scenarios: optimistic, baseline and pessimistic. A sensitivity test analyses the influence of different variables on the project's financial and economic performance. Regarding the uncertainties over demographic, economic and behavioural trends, TAG states that reported national data should be used.

In order to analyse uncertainties, TAG prescribes that the appraisal must consider at least two alternative scenarios or two sensitivity tests. To forecast transport demand, the Trip End Model Presentation Program (TREMPO)[6] is used, however, this model only includes data on trips on foot, by bicycle, motor vehicle, rail and bus, but not for aviation.

2.7 Commonly made mistakes in CBA

Cost benefit analysis has a scope to include all the impacts on the economy, the environment, and social effects. However, too often proponents and opponents stress only parts of the CBA that show results in their favour. This section discusses commonly made mistakes in CBA.

Ignoring negative effects

Templates often omit the external effects and ignore the negative impacts on, for example, the environment, noise and pollution, even though these have well documented economic impacts. Noise depresses property values and has negative impacts on health, including an increase in the risk of high blood pressure and consequences for myocardial infarction and cerebrovascular accident, in cognitive impairment in children, and sleep disturbance (WHO, 2011). These impacts not only lower the wellbeing of the affected individuals but may also reduce their productivity (CE, 2012). Other negative impacts that are often omitted are the expenditures of UK inhabitants abroad and investments abroad. The aviation industry does not facilitate just inward investments, but also outward investments. Ignoring these negative effects will result in an underestimate of the net impact of the investment project.

Overestimation of positive effects

On the other hand, there is a tendency in the aviation industry to overestimate the positive impacts of aviation. Many studies are based on the ACI-Europe study kit which has been developed by York Aviation and is widely used by airports and organisations like the Air Transport Action Group (York Aviation, 2004; ATAG, 2005).

6 http://www.dft.gov.uk/tempro/intro.php.

The ACI framework includes directs effects, indirect, induced and catalytic effects.

– Direct effects are measured by the economic activity (value added and/or jobs) at the airport.
– Indirect effects denote economic activity in the aviation sector's supply chain (backward linkages).
– Induced impacts are second order effects and can be described as the expenses of people employed at the airport on goods and services (forward linkages).
– Catalytic impact is economic activity created in other industries caused by the existence of an airport. It is the employment and income generated by the role of the airport as a facilitator of economic growth, also called spin-off benefits.

Summing these direct, indirect, induced and catalytic value-added leads to double counting and an overestimation of the positive effects. The method fails to recognise that aviation is a supplier and a client of other sectors. For example, indirect and induced employment includes spending on goods produced abroad, so the effect on domestic employment is likely to be overestimated. Secondly, tourism jobs impacts should also include the loss of income through money that local residents spend abroad. The same argument holds for inward and outward investment (CE, 2012). According to the CBA guideline of the EC, indirect impacts in secondary markets should not be included in the economic appraisal whenever an appropriate shadow price has been given for the benefits and costs (EC, 2008).

Employment as a benefit

Another commonly made mistake is that employment is often counted as a benefit. Investment projects and politicians often mention the number of jobs created by the project as a benefit. Employment is however an indirect effect, and should not be included assuming that the labour market functions well. Only in the case of a market failure (structural unemployment) additional welfare could be created. Only in this situation is it correct to fully count the on-site job creation of the project as a benefit. This requires the vacancies to be filled by long-term unemployed who would be unable to find employment now or in the future. Due to the economic recession and increased unemployment in the UK, jobs are an important subject in the public debate. When considering the inclusion of employment effects in CBA, this should be carried out with caution because of double counting. Wages are part of the cost of the project, not the benefits. The social benefits of employment are already given by using shadow wages. Including these effects in CBA might lead to double counting, which should at all times be prevented.

2.8 Conclusion

In this chapter we analysed the impacts that are included in CBA in order to get a complete overview of all costs and benefits of an airport investment project. A CBA should - besides economic impacts- also include external effects, such as social and environmental impacts, that are not internalised in market prices. At first sight TAG seems to be an adequate guideline to analyse costs and benefits of aviation investment projects. It compares well with other CBA in some aspects, but could still be improved.

Comparing TAG to other CBA, it appears that several important effects have been excluded, such as:

- impacts on property and land values;
- impacts on other markets, such as the costs and benefits to businesses in the supply chain (backward linkages);
- impacts on other transport modalities (effect on rail and road transport);
- strategic effects (locational advantages);
- regional inequality.

Furthermore, there are several non-monetised impacts of transport project investment, such as biodiversity, landscape, water, townscape and heritage of historic resources, which are not included in the CBA. The reason for this is that there have not yet been developed any monetary tools to value these impacts to the satisfaction of those designing the TAG. In consequence, omitting non-monetised impacts will result in an underestimation of the net impact.

This chapter also considered the uncertainties and risks which may arise when estimating costs and benefits of the different effects. Examples are the uncertainties about physical effects, statistical analysis and future projections. TAG takes these risks and uncertainties into account by including risk and optimism bias, developing scenarios and sensitivity tests.

Last, we discussed commonly made mistakes in CBA. In general, there is a tendency to ignore the negative effects (such as noise and pollution) and to overestimate the positive economic effects (by including induced and catalytic effects). This again leads to an overestimation of the net results in favour of the investment project.

3 Airport capacity, connectivity, economic growth?

3.1 Introduction

In CBA, a major part of the total benefits is determined by the economic benefits of an investment project. In aviation development projects, these economic benefits are largely dependent on the wider impact of connectivity. Connecting buyers with suppliers, investors with ideas and businesses to sit cheek-by-jowl with their competitors - connectivity - may be a key to economic growth. Although this statement is often taken for granted, there is still large uncertainty about the (causal) relationship between connectivity and economic growth.

In the UK, there have been discussions for many years on the expansion or new airport development around Heathrow and other airports in the South-East. Proponents of aviation expansion argue that expansion of the airport increases the airport's capacity and improves the connectivity of London and the UK in general, which would boost economic growth and employment. Opponents claim that the impact on economic growth is overstated.

In this chapter we study the relationship between capacity, connectivity and economic growth. Section 3.2 explains the concept of capacity and constraints. Section 3.2 discusses the relationship between airport capacity and connectivity. Section 3.4 examines the relationship between connectivity and economic growth.

3.2 Airport capacity and demand

Airport capacity and demand are crucial factors to determine transport economic efficiency, which is one of the largest benefits in CBA. First, we discuss the concept of capacity and demand and to what extent there is unmet demand, followed by the impact of capacity constraints on connectivity.

3.2.1 Airport capacity

Capacity refers to the ability of an airport to handle a given volume or magnitude of traffic (demand) within a specific period of time, often expressed as a maximum number of aircrafts that an airport is able to process per unit of time (Senguttuvan, 2006). The determination of airport capacity is, however, complex. Capacity constraints may arrive at landside or airside areas of the airport and may occur due to operational, economic, environmental constraints. [7] Other factors affecting capacity are administrative constraints, meteorological conditions, runway configurations, arrival/departure ratio, and fleet mix (DLR, 2009).

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[7] Landside area encompasses the surface-access systems connecting the airport to its catchment area and the terminal system. The airport airside consists of airspace around the airport (airport zone or terminal airspace, like runways, taxiways, and the apron and gate complex.

In the short term, airport economic capacity is determined by the airport service charges which regulate demand access, in the long run capacity is determined by availability of airport infrastructure (Janic, 2004).[8] The infrastructural supply is often related to the number of runways and terminals at an airport. Table 2 gives an overview of London's aviation operational capacity.

Table 2 Airport capacity at London airports (2012)

Airport	Number of runways	Number of destinations	Number of passengers*	Air traffic movements*
Heathrow	2	193	69.4 mln.	480,906
Gatwick	1	200	33.6 mln.	251,067
Stansted	1	150	18 mln.	148,317
Luton	1	54	9.5 mln.	104,000
London City	1	46	2.9 mln.	68,792
Southend	1	16	0.4 mln.	25,470

Source: Local airport websites and CAA (2012), *data for 2011.

London's capacity versus other European airports

London has one hub airport (Heathrow) and 5 point-to-point airports. In total, London's capacity is determined by 7 runways, which is, together with Paris (Orly and Charles de Gaulle), the highest amount of runways compared to other European cities. Amsterdam (Schiphol) has 6 runways and the airports at Madrid (4) and Frankfurt (3) operate with substantially less runways. Heathrow (2012) states that it operates at almost full capacity. However, this refers to slots during the busiest period of the year. Heathrow does not run at full capacity outside the summer period and Eurostat data (2012) show that the load factor of airplanes is less than 75%. Regarding Heathrow's terminals, capacity can be expanded by another 20 million passengers. The new Terminal 5, opened in 2008, increased Heathrow's capacity up to 90 million passengers maximum.

Seat capacity

Also regarding seat capacity, London is the largest airport system in Europe with 172 million to/from seats in 2012 (OAG data)[9]. It has 50% more seat capacity than the next largest European airport system, which is Paris.
In 2012, Heathrow reached seat capacity of 94.5 million to/from seats retaining its position as the 3rd largest airport in the world.

3.2.2 Demand for air travel

The airport operational capacity mainly depends on factors such as air travel demand by passengers, safety constraints, and delays (Janic, 2004). Airports try to control the flow of air traffic such that the demand meets but does not exceed the operational capacity.

Table 3 shows the airport passenger demand forecasts of the Department of Transport for UK airports till 2050.

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8 Economic conditions may significantly influence the number of units of demand accommodated at an airport. In the short term, charges for airport services during the peak and off-peak capacity at Europe's largest airports (runways)hours regulate demand access.

9 http://www.oagaviation.com/OAG-FACTS/2012/December-Executive-Summary.

Table 3 **UK terminal passenger forecasts, central estimates (mln. passengers per annum, mppa)**

	Unconstrained				Constrained (maximum use)			
Forecast year	DfT (2007)	DfT (2009)	DfT (2011)	DfT (2013)	DfT (2007)	DfT (2009)	DfT (2011)	DfT (2013)
2010	270	260	211	211	270	260	211	211
2020	385	365	275	260	355	345	270	255
2030	495	465	345	320	425	405	335	315
2040	-	-	425	390	-	-	405	370
2050	-	-	520	480	-	-	470	445

Source: DfT (2007), DfT (2009), DfT (2011), DfT(2013).

It shows that DfT's forecasts of UK terminal passengers have been routinely downgraded over the past years. For 2030, forecasted unconstrained passenger demand has been downgraded by 65% between 2007 and 2013. While in 2007 unconstrained passenger demand for 2030 was forecasted at 495 million passengers, in 2013 this amount was revised downwards to 320 million passengers. It appears that the 2011 estimate of 345 mmpa in 2030 did not even fall in the range forecast in 2009 (low growth scenario estimate was 415 mmpa).

Forecasts of air passenger demand are not straightforward, due to large uncertainties in oil prices, carbon prices, economic growth and many other factors. This is apparent from the DfT passenger forecasts. These uncertainties can be explained by the fact that scenarios and forecasts of aviation demand depend to a large extent on assumptions on:

– GDP per capita growth because demand for aviation is elastic.
– The income elasticity of demand or the propensity to fly. Often, these are assumed to be constant while cross sectional studies suggest a saturation of the demand for aviation and hence a decrease of the income elasticity over time.
– Costs of aviation, which in turn are driven by fuel price assumptions, assumptions on taxation, assumptions on environmental regulation, assumptions on the market share of low cost carriers, etc..
– Alternative technologies, such as other modes of communication.

Often, aviation demand forecasts tend to take an optimistic view on many assumptions, such as low oil prices and being too optimistic on technological development, an approach which results in an overestimation of the demand and the severity of the constraints (CE, 2008, 2009, 2012 and 2013).

Does London's capacity meet future demand?

The question for London's airports is whether it can also meet demand for air travel in the future and to what extent there might be unmet demand caused by constraints in the future. Heathrow (2012) and DfT (2011) argue that capacity at London's airports is constrained. AEF/WWF (2011) however state that there is sufficient capacity available at the airports in South-East London and other regions to meet the level of aviation growth within the environmental limits recommended by the Committee on Climate Change, consistent with UK climate targets. Their analysis shows that a small shortfall is expected in the South East which is not sufficient to require a new runway, so long as the trend towards larger aircraft and higher passenger loading continues. AEF/WWF (2011) concluded that the shortfall in Air Traffic Movements in the South East by 2050 would be less than one per cent.

3.2.3 Environmental constraints

Apart from infrastructural constraints, there may also be environmental constraints, such as policies on noise and air pollution. These polices intend to protect local people from the damaging effects of airport operations, by means of night curfews or constraints on emissions.

According to Janic (2004), the environmental constraints that are present at Heathrow are related to noise and land use. They affect runway capacity by (a) restricting the use of runways to achieve maximal operational capacity and (b) restricting land use for physical (spatial) expansion of airport infrastructure outside of the existing airport area.

3.2.4 Expanding capacity

Regarding capacity, or actually the lack of it, the only solution that often seems to be considered is expansion in terms of building new infrastructure (new runways or terminals). However, there are different ways in which an airport's capacity can be expanded without building new infrastructure, such as by extending operating time, more efficient use of runways, use of larger aircrafts, or changing the fleet mix. Extending operating times and changes in the fleet mix will however have noise and environmental consequences.

AirportWatch (2011) argues that the key question is not the lack of capacity, but how that capacity is used. The study finds that the majority of flights from all European airports is intra-European, often covering relatively short distances. They state that European governments need to decide whether to continue to permit most of the capacity at Europe's airports to be taken up with short distance flights or whether to reduce the number of those flights – through fiscal measures and slot allocation – in order to free up capacity for more intercontinental flights from key business destinations.

This shows that there are many ways to address capacity constraints, which do not necessarily mean building a new runway, but instead achieve the same thing by more efficient use of runways, or freeing up capacity normally used for short haul destinations.

3.3 Connectivity

Although connectivity does not formally play a role in CBA, it is one of the main arguments used in the public debate on airport expansion. Therefore, we scrutinised the facts on connectivity and economic growth side by side. Prior to the discussion on whether and how airport capacity influences connectivity and economic growth, it is important to define the term connectivity.

3.3.1 Definition of connectivity

In its broadest context, connectivity refers to the density of connections of a country or city with the rest of the world and the directness of those links. Connectivity encompasses centrality, the degree to which a country or city is linked to other destinations. Connectivity further embodies the ease and speed in which those destinations can be reached. This includes all types of transport modes such as aviation and rail or transport replacement such as videoconferencing.

In the aviation context, connectivity is defined as "a combination of the range of destinations served and the frequency of flights" (DfT, 2012b).

The broader the range of destinations and the higher the frequency of flights, the better connected an airport, city or country is. This includes direct connections, but also indirect connections by transfer. Very often however, a very narrow definition of connectivity is used, implying that connectivity is only related to direct flights between two destinations. This also neglects the economic importance of the destination and omits the importance of key business centres.

3.3.2 Connectivity: in number of destinations

Based on Eurostat data (2012), we investigated the connectivity of Heathrow compared to the other main European airports. Table 4 shows the number of destinations between 2003 and 2010.

Table 4 Number of direct destinations at the four main European airports

	2003	2004	2005	2006	2007	2008	2009	2010	% change (2003-2010)
Heathrow	128	132	135	134	133	135	134	139	8.6%
Schiphol	137	142	145	147	154	168	149	154	12.4%
Paris CDG	141	150	152	163	167	167	167	177	25.5%
Frankfurt	182	184	189	196	211	209	208	211	15.9%

Source: Based on Eurostat data (Eurostat, 2012).

Between 2003 and 2010, Heathrow served the lowest number of (direct) destinations (139). It also had the smallest increase in new destinations (8.6%) between 2003 and 2010 compared to Schiphol (12.4%), Paris CDG (25.5%) and Frankfurt (15.9%).

It must be mentioned that these figures only show the total number of destinations and do not say anything about the importance of the destinations. Most of the destinations are domestic or minor destinations. What matters for economic growth and employment is the number of flights to the key business destinations. AirportWatch (2011) investigated the connectivity of Heathrow with the key business destinations in the world[10]. They found that Heathrow has more flights to these business destinations than any other airport in Europe. It has many more intercontinental flights than the other European airports, but flies to a smaller number of European and domestic destinations. Flaws of this report include that it did not look at the new emerging economies, such as Mexico, or Indonesia and that it only looked at departures during one week in July, 2011.

3.3.3 Connectivity: in frequency of flights

Although Heathrow had the lowest amount and smallest increase in destinations compared to the other main European airports, between 2003 and 2010 it had the highest frequency per destination, with an average of 3,467 flights in 2010. Table 5 shows the average frequency of flights per destination between 2003 and 2010.

[10] As key business destinations, Airportwatch (2011) included important business cities in the U.S., Canada, Japan, South Korea, the Gulf States, China, India, Brazil, Indonesia and South Africa.

Table 5 **Frequency of flights (average per destination)**

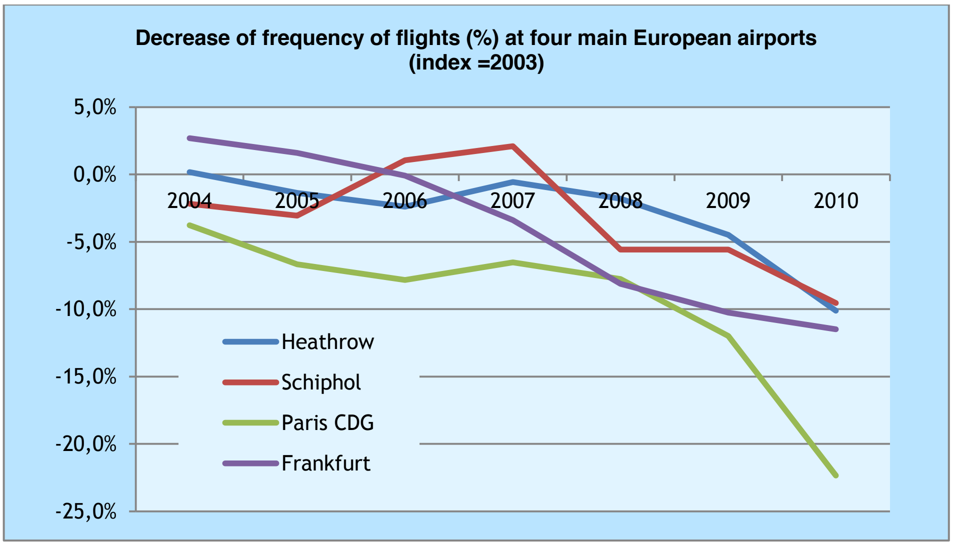
	2003	2004	2005	2006	2007	2008	2009	2010	% change (2003-2010)
Heathrow	3,857	3,864	3,804	3,765	3,835	3,788	3,685	3,467	-10.1%
Schiphol	2,467	2,414	2,392	2,494	2,519	2,330	2,330	2,232	-9.5%
Paris CDG	3,152	3,033	2,941	2,905	2,946	2,907	2,774	2,447	-22.3%
Frankfurt	2,617	2,688	2,659	2,615	2,529	2,405	2,349	2,317	-11.5%

Source: Based on Eurostat (Eurostat, 2012).

In the observed time period, it appears that all four main European airports decreased the frequency of flights. Heathrow decreased its frequency of flights by 10.1% between 2003 and 2010. However, it did not decrease as much as Paris CDG (-22.3%) or Frankfurt (-11.5%) and still remains on top.

Research carried out by AirportWatch (2011) confirms that, compared to other European cities, London has the best connections to the key business centres of the world. London's airports had 1113 departure flights in one observed week, compared with Paris's 499, Frankfurt's 443, and Amsterdam's 228. This shows that London's strategy is to focus on a smaller number of important and profitable routes, while other airlines invested in a more widespread network.

Figure 1 **Decrease of frequency of flights (%) at four main European airports (index =2003)**



Source: Based on Eurostat (Eurostat, 2012).

Load factor

The low number of destinations and the high frequency of flights at Heathrow, raises the question of whether the flights are fully booked or whether Heathrow is offering too many flights to the same destinations. Therefore, it is interesting to look at the load factor (what percentage of the seats is filled)[11]. This shows us how capacity is used at Heathrow.

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11 Load factor is measured by: total passengers carried/total seats available.

From our data analysis, it appears that seat capacity at Heathrow is similar to the other large European airports. The load factor is 74%, which indicates that 26% of seats are empty (Eurostat, 2012). Therefore, there is some scope for improvement.

Table 6 **Load factor at four main European airports**

	2007	2008	2009	2010
Heathrow	74%	72%	73%	74%
Paris CDG	NA	NA	98%	77%
Frankfurt	75%	75%	74%	76%
Amsterdam	76%	76%	75%	78%

Source: Based on Eurostat (Eurostat, 2012).

Number of passengers

In order to get a complete view of the capacity and development of the four main European airports we also looked at the total number of passengers on board and the total annual (commercial) flights.

Table 7 **Number of passengers (2003-2010) in millions**

	2003	2004	2005	2006	2007	2008	2009	2010	% change (2003-2010)
Heathrow	68.2	72.4	72.9	71.5	72.0	70.9	70.0	69.7	2.1%
Schiphol	36.7	39.2	40.8	42.4	44.5	46.1	40.4	42.5	15.8%
Paris CDG	44.6	47.4	49.9	53.5	56.6	56.8	54.8	57.1	28.1%
Frankfurt	55.2	58.1	58.8	59.6	63.4	59.9	57.3	59.3	7.4%

Source: Based on Eurostat data (Eurostat, 2012).

Table 7 shows that Heathrow is still the largest airport in terms of the total number of passengers However, the gap with the other airports shrank between 2003 and 2010. The increase in the number of passengers compared to 2003 was small at Heathrow (2.1%), while Paris CDG (28.1%), Schiphol (15.8%) and Frankfurt (7.4%) increased their passengers at higher rates.

Total annual flights

Table 8 **Total annual flights**

	2003	2004	2005	2006	2007	2008	2009	2010	% change (2003-2010)
Heathrow	493,704	510,069	513,605	504,461	510,113	511,356	493,737	481,894	-2.4%
Schiphol	338,032	342,734	346,882	366,546	387,935	391,467	347,140	343,690	1.7%
Paris CDG	444,385	454,937	444,876	473,492	489,923	483,666	461,494	436,950	-1.7%
Frankfurt	476,337	494,520	502,621	512,484	533,554	502,586	488,611	488,855	2.6%

Source: Based on Eurostat data (Eurostat, 2012).

In 2010 Heathrow had the second largest number of total flights, following Frankfurt. However, Heathrow had decreased its total flights by -2.4% compared to 2003 and Frankfurt increased its total flights by 2.6%.

Summary
In general, we see a trend in the period 2003-2010 among the four main European airports to increase the number of destinations and to reduce the frequency of flights.

With respect to Heathrow, the airport seems to develop at a slower rate than the other large European airports or even to decrease. The data show the following:
- Heathrow has lowest number of destinations (139) and smallest increase of new destinations (2.1%) compared to other main airports.
- Heathrow still has the highest frequency of flights, but decreased its frequency over time (-10.1%) compared to 2003.
- Heathrow has a load factor of 74% which indicates that 26% of the seat capacity is unused.
- Heathrow still has the highest number of passengers, but the gap with other main airports becomes smaller.
- Heathrow has the second largest number of total flights after Frankfurt, but Heathrow decreased its annual flights (-2.4%) and Frankfurt increased (7.4%) compared to 2003.

Concluding, it appears that Heathrow's strategy for the last decade has been to focus on a limited amount of destinations, but with a very high frequency. Where other airports focussed on a more widespread network, Heathrow focussed on a small number of destinations with a high frequency. Looking at load factor it appears that 26% of the seats is unused, which gives some scope for improvement. The question is whether Heathrow is constrained by capacity restrictions or whether UK demand for air travel has decreased over time.

3.3.4 Impact of capacity constraints on connectivity
Capacity constraints could in the intermediate term lead to congestion both in the air and on the ground, which in turn results in delays and reduced reliability. Furthermore, it might complicate the accommodation of hubbing 'waves' of landing and take-off to other connecting flights.

In the longer-term, any new destinations or increased frequencies come at the expense of another destination already being served. Furthermore, capacity constraints could influence the fleet mix and result in larger aircrafts.

The relationship between airport capacity and connectivity, and between connectivity and economic growth is complex. At a capacity constrained airport, the number of flights is less than it would be if the constraints were relaxed. If the airport were allowed to expand, the number of flights would increase. This can result in a number of changes in the flight network, such as:
- more frequent flights to the same destinations, increasing the number of seats available;
- more frequent flights to the same destinations, using smaller aircraft;
- flights to more destinations.

If the network were optimised in the constrained situation, the additional flights would have lower benefits than the other flights.

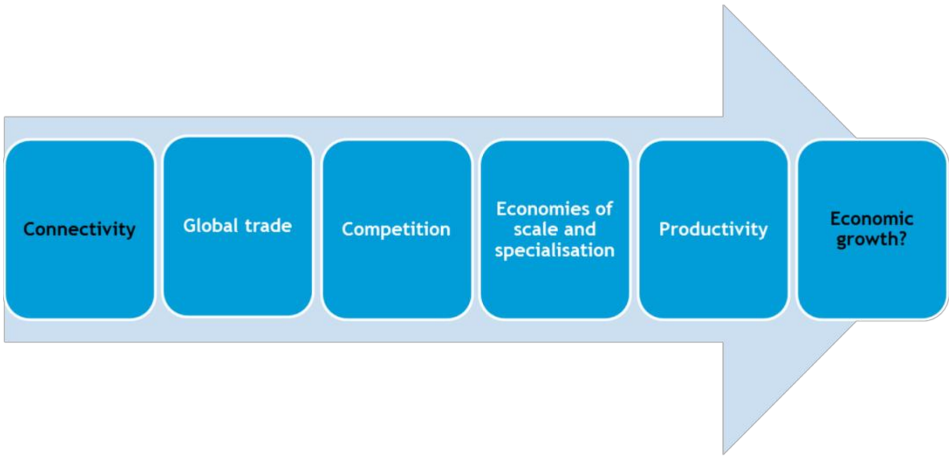
The relationship between connectivity and economic growth is less clear. As subsequent sections will show, there is a large body of literature on the relationship between aviation demand and economic growth, but very little on the causal relationship between connectivity and economic growth.

3.4 Economic growth

Many studies have investigated the economic benefits of aviation and its impact on economic growth. The relationship between connectivity and economic growth is, however, less investigated and there remains much uncertainty. We analysed the existing literature and tried to unravel the impact of connectivity on economic growth step by step.

The aviation industry often portrays connectivity as the driver of economic growth and innovation - it would generate wider economic benefits for businesses, increase global trade and productivity. Figure 2 shows the assumed linkage between connectivity and economic growth.

Figure 2 Does connectivity lead to economic growth?



We analysed the linkages between connectivity and economic growth step by step.

3.4.1 More global trade

Connectivity is defined as the range of destinations and/or the frequency of flights. When the number of destinations increases, this could open up new markets and lead to new trading partners. Trade with distant markets becomes easier and cheaper and goods and services can be marketed on a global basis. The export from UK companies to foreign countries and import from foreign business to UK increases.

More connectivity in terms of a higher frequency of flights, on the other hand, will lead to more reliability and a more frequent supply of goods or services. The question is however, whether more frequent flights will also increase global trade. Trade could increase by industries for whom frequency of supply is increasingly important (such as transport of flowers).

The relationship between connectivity and global trade assigns a large role to business passengers. And although they pay in general higher fares (business class, last minute booking) and hence contribute to a larger extent to the aviation revenues, their role should not be exaggerated. Only 25% of London's air travel demand is for business, and 75% for leisure travel (Prime, 2012).

Connectivity and global trade

The concept of air connectivity is usually ill-treated in reports commissioned by the aviation industry. One claim in particular is often made, which is unsubstantiated at best and misleading at worst "that connectivity leads to more trade".

Connectivity leads to 20 times more trade?

Frontier Economics (2011, page 11) for instance states that: "There are very clear correlations between the levels of trade and connectivity". They validate this claim by stating that "UK businesses trade 20 times as much with countries (i.e. Brazil, China, India, Russia, South Korea and Turkey) where there are daily flights than with those (i.e. Indonesia and Mexico) with less frequent or no direct service."

The bulk of U.K. trade with the aforementioned countries is of course maritime. It should come as no surprise then, that UK patterns in trade-intensity are no different from those of EU countries with direct air links to all Emerging Markets. CE Delft has calculated (based on UN COMTrade data) that Germany's exports to Indonesia and Mexico as a share of its exports to all eight EMs is the same as that of the UK. Dutch exports to Mexico and Indonesia as a share of exports to all eight EMs is even lower than that of the UK in spite of the direct flights from Schiphol to Jakarta and Mexico City.

Similar reservations apply to Frontier Economics' assertions on trade and growth. CE Delft has compared real export growth to six connected EMs (from a UK perspective) and to ten unconnected EMs (i.e. Mexico, Indonesia, Venezuela, Colombia, Chile, Philippines, Pakistan, Peru, Ukraine and Vietnam) which have direct air links to EU competitors. CE Delft finds that the yearly real growth in UK exports to connected countries was on average 5% higher than real export growth to unconnected countries in the period 2000-2010. This is slightly higher than the difference in real export growth for Spain (4%), but lower than its was for France (6%). the Netherlands (7%) and Germany (9%). The observed patterns in trade-intensity for the UK were in all likelihood not caused by connectivity.

Economic loss of 14 billion a year?

Frontier Economics also states that not expanding Heathrow could cost the UK economy £ 14 billion a year in lost trade. That figure could rise to £ 26 billion a year by 2030. Increased international direct connectivity through a hub airport would be vital to supporting increased trade and economic growth; and that a lack of connectivity could choke off trade that would otherwise develop. Frontier Economics implies a causation here which to date no scientific study has been able to show (as indeed they themselves acknowledge reluctantly on page 38 of the report, right before they repeat their earlier claim). There is indeed a correlation between connectivity and trade, but the causation might run backwards (trade drives connectivity) or some third factor (population growth) might drive both trade and connectivity.

3.4.2 Increased competition

Better connectivity is said to lead to more global trade by opening domestic markets to foreign competitors. The entrance of foreign firms to the market increases competition. This would force domestic firms to adopt best international practices in production and management methods and encourage innovation.

According to OEF (2006) “air services help to improve competitiveness of almost all aspects of companies’ operations, including sales, logistics, inventory management, production and customer support”.
The capacity constraints on Heathrow could therefore be a drag on London’s competitiveness. Prime (2012) argues that this relates far more to its poor facilities and problems around security and immigration services. Heathrow has long suffered from excessive queues to enter the UK and in particular for transfer passengers.
They argue that BAA has failed to upgrade the facilities over many years and in order to improve its competitiveness passenger experience should be improved.

3.4.3 Economies of scale and specialisation

Trade and increased competition encourages firms to specialise in areas where they possess a comparative advantage. Because of this specialisation, production takes place at a larger scale, which leads to economies of scale. A benefit for consumers is that it drives down product prices and improves the quality of goods. According to ATAG (2005) around 25% of the businesses report that air transport services enables them to exploit economies of scale.

3.4.4 Productivity

The increased access to foreign markets, the increased competition and the increase in economies of scale, specialisation advantage and availability of new technologies and management techniques enables firms to produce more efficiently. This enables firms to increase the output per one unit of a total input, and thus increase productivity.

A rise in productivity in firms outside the aviation sector comes through two main channels. There are effects on domestic firms of increased access to foreign markets and increased foreign competition in the home market and there is freer movement of investment capital and workers between countries.

A number of studies have attempted to quantify the long term impact of connectivity on productivity. This is not straightforward and resulted in a wide range of estimates.

Table 9 Impact of connectivity on productivity

	Impact of 10% increase in connectivity (relative to GDP), on productivity
IATA (2007)	0.07%
EEC (2005)	1.3%
OEF (2006)	0.56%

The estimates of the impact of a 10% increase in connectivity on productivity range from 0.56 to 1.3%. IATA (2007) finds an impact of 0.07% on productivity if connectivity increases by 10%. This is a very small effect and causality is not proven[12].

[12] A Granger causality test was undertaken on the relationship between connectivity and labour productivity. This is a technique for determining whether one time-series causes changes in another or vice versa. The test was unable to clearly determine that connectivity granger-causes productivity growth, nor that productivity granger-causes connectivity. In other words, no causality was detected in either direction between these two variables.

BCC (2009) has studied the economic impacts of hub airport expansion and find that improved airport expansion could benefit the UK economy by £ 8.6-12.8 billion (present value) in direct productivity. It must be mentioned that these benefits are spread out over 60 years and includes double counting of indirect benefits.

The British Chambers of Commerce commissioned a report in 2009 in which the direct and indirect benefits of the expansion of Heathrow were estimated. Direct benefits would amount to £ 8.6 to £ 12.8 billion (present value) and another £ 20 billion (PV) in wider economic benefits (BCC, 2009).

The direct benefits were obtained by multiplying the assumed reduction in travel times for business trips with the value of an hour to business passengers. Yet this figure is already contained in the estimate for wider economic benefits, where productivity gains have been calculated as the rise in GDP as a result of an increase in connectivity. The two impacts are presented separately, but they are the same impact calculated in different ways: the gains in productivity are largely the result of the reduction in travel times.
The other indirect benefits refer to gross impacts on employment, neglecting the economic reality of displacement of labour elsewhere and discarding any negative impacts (noise, pollution) of more air traffic.

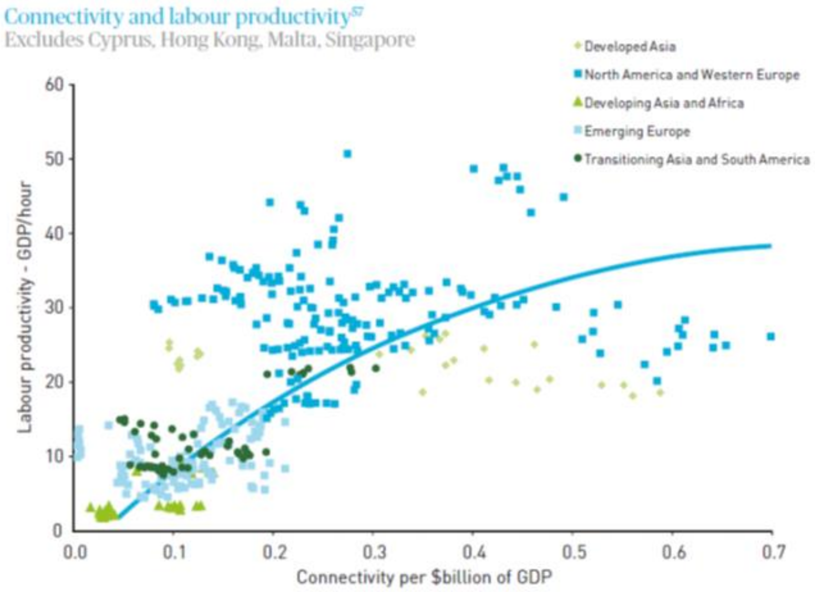
BCC further claims that increased connectivity boosts economic growth. Trade would seem the most direct impact of better connectivity alongside tourism. CE Delft has calculated that the UK did not fall behind its EU competitors in exporting to unconnected (from a British perspective) Emerging Markets.

Another noteworthy result in the scenario analysis, is that if Heathrow were expanded, gains from opening up new destinations would amount to £ 9,850 billion in PV, whereas the less profitable strategy aimed at increasing the frequency of existing flights would lead to gains of £ 6,200 billion in PV. Section 3.3 of this report has revealed that Heathrow's strategy went in the exact opposite direction: an increase in frequency at the expensive of (the seemingly more profitable) increase in centrality.

On the whole, the main flaw of the report remains the double-counting of benefits from a reduction in travel times.

IATA (2007) has studied the relationship between productivity and connectivity and found a positive relationship, as shown in Figure 3.

Figure 3 Connectivity and productivity



Source: IATA (2007).

Figure 3 shows that developing and transitional economies (bottom left) typically have low connectivity relative to their GDP and also relatively low labour productivity. The top right of the figure shows the developed economies (Asia, North America and Europe) with high levels of connectivity and high labour productivity.

The flattening of the curve suggests that there is a positive relation between productivity and connectivity for developing economies, but that this relation is much smaller for developed economies like the UK. Therefore, it seems that developing countries have a great deal to gain from expansion, while developed countries receive diminishing returns from each increase in connectivity. Also the large amount of variation in this figure shows that there might be other – potentially more important – drivers of labour productivity as we can see from nations with lower connectivity but much higher labour productivity.

The underlying model of InterVISTAS is presented in the Annex of the IATA (2007) report. The model fails the test for 'Granger-causality', i.e. productivity did not cause connectivity, nor did connectivity cause productivity. This could imply a number of things:

- The model does not contain a time trend: trend growth in connectivity coincided with trend growth in productivity, with no causal relation.
- Some non-modelled factor could have caused both connectivity and productivity.
- Connectivity is first divided by GDP in the model: the model could have captured the short term relation between productivity growth and GDP growth[13].

13 Productivity growth is a major determinant of economic growth, alongside growth in labour supply and technological growth. During the investigated period (1996-2005) however, many EU countries experienced an unexpected drop in productivity while maintaining a robust economic growth.

Although the theoretic link between connectivity and labour productivity seems straightforward, is has been difficult to prove a causal link in practice.

3.4.5 Economic growth

Lastly, we discuss the effect of connectivity on economic growth. The benefits of connectivity and its assumed impact on economic growth are often mentioned as an argument in favour of airport expansion. In this section, we discuss the different studies found on the impact of connectivity on economic growth. Since this number is limited, we also looked at studies that investigate the impact of aviation in general on economic growth, either in terms of GDP or employment.

Connectivity and economic growth (GDP)

Although there has been much research on the broader impact of aviation on economic growth, so far, there has been no academic research carried out on the specific relationship between connectivity and economic growth. The aviation industry has published several reports on the impact of connectivity on economic growth, of which the results are shown in Table 10.

Table 10 Effect of connectivity on economic growth (GDP)

Study	Impact of a 10% increase of connectivity on economic growth (GDP)
IATA (2006)	1.2%
IATA (2007)	0.07%
EEC (2005)	1.9%
OEF (2006)	0.6%

The impact of a 10% increase of connectivity on GDP varies between the studies from 0.07 to 1.9%. There remain large uncertainties about the elasticities of connectivity on economic growth. The differences between the IATA data result from a different method used to estimate the elasticities. The 2006 study used modelled data from world economy models. The results of the 2007 study are based on cross sectional statistical analysis of air connectivity and labour productivity. The 2006 estimation may have been overestimated due to constraints on available data. Also the impact of 0.07% on economic growth does not provide us an answer to our question whether connectivity causes economic growth, since there was no causal relationship found.

Since there is not much scientific research carried out on the relationship between connectivity and economic growth, we also examined the broader impact of aviation demand on economic growth (measured by GDP or employment).

Air travel and economic growth (GDP)

The results of different studies on the impact of air travel on economic growth are shown in Table 11, where economic growth is measured as an increase in GDP.

Table 11 Impact of air travel on economic growth: GDP

Study	Impact of air travel demand on GDP	Type of research (method)
NYFER (2000)	10% increase in aviation growth results in 1.7% economic growth (elasticity of 0.17). Causal relation	Panel data van 175 Europese luchthavens (3LS)
Mukkala and Tervo (2012)	Strong correlation between air traffic and economic growth. Causality from air traffic to regional growth in peripheral regions but causality is less evident in core regions	Empirical analysis herein is based on European-level annual data from 86 regions and 13 countries on air traffic and regional economic performance between 1991-2010. Granger-non-causality test applied
MIT ICAT (2009)	Strong positive correlation between air transport passengers and GDP of 0.99 for the UK (mutual causality)	Country-data analysis for 139 countries between 1975-2005
Tittle et al. (2010)	Positive relationship between the number of runways and real gross metropolitan product	Panel data analysis for 33 U.S. airports between 2001-2007
Oxford Economics (2012)	Constraints at Heathrow airport reduces economic activity in UK by 2021 by £ 8.5 billion each year	Analysis based on Input-output model and ad hoc econometric models

Table 11 shows that there remain large uncertainties about the impact of air travel demand on economic growth. Most of the studies find a positive correlation, but cannot find causality. In other words, it is not clear whether connectivity causes economic growth or the other way around.

Mukkala and Tervo (2012), for example, studied the role of air transportation in regional growth. They find a strong correlation between air traffic and economic growth, but find no clear causality. In peripheral and remote regions provision of air transportation may result in a boost for the regional development of the economy (supply effect), but this effect is less likely in core regions. In remote regions, the implementation of transportation infrastructure and accessibility leads to economic development and airports may act as catalysts for local investment. In core regions, however (like London), these agglomeration effects are already exploited and here it is economic development that spurs a region to provide increased and better air transportation. Hence, in core regions it is the economic development that determines transportation needs and services. Furthermore, they state that the development of core regions is led by many agglomerative forces, and their success is not inevitably dependent on the impact of airports, although they naturally require efficient airlines.

Tittle et. al. (2010) explored the economic impact that additional runway capacity has upon a metropolitan growth and economic development. Based upon panel data for 33 medium and large airports, they find a positive relationship between the number of runways and real gross metropolitan product[14]. Capacity constraints (measured by flight delays) were found to be an important determinant of economic development, decreasing gross

[14] Gross Metropolitan Product (GMP) is similar to Gross Domestic Product (GDP), but then for a metropolitan area. GMP is defined as the market value of all final goods and services produced within a metropolitan area in a given period.

metropolitan product by 2.9% ($ 1.5 billion) and labour productivity by 1.31% ($ 1,029) on average.

Many studies show a strong correlation between aviation and economic growth, but no clear causation. Furthermore, effects might be overestimated due to a failure to account for changes in other strategic variables, such as prices and network development and Open Skies air service agreements.

Oxford Economics (2012) has prepared a position paper for Heathrow which builds upon their earlier research for the aviation industry. Oxford Economics claim that "if Heathrow is constrained, it is likely to reduce economic activity in the UK (as measured by GDP) by 2021 by £ 8.5 billion each year and lower employment by 141,400."

CE Delft has critically assessed the framework used by Oxford Economics on two occasions (CE, 2008 and 2012). Our main points of criticism are:

- Oxford Economics presents gross impacts of aviation on employment, taxes and GVA. An estimate of the net impacts on the UK economy would take account of the displacement of jobs, changes in the wage and air freight rate.
- Connectivity moves in both directions: an increase in tourism would lead to more spending of foreign visitors in the UK, but would also lead to higher spending of UK residents abroad. Oxford Economics only addresses the first issue.
- A loss of connectivity at Heathrow does not mean that trade and passengers are lost to the UK. They could reach the country through other UK airports, by connecting flights from continental hubs or by other modes of transport. Alternatives travel modes are insufficiently addressed.
- Scenarios used contain several unrealistic assumptions. Upper limits are applied for projections on passenger and cargo growth and capacity. For instance, capacity during the busy summer period is used as an estimate for capacity throughout the year.
- Air connectivity is confused with air centrality*, most losses reported by Oxford Economics are in all likelihood related to the latter rather than to the first concept.
- Some impacts (e.g. the economic value of business trips, GVA of non-airliner entities at Heathrow airport) are counted twice.
- Taxes are treated as benefits to the UK economy, but this only applies to taxes paid by foreign entities in the UK. Taxes are transfers within the UK, with possibly distortionary impacts.
- The value added of foreign airliners is incorrectly added to UK GDP.
- The negative impacts of aviation (noise, pollution, congestion, lower property values) are not addressed.

CE Delft has assessed that Oxford Economics' estimates of the gross impacts on GVA are inflated by a margin of 65 to 72.5% and presumably by even more. A social cost benefit analysis conducted by CE Delft (2011) suggests that net impacts of Heathrow expansion are likely negative, due to lower gross benefits and high social costs of noise impacts.

*Connectivity is often confused with centrality, which is measured by the number of routes (and ignoring frequency of flights and importance of destinations)

Air travel and employment

Air travel is said to have a large contribution to the creation of jobs, not only in the aviation industry, but also in the service industry due to a large amount of incoming passengers. The results of different studies on the impact of air travel on employment are shown in Table 12.

Table 12 Impact of air travel on employment

Study	Impact of air travel demand on employment	Type of research (method)
Oxford Economics (2012)	Constraints at Heathrow airport lowers employment in UK by 2021 by 141,400 jobs	Input-output model (multiplier used for indirect employment is 1.7)
NYFER (2000)	10% increase in aviation growth results in 1.8% employment in the service sector (elasticity of 0.18). Indication of positive causational relation between aviation and employment	Panel data of 175 European airports between 1992-1997. Correlation coefficient and Spearman rank correlation applied
Green (2007)	Hub cities see their employment grow between 8.4 and 13.2% faster than non-hub cities	Regression analysis with panel data of 83 metropolitan cities in US between 1990-2000
Hakfoort et al. (2001)	One job at the airport leads to one job in indirect and induced employment (Amsterdam Schiphol)	Input-output model (MADAM) for Amsterdam Schiphol between 1987 and 1994
Button and Taylor (2000)	Increasing destinations from 2 to 3 increases jobs with 2486. But diminishing returns: from 20-21 destinations results in additional 450 jobs. (Assumption that new destination increases number of on-board passengers)	Regression analysis on 41 US airports in 1996 with new EU-destinations
Percoco (2010)	Elasticity of service-sector employment to air passengers is 0.045 (Italy)	Two step procedure with tobit model with data including 35 Italian airports in 2002
Brueckner (2003)	A 10% increase in passenger enplanements in a metropolitan area leads approximately to a 1% in employment in service-related industries (but not in manufacture or other goods-related employment)	2SLS regression analysis with 91 US metropolitan areas in 1996. Causality accounted for with instrumental variables
Neal (2011)	Central position in the network (centrality) leads to economic growth in terms of jobs	Analysis on 128 U.S. metropolitan areas from 1993-2008 using a series of lagged regression models

Most studies find that an increase in air travel and employment are positively related, however causality can not always be proven. Green (2007) finds that passenger activity can be a powerful predictor of growth under a variety of specifications. He finds a strong correlation between air traffic and employment, but the direction of the causality is not clear. Button and Taylor (2000) find that increasing the number of destinations from 2 to 3 (accompanied by an increase of passengers) results in higher employment by 2,486 jobs. This effect becomes smaller as the number of destinations increases (diminishing returns). An increase from 20 to 21 destinations (with an increase in on-board passengers from 145,000 to 150,000) results in additional 450 jobs. Brueckner (2003) and Percoco (2010) state that the positive employment effect is quite small (0.4 to 1%) and only found in the service sector (not in the manufacturing or other goods-related sectors).

Neal (2011) examined the relationship between centrality and employment for 128 US cities. He finds that a city's economic growth is closely related to its position in networks of inter-urban exchanges i.e. its centrality.
Yet centrality is a narrower concept than connectivity. Centrality refers to the number of destinations that can be reached directly, not to the frequency of flights on these routes. He questions whether a city occupies a central position in the network because of its significant economic activity (demand based theory) or whether cities experience economic growth because they occupy a central position in the network (supply based theory)[15]. The latter appears to be the case, albeit in a different way from that in which the author interprets his results: cities with a central position in the network experienced more economic growth (employment in jobs), whereas centrality seems to be a process that is unrelated to the level of employment. Therefore, this study does not fully answer the question of whether increased connectivity leads to more economic growth, it only implies that one of its components, centrality, may perhaps cause more economic growth and employment.

Neal incorrectly assumes that problems with causality are circumvented by using a lagged value for centrality in explaining employment. His estimation results however, reveal that centrality today was similar to centrality one year ago supplemented by some random factor (i.e. the addition or cancellation of air links or airport expansion or closure). As such, it would probably make no difference to his relation between employment and centrality if the current value of centrality is substituted for its lagged value. The question on the causality between centrality and growth remains unsettled.

3.4.6 Causation or correlation?

This study investigates the relation between connectivity and economic growth. In many of the studies discussed above a positive relation (correlation) is found between connectivity and economic growth. However, it is important to mention that a differentiation should be made between correlation and causation. Correlation merely means that two variables appear to be related to one another by some statistical function over the period examined. Causation shows a clear relation and direction: a change in one variable *causes* a change in the other variable but not the other way around. Often correlation is misinterpreted for causation e.g. there is a clear correlation between shoe sizes and the reading skills among children, but it is obvious that there is no causal relationship between the two.

The question raised in this study is whether connectivity leads to economic growth or not. Regarding the relationship between air traffic and economic growth, there is a lot of literature provided by the aviation industry, but there is only a limited number of scientific studies. Most of the studies find a positive correlation between air traffic and economic growth, but the causality is not clear. Brueckner (2003), Nyfer (2000), and Green (2007) studied the causal relation of air traffic and economic growth (measured by employment) and claim that there is a causal relationship. Brueckner (2003) and Green (2007) utilised the methodology of instrumental variables (IV) in panel data to control for the potential endogeneity of airline traffic.
The problem with the IV method as applied here is to find appropriate instruments that explain only airport activity, not regional growth. NYFER (2000) suggests that an increase in aviation growth results in 1.7% economic growth. These studies found support for bidirectional influence, but conclude

[15] Centrality is expressed by the volume of air traffic in terms of number of passengers for whom a city is either their origin or destination. More centrality in the network implies a higher volume of air traffic.

that air traffic has a larger impact on economic growth than vice versa (Brueckner, 2003; Button and Lall, 1999; Irwin and Kasarda, 1991; Ivy et al., 1995). These studies suffer, however, from several limitations with respect to the measurement of air traffic and the connectivity of cities in the network, by ignoring leisure travellers (Neal, 2011). Neal states that there is a causal relation between centrality and employment, which covers only one part of connectivity (number of destinations) and ignores frequency of flights. Concluding we can state that the methodological shortcomings of these papers undermine their ability to differentiate between correlation and causation.[16]

3.5 Conclusion

In this chapter, we analysed the relationship between capacity, connectivity and economic growth. We have seen that capacity refers to the ability of an airport to handle a given volume or magnitude of traffic (demand) and constraints result when there is unmet demand. Capacity constraints can be caused by operational, economic or environmental restrictions.

The impact of capacity constraints on connectivity can be twofold: either the number of destinations served or the frequency of flights is reduced. Regarding Heathrow's capacity, we found that compared to other main European airports.:
- Heathrow has lowest number of destinations (139) and smallest increase of new destinations (2.1%) compared to other main airports.
- Heathrow has the highest frequency of flights.
- Heathrow has the highest number of passengers, although the gap with other main airports has closed somewhat.
- Heathrow has the second largest number of total flights after Frankfurt.

It appears that Heathrow's strategy for the last decade has been to focus on a limited amount of destinations, but with a very high frequency. Heathrow has developed itself differently than the other main European airports, which may have been the result of capacity constraints.

Capacity constraints may in the long run affect connectivity in two ways: fewer destinations or lower frequency of flights. What this implies for economic growth remains unclear. Although connectivity is said to increase global trade, and to contribute to competitiveness, productivity and eventually economic growth, proof is extremely difficult to establish. There remain large uncertainties and although many studies show a strong and positive correlation, causation cannot be proven.

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[16] The problem of causation can be addressed in two ways: a co-integration analysis to differentiate between the long-term and short-term relationship between growth and connectivity or better yet, an approach in which connectivity is first instrumented. The 'instruments' in the latter approach should be able to predict connectivity without being related to economic of employment growth. The predicted value for connectivity, which will now be no longer dependent upon growth, can be used to reveal the proper impact on employment or economic growth.

4 Conclusions

This report set out to answer two questions:

1. What framework should be used to assess the economic impacts of airport investment projects?
2. Does airport expansion lead to increased capacity, more connectivity and more economic growth?

Assessing the economic impacts of airport projects

The most widely recognised method to assess the economic impacts of airport investment projects is a social cost benefit analysis (SCBA). A SCBA identifies all the effects of an investment project over time and expresses them in monetary terms. For effects that are traded, such as building a runway, market prices can be used. For most effects that are not traded, such as time savings, various well-established methods exist to estimate their monetary value. By expressing all effects in monetary terms, the relative importance of the various costs and benefits can be analysed. Some effects, such as the impact on biodiversity and landscape, are often not expressed in monetary terms.

In the UK, the Transport Assessment Guidelines recommend social cost benefit analysis for airport investment projects. A SCBA yields very different results from other methods that are sometimes used to determine the economic impact of airports or aviation. A commonly used method is to add the direct, indirect, induced and catalytic effects. The results cannot be used in a SCBA, however, since the indirect and induced effects are in fact part of the direct effects. For example, if an airport expansion results in more passengers using the airport, this indicates that a consumer surplus exists. Passengers may decide to use a share of the surplus to buy something at the airport. Thus consumer or producer surplus created in shops and restaurants at the airport is included in the consumer surplus of the expansion and should not be added to the former.

A SCBA shows whether or not a particular project creates wealth and, if there are alternatives, which of these creates the greatest wealth. Of course, creating wealth need not be the only policy objective. A political decision-making process may also take into account distributional effects, legal aspects, public opinion, equity, fairness and employment effects, which do not feature in SCBAs.

The relation between aviation activity and economic performance

Among the wider economic benefits of airport expansion are the impacts on productivity agglomeration, output change, labour market supply and the move to more or less productive jobs. These are often captured under the heading ‘benefits of connectivity’. They provide one of the main arguments used in the public debate on airport expansion and studies have been published which claim the benefits of expanding London’s airports will be very large for the capital as well as for the country as a whole.

This study has reviewed the evidence on the relation between connectivity and economic performance. Although the few academic studies found report some degree of correlation, this study has not identified any evidence of causation either way. Hence, claims about the economic benefits of connectivity are not founded on solid evidence.

The relation between aviation activity and economic performance has attracted more attention. A review of the academic literature suggests there is a two-way causal relation between aviation activity and regional economic performance, with an increase in aviation activity causing an increase in GDP, and vice versa. This relation appears to be stronger for remote regions and stronger for poorer regions and countries than for well-developed ones. When reviewing this evidence, one should be aware that the method used to establish a causal relation cannot establish whether airports cause additional economic activity per se, or whether regions with airports grow at the expense or surrounding regions without airports.

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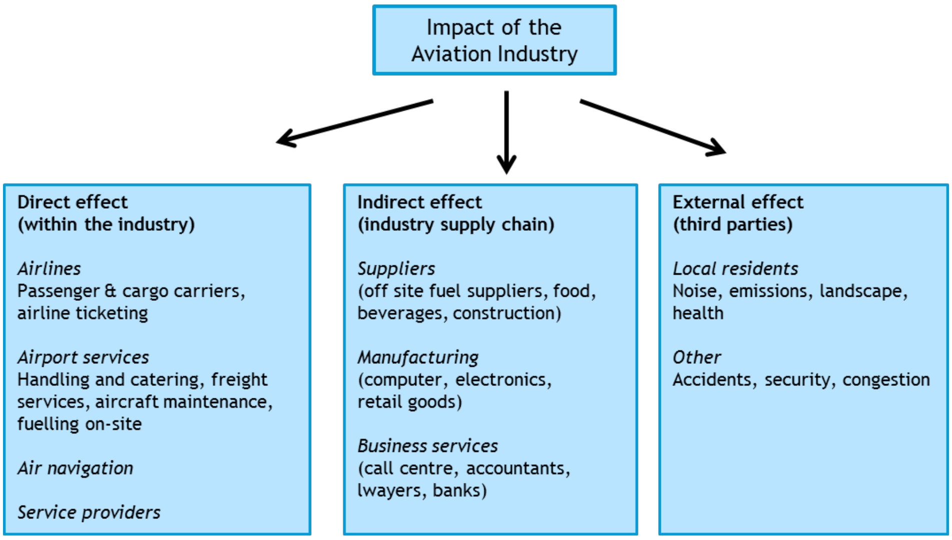
Annex A Direct, indirect and external effects of the aviation industry



Direct effects are impacts that are a direct consequence of the expansion/new airport development of the airport. It includes the employment and income generated within the aviation industry, including airline and airport operations, aircraft maintenance, air traffic control and regulation and activities directly servicing air passengers.

Indirect effects denotes economic activity created by the industry supply chain. These include the employment and activities of suppliers to the air transport industry, such as aviation fuel suppliers, construction companies that build additional facilities, manufacture of goods sold at airport retail outlets, and the production of airline meals and of the goods. These effects are also called backward linkages.

External effects relate to unintended changes in the welfare of third parties due to a certain action or change in policy for which no compensation is received. These often concern the environmental impact, such as the effects on human health, nature (soil, water), landscape, noise, air quality, GHG emissions, but also security. Since these impacts are not incorporated in market prices, they are denoted as external effects.

Annex B Overview CBA framework in the UK, the Netherlands and the EU

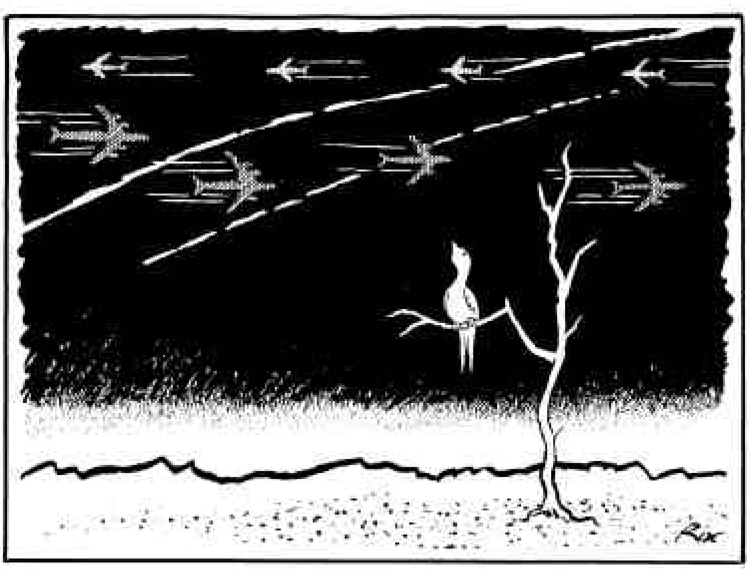
Transport Analysis Guidance (UK, DfT)	OEI (Netherlands)	EU - CBA Guideline
Economic impacts	**Direct effects (1st order)**	**Economic impacts**
– Transport economic efficiency (PS,CS) – Time savings from delay reduction – Wider economic impacts – Surface access impacts (new levels of traffic) – Impact on non-UK residents – Public account	– Exploitation profits of the new infrastructure (PS) – Transport related benefits (CS) – Location related effects – Economies of scale	– Consumer surplus (passengers) – Producer and user surplus – Time benefits – Impact on land values – Public account
Social impacts	**Indirect effects (2nd order)**	
– Accidents – Security – Accessibility – Integration	– Labour market (jobs) – Real estate market – Impact on other transport modalities – Strategic effects	
Environmental impacts	**External effects**	**External effects**
– Noise – Air quality – GHG emissions Non monetised effects: – Landscape – Biodiversity – Water – Historic heritage	– Noise – Emissions – Air quality – Landscape – Security – Congestion – Regional inequality	– Environment (landscape, noise, pollution) – Safety and accidents – Congestion – Health
Costs	**Costs**	**Costs**
– Investment costs – Maintenance costs – Exploitation/ operating costs	– Investment costs – Maintenance costs – Exploitation/ operating costs	– Investment costs – Maintenance costs – Exploitation/ operating costs
Net result	**Net result**	**Net result**

Annex C Appraisal Summary Table

Impacts		Summary of key impacts	Assessment				
			Quantitative		Qualitative	Monetary £ (NVP)	Distributional 7-pt scale/ vulnerable grp
Economy	Business users & transport providers		Value of journey time changes (£)				
			Net journey time changes (£)				
			0-2min	2-5min			
	Reliability impact on Business users						
	Regeneration						
	Wider Impacts						
Environmental	Noise						
	Air Quality						
	Greenhouse gasses		Change in non-traded carbon over 60y (CO_2e)				
			Change in traded carbon over 60y (CO_2e)				
	Landscape						
	Townscape						
	Heritage of Historic resources						
	Biodiversity						
	Water Environment						
Social	Commuting and Other users		Value of journey time changes (£)				
			Net journey time changes (£)				
			0-2min	2-5min			
	Reliability impact on Commuting and Other users						
	Physical activity						
	Journey quality						
	Accidents						
	Security						
	Access to services						
	Affordability						
	Severance						
	Option values						
Public Account	Cost to Broad Transport Budget						
	Index Tax Revenues						

Source: DfT (2012).

The Hidden Cost of Flying



Brendon Sewill

aef Aviation Environment Federation

Important decisions *about the future of aviation are due to be announced around the end of 2003 in a White Paper covering the next thirty years. The Department for Transport (DfT) published consultation papers in July 2002 setting out proposals for expansion at many airports, with options for new runways at Heathrow, Stansted, Birmingham, East Midlands, and in Scotland; and possible new airports at Cliffe, at Church Lawford between Coventry and Rugby, and perhaps at Bristol. Following judicial review of the decision to exclude Gatwick, a further consultation is being undertaken.*

The airlines are lobbying hard for expansion while, not surprisingly, the plans are creating substantial opposition. The environmental case against expansion is well known: the growing impact of aviation on climate change, noise and pollution around airports, destruction of landscape, wildlife and heritage. This booklet, however, is designed to subject the economic case for aviation growth to critical examination.

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The Hidden Cost of Flying

No one would deny that aviation is an important industry. The airlines tell us so. The Government tells us so. The Department for Transport (DfT) introduce the consultation on their proposals for airport expansion by telling us that “Aviation is a great British success story, and one of the major strengths of the UK economy. ... Our airlines and airports are also a major UK success. ... The British people are well served by our airlines and airports.”[1]

Powerful stuff but it needs to be kept in proportion. According to the Office of National Statistics, in terms of its contribution to the Gross Domestic Product, aviation is the 29th most important industry in the UK. At 28 in the league, slightly more important, is sewage and sanitary ware.[2]

Two great industries, each vital to the functioning of our national life. Yet with different characteristics. Aviation is new, exciting and romantic; sewage has been around a long time. Aviation means holidays and fun; sewage is taken for granted. Aviation is a dirty industry, top of the world league for increasing pollution; sewage has cleaned up the rivers and the beaches. Another big difference is in the amount spent on public relations, advertising and lobbying. Because so many people are paid large sums to proclaim the achievements of aviation, it is necessary to take a cool look at the situation, to examine the facts behind the hype.

Aviation is certainly very successful. In the 100 years since the Wright brothers’ first flight at Kittyhawk it has achieved amazing technical progress. Air travel has helped to widen the horizons of mankind. Yet in the last century other products can claim similar advances: the motor car; the telephone; television; the computer; and medicine and surgery.

Aviation is an important industry and employs a lot of people. There would be a serious loss if it were to be closed down. To imply, however, that because aviation is important therefore it should be encouraged to grow without question, is more doubtful logic. The sewage industry is important but that is not taken as self-evident proof that it must treble in size.

Aviation pays remarkably little tax. There is no tax on aviation fuel. There is no VAT on anything to do with air travel. Travellers to destinations outside the EU buy goods duty free. Landing fees and airport charges at the busiest airports are held down well below market levels. And there is no tax on the noise or pollution caused by aircraft. The air passenger duty is small by comparison with these tax breaks.

These issues are discussed in detail later in this booklet. For the present it merely needs to be noted that this favourable tax treatment helps to account for the apparent success of the industry; and artificially inflates the forecasts of future growth.

The forecasts

The Air Traffic Forecasts for the United Kingdom 2000[3] show passenger numbers at UK airports rising inexorably from 160 million in 1998 to 400 million in 2020. This is projected forward in the consultation documents to 500 million in 2030. The increase is equivalent to five new airports the size of Heathrow today.

The forecasts are based on predictions of growth in the national income, both in the UK and abroad. In the past the forecasts have proved accurate, even under-estimates, but that is no proof that they will prove accurate in future. They show a rising exponential curve. Growth is assumed to proceed at around 4% throughout the period (slightly less in later years). 'Exponential' means that 4% of a large figure at the end of the period is a lot more than 4% now.

Practical economists are taught to distrust exponential curves, and to apply a test as to whether any forecast is realistic. The test is to check on what is happening at the end of the period, and see if it looks silly. In this case, the forecasts show that by 2030 demand will be growing at a rate of a new Gatwick every 18 months, or a new Heathrow every three years. Looks silly.

In assessing the economic benefits of the proposed new runways, DfT include the whole period to 2060.[4] Quite right, because runways last a long time, and provide benefits for many years. The statisticians have reduced the forecast annual growth rate in the period 2051-2060 to the (amazingly precise) figure of 3.79%.[5] But at this rate demand for air travel in the UK in 2060 will be over 1.5 billion passengers a year, and to cope with them we will need 24 new Heathrows, mostly in the South East. And demand will be growing at a rate of one new Heathrow, with two new runways, every year. Looks even sillier.

Common-sense tells us that these forecasts, based on past trends, must be wrong. The years since 1945 have seen an exceptional period of almost uninterrupted expansion, but economic progress is not always onwards and upwards. Trends and fashions change. War or terrorism may increase the cost of fuel. Eventually fuel runs out. People might actually get bored with flying. Ryanair failed to give away 230,000 free flights out of 1.1 million free seats offered last year, and blamed it on "passenger inertia".[6] So if the forecasts are wrong, it is all your fault for choosing not to fly.

An alternative forecast

Economic history demonstrates 'the Sewill rule': that a new form of mass transport emerges about every fifty years.

1750.	Canals.
1800.	Turnpike roads and the stagecoach.
1850.	Railways.
1900.	The motor car.
1950.	Civil aviation.

In each case the dates roughly mark the time when a combination of technical progress and cost reduction brought the new method of transport into general use, although the relevant inventions had been made many years previously.

So perhaps we can forecast a new form of transport coming into general use any time now? Not a totally reliable forecast, you may think, because it is based solely on past trends. That is the point.

Every student of economics learns in one of their first lessons that demand depends on price. If the price of a product goes up, people buy less; if the price goes down demand goes up. The air traffic forecasts, when published in 2000, were based on the assumption that the price of air travel would fall at a rate of 1% a year between 1998 and 2020. DfT now suggest that the low-cost airlines, competitive pressure and other factors may lead to prices actually falling by 2% a year over the period to 2030.[7] So they feel confident in sticking to their original forecasts.

That does not look unreasonable since a sizeable fall in prices has already occurred in the past two or three years as a result of the advent of the low-cost airlines. It is, however, not certain that these airlines will be able to keep their prices down: airport charges and fuel prices may rise, and their staff may demand higher pay. When the EU proposed compensation for delayed or cancelled flights, the airlines said that "cheap air fares will disappear".[8]

The guess about future prices makes a big difference. If instead of falling by 1% a year, the price of air travel were to remain level, the equivalent of several new runways would no longer be required.

The Sustainable Development Commission has criticised the consultation papers as being "based on a classic predict and provide model".[9] Predict and provide got a bad name because, with roads, it was proved that when new roads were built, traffic tended to increase to fill them. The quicker the journey, the further people tended to drive. So also with housing. The more houses built, the more demand expanded. In each case it took massive public protest against the wanton destruction of countryside before the government statisticians were prepared to revise their forecasts.

Exactly the same is true of aviation. Unlimited provision of ever cheaper air travel encourages people to take more short breaks instead of longer holidays; more people fly off for weekends for weddings or funerals or family parties; more decide to take jobs abroad and commute home at weekends; more decide to buy second homes abroad.

One way of looking at this, much favoured by the airlines, is that it is hugely beneficial and widens opportunities and horizons. That might be so if it was not subsidised by tax concessions and had no environmental cost.

A powerful lobby

Aviation possibly spends more on advertising, public relations and lobbying than any other UK industry.

That is the nature of the industry. Airlines, because they have always been subject to regulation by national governments around the world, have honed lobbying to a fine art. They are in league with the package holiday industry and the travel correspondents of the press to present a glorified concept of foreign holidays as unlimited sun, sex and joy. And because they invest in large and expensive aircraft which need to be filled, there is always scope for advertising seats at cut prices.

The aviation correspondents of the national press, as with other specialist correspondents, depend on the airlines for their news stories and thus some may be reluctant to offend their source of information. They are well rewarded. For example, it was reported that British Airways spent an estimated £500,000 on corporate and media entertaining for the World Cup. The editor of every national newspaper was offered a free flight to Tokyo, two nights in a top international hotel, plus a string of lavish drinks receptions, parties and meals. In all the package was worth £10,000 per person. To their credit not all accepted.[10]

The airlines have been skilful in sidling up to the prime minister of the day. Lord King, Chairman of BA, was Margaret Thatcher's favourite businessman. Colin Marshall, also Chairman of BA, filled the same role for Tony Blair, but BA Chief Executive Bob Ayling came unstuck when he volunteered to mastermind the Millennium Dome. MPs are regularly wined, dined and flown around the world by the airlines. British Airways, Virgin, BAA, the CBI and some trade unions have set up a special organisation "Freedom to Fly" to lobby for runways. Its director, reported to be paid over £100,000 a year, is Joe Irvin, former adviser to John Prescott.

It is perfectly fair for any industry to put its view to government. What would not be acceptable would be the secret use of inside contacts to influence Ministerial decisions, or the use of big business money to sway the views of MPs and journalists. Whether or not as a result of Irvin's influence, DfT ministers have had far more meetings with the airlines than with environmental groups. If the Ministers were in local government, and were deciding on a planning application in which they had become so close to the applicants, they would have to declare an interest, leave the room and take no part in the decision.

When young people demonstrate against globalisation, one of their complaints is that multinational corporations have too much power. In particular they point to the threat by big firms to move their business abroad if strict environmental standards are imposed. That of course is one of the favourite ploys used by the airlines - if new runways are not built in Britain they will be forced to move to continental airports.

Aviation lobbying has been very successful. In what was described as 'a wonderful piece of special pleading" the U.S. airline lobby in the aftermath of the 1988 Pan Am 103 bombing succeeded in weakening measures to toughen airport security.[11] New proposals for tighter security put forward by the then Vice President Gore were defeated by the airlines shortly before the hijackings of September 11 2001. Another example is the lobbying which succeeded in getting aviation excluded from the Kyoto accord. This was based on the tactic of emphasising all the practical difficulties with no attempt to put forward solutions. Similarly the continued exemption of aviation from most forms of taxation owes not a little to constant lobbying in the rarefied gatherings of the International Civil Aviation Organisation.

A skilful move by UK airlines was to offer to pay 90% of the cost of a study for DfT into the economic benefits of aviation. The study by Oxford Economic Forecasting Ltd (OEF)[12] read like a publicity blurb for the industry, and even had a foreword by the Chairman of the Airport Operators Association and the chairman of the British Air Transport Association. It revealed one key fact about aviation economics - that consultants know on which side their bread is buttered.

The situation has been summed up by Chris Mullin MP: "During my 18 undistinguished months as aviation Minister, I learned two lessons about the aviation industry. First, its demands are insatiable; secondly, successive Governments have always given way to them."[13]

Doubtful arguments

Reliance on research sponsored by the airlines has produced some dodgy arguments. The following examples are all taken from the consultation documents published in July 2002.

"Aviation is itself a high productivity industry…" Simple economic fallacy: an airline pilot appears to have high productivity because he is operating an expensive piece of equipment. But when the cost of the capital is deducted, productivity is no higher than in any other industry.

".... and it adds to the productivity of the wider UK economy." Improved transport is said to lead to economies of scale, increased specialisation, and stiffer competitive pressures on companies. That is exactly what many of the anti-globalisation protesters are worried about: that each country is forced to become more specialised, with no diversity of employment, and open to the risks of global shifts in demand. The decline in British horticulture as a result of cheap air freight is a good example. There are now over 6,000 call centres in the UK: no doubt there is higher productivity in call centres than in picking fruit.

Business travel promotes productivity. But according to John Humphrys "Those businessmen would be better off staying at home and using a telephone or e-mail or video conferencing. We could probably double our productivity if we put to better use all the time spent by all those middle-ranking executives in airport lounges and business-class seats."[14]

Even without going that far, it is difficult to see how productivity would be increased by tripling, as forecast, the amount of business travel.

"Inward tourism is worth about £13 billion to the UK each year..." That is given in the introduction to the South East consultation documents as a reason for airport expansion. Tucked away on a later page, however, is the admission that: "At present the number of UK tourists travelling abroad is almost double the number of foreign tourists visiting the UK. ... expenditure in the UK is less than expenditure by UK residents travelling abroad." It is then argued, rather desperately, that building new runways will bring in more foreigners than send out UK tourists. But even that argument is belied by the figures. The forecast shows that if, for example, three new runways were to be built at Stansted, 18 million more foreign tourists would fly in; but 19.6 million more British tourists would fly out.[15]

"The increase in foreign direct investment...". The theory is that more airport capacity would enable more foreign businessmen to fly in and invest in the UK. Difficult then to explain why the Japanese have invested in North East England which has no direct air service to Japan. In fact only 1 in 10 top executives cite air access as the reason for the choice of their location. KPMG asked 801 top executives of foreign-owned firms in Britain what factors influenced their decision to locate here: the main factor was quality of life.

"a lot of our exports are high value, low weight goods which are transported by air". A poor argument for the expansion of air freight: the Royal Commission on Environmental Pollution has calculated that carbon dioxide emissions for freight carried on rail are a factor of 20- 100 times lower than for long haul air freight, with marine freight a factor of two or more lower again.[16]

Disadvantages ignored

The disadvantages of cheap air travel are not mentioned by the lobbyists. Most obvious is the decline of the British seaside resorts. You only have to look at the rundown state of many seaside towns to see the damage done by cheap holidays in the sun. Yes, of course the world moves on, and no one would dream of compelling people to spend a wet week in Skegness when they could be getting a tan in Torremolinos. But should British hotels, guest houses and b & b's be unfairly undercut by subsidised air travel?

Air travel spreads disease. Diseases have, of course, always spread, but more slowly. For example, in the 14th century the Black Death originated in China, arrived in Europe via Marseilles two years later, and took a further six months to reach London. These days disease can take a cheap flight from the other side of the world, travel in comfort and arrive in under 12 hours. As has been pointed out by an eminent doctor: "the millions who travel by air and share the same viral-laden atmosphere in the aircraft are confronted by bacteria and viruses which have hitherto been strangers to their immune system."[17]

There is another downside to mass tourism: the damage to the environment and cultures of the recipient countries. The Galapagos islands and many other rare habitats are under growing threat. The damage to the Thai islands made famous by the film The Beach was, for example, recently detailed in the Times.[18] Hatred of western values, leading in extreme cases to terrorism, is fuelled by brash tourist behaviour. It has been said that "mass tourism is hawking a superficial exoticism and has generated a form of sub-culture that humiliates both the tourist and his host community." I do not quote some extreme eco-warrior, I quote the Pope.[19]

An argument often used by the airline lobbyists is that if South East airports are not expanded, London may lose its position as a 'world class city'. But London's position depends more on its quality of life, on its financial expertise (and position in a time zone), and on the English language, than on its airports.

It is true that if continental airports grow faster, jobs in aviation will increase faster there. But the converse is also true. Aviation is seen as one of the driving forces for economic expansion in the UK. Aviation employs over 180,000 people and Government estimates show that 260,000 extra jobs could be created by the proposals for expanding airport capacity. But the lobbyists also tell us that aviation indirectly supports three times that many jobs. So it looks as if around a million extra jobs could be created many of them in the South East.

Either even more people will have to move from the north to the south east, or there will be large scale in-migration from other EU countries. Britain is the only major EU country which is not putting restrictions on immigration from the new EU member nations in Eastern Europe. The alarm bells are already ringing. The Government Actuary's Department forecasts that UK population will increase from an estimated 59.8 million in 2000 to reach nearly 65 million by 2025. Around two thirds is attributable to the assumed level of net inward migration. Two million extra homes will be required if immigration continues at its present record level according to the Government's Population and Housing Research Group.[20] The level of in-migration is already equivalent to importing a new city the size of Cambridge every six months, according to Migrationwatch UK.[21] Good-bye green fields!

Not, of course, all due to the forecast growth in aviation, but those who lobby for unrestricted growth do need to explain where the extra labour is going to come from, and where all the extra workers are to be housed.

Tax free aviation

Air travellers, unlike those who travel by car, make little contribution to the cost of providing public services. Nor do they pay any compensation for the environmental damage they cause. The hidden cost of flying is seen in under-funded hospitals and schools and other public services, and in a deteriorating world environment.

Higher taxes on aviation would NOT on average make people worse off. The revenue would be used either to reduce other forms of tax, or to make possible higher expenditure on public services.

There are two separate issues.

a. Should aviation pay tax to cover its external costs? The Government has firmly stated that it should,[22] but has done nothing about it. The principle of making the polluter pay is well established. The purpose is to ensure that the price of any product fully reflects the cost of production, including any hidden costs. Also to provide funds either to rectify the environmental damage, or to compensate those affected.

b. Should aviation contribute to public finances? It is generally accepted that economic welfare is maximised if all industries pay the same rate of tax. A level playing field ensures fair competition. Airlines do, of course, pay normal corporation tax, and pay income tax and national insurance contributions on behalf of their employees. That is the basis of the figure, sometimes produced by the airline lobbyists, that aviation already contributes £2.5 billion to the Exchequer. The big questions, however, relate to fuel tax and VAT.

Economic theory would suggest that antisocial industries, such as aviation, should pay the same rates of tax as other industries, and should then, *in addition*, pay extra tax to cover their hidden costs.

No tax on aviation fuel

There is no duty and no VAT on aviation fuel. Petrol for cars (unleaded low sulphur) is subject to duty at 45.82p a litre. VAT at 17.5% is charged on the price after payment of duty, and amounts to about another 11p.

The result is that motorists pay around 75p a litre while airlines pay around 18p. (Airlines negotiate private contracts for their fuel, and the price varies from month to month depending on the state of the world market. In 2002, a comparatively normal year, it did not exceed 18p.)

Petrol tax was originally introduced to pay for the cost of road building and maintenance. This is now, however, covered by the revenue from vehicle licences. In a similar sort of way airlines pay the full cost of airport facilities and air traffic control through airport charges.

There are two good reasons for putting tax on aviation fuel.

1. The first is that those who choose to fly should make a fair contribution to the cost of running the health, education and police services. Ever since Winston Churchill 'raided the road fund' in 1926, Chancellors of the Exchequer have seen the revenue from petrol duty as a valuable way to finance general public services. The tax has the fiscal advantage of being easy to collect and of not being harmful in its economic effects. There is an equally good case for raising revenue from aviation. Since it is the rich who fly most, and since nearly 80% of flights are for leisure,[23] tax on air travel would be fair and progressive.

2. The second good reason for taxing aviation fuel is that it would help to ensure that aviation covered its external costs. In recent years the justification for petrol tax, and in particular for the 'escalator' annual increases, has been that the tax is actually beneficial as it goes some way to ensure that the cost of using a car reflects the costs of congestion, pollution and noise which are imposed on the community. Exactly the same applies to aviation. As the consultation paper issued in December 2000 stated " The Government believes that the tax exemption on aviation fuel is an anomaly. Introducing such a tax would help to place environmental costs on the polluter..."[24] The Royal Commission on Environmental Pollution has stated that in terms of climate change, "travelling by air is broadly equivalent to one or two people travelling [the same distance] in a passenger car."[25]

Two good reasons for taxing aviation fuel. Both are just as strong as in the case of motor fuel. It therefore follows that there is justification for imposing duty on aviation fuel at a rate at least as high as that for petrol, i.e. 45.8p a litre.

The Treasury has stated that duty at this rate would raise £5.7 billion a year.[26]

It would, however, be double counting to suggest that aviation fuel should be taxed at the same rate as motor fuel and that aviation should pay a tax on its external costs.[27]

The counter argument deployed by the airline lobbyists is that trains and ships do not pay fuel tax so why should aircraft? Trains and ships, however, cause less pollution. Trains have no taxable capacity (the rail companies could not afford to pay, and would merely require a higher subsidy). It is true that taxing aviation fuel might cause some 'unfair competition' on UK domestic routes which might cause some people to divert from air to rail, but that is exactly what has been recommended by the Royal Commission on Environmental Pollution. Even in terms of economics, it would be a much less serious distortion than the artificial expansion of air travel caused by its tax free status.

Just to complicate the picture, buses get a rebate on their fuel, and in effect pay duty at 12.8p a litre. Private aircraft on flights within the UK pay duty at 27.34p a litre. If you are rich enough to fly your private aircraft abroad, however, you get fuel tax free. There seems no good reason why fuel for all aircraft, private or commercial, should not be taxed at the same rate as fuel for cars.

Fortunately for the airlines, the practical difficulties of introducing a tax on aviation fuel are great. It would need to be done on an international basis, or at the very least for the whole EU, because otherwise aircraft might merely refuel in countries where fuel is not taxed. Moreover, any tax on aviation fuel is ruled out by the Chicago Convention.

Signed in December 1944 during the Second World War, when mass aviation was still a dream for the future, the Convention set up the International Civil Aviation Organisation (ICAO). Article 15 of the Convention rules out any "fees, dues or other charges" imposed solely in regard to the right of entry or exit of aircraft, and this has been held to rule out any tax on aviation fuel. The Convention can be amended by a two-thirds vote of the contracting parties but at present it is thought that the United States, and a majority of the developing nations, would not favour tax on aviation fuel.

The 1998 Transport White Paper stated that the Government "will continue to pursue in ICAO the potential for environmental levies and press for the removal of the exemption from tax on aviation fuel..." There is, however, absolutely no evidence that the UK Government has pursued its stated policy with any strength of purpose. Have British Embassies, for example, been instructed to discuss with developing countries the impact of aviation on climate change?

Some European States, led by Belgium, were about to force a debate on aviation fuel tax at the meeting of ICAO in September 2001. The airline lobbyists were out in force, and were in luck - the debate took place only a few days after the September 11 terrorist attacks and all attention turned to how to prevent the airlines going bust. So the matter got postponed. Yet as Environment Minister, Michael Meacher, has said: "We cannot go on negotiating endlessly [about tax on aviation fuel] and getting nowhere"[28]

The EU Commission has also expressed frustration and is exploring the possibility of Europe going it alone. The EU White Paper 'European transport policy for 2010' stated: "In air transport... several options are being examined, such as taxes on ticket prices, charges based on the distance covered, and charges for take-off and landing."[29] One possibility is an emissions charge related to the distance flown and the amount of pollution caused. A recent study for the Commission found that this would be similar in effect to a tax on aviation fuel, could not be avoided by filling up elsewhere, and - if solely related to pollution in EU airspace - would not fall foul of international agreements.[30]

No VAT on air travel

Value added tax at 17.5% is applied to all goods and services, except those thought to be essential, such as food or medicines. It is not charged on exports. The purchase of cars, their servicing, and petrol are all subject to VAT. But there is no VAT on any aspect of air travel, not on airline tickets, nor on purchase of aircraft, nor on their servicing, nor on their fuel, nor on air traffic control, nor on baggage handling, nor on aircraft meals. Everything to do with air travel, after passport control, is zero rated.

Imposing VAT on airline tickets would have the effect of bringing all aspects of aviation into the VAT net. It would seem practical to do so, either for the UK alone or, preferably, for the whole EU. Tax might be charged on the cost of all flights within the EU, and on all flights departing from the EU, but not on arrivals. Although airline tickets can be bought anywhere in the world, it would be comparatively simple to check at the departure gate that the correct tax had been paid.

The airline lobbyists don't miss a trick: they argue that trains and buses are not subject to VAT, and so it would be unfair to tax air travel. In fact in many other EU countries travel by train or bus is subject to VAT. The reason for the zero rating of public transport in the UK is historical. When VAT was introduced in 1972 the ownership of cars was confined mainly to the higher income groups: most industrial workers still travelled to work by train or bus. Travel to work was considered 'essential' and therefore all public transport was excluded from VAT.

That no longer justifies the exemption of air travel from VAT. There is nothing "essential" about most air travel. Passengers in planes sit in rows like those in buses, but apart from this, unless you are very old Labour, there is nothing special about public transport, especially when it is provided by ultra-capitalist airline entrepreneurs. Aircraft create more pollution and more noise than trains or buses. There seems no valid reason why air tickets should not be subject to VAT.

That is not politically inconceivable. Virtually all EU countries except the UK already charge VAT on internal domestic flights.[31] In October 2002 the new German Government, a coalition between the Social Democrat and Green parties, announced a programme which included the policy that flights from Germany to other EU nations should no longer be exempt from VAT.[32]

The British Government are coy about saying how much extra revenue would be raised. When asked Parliamentary Questions, they merely reply that the Chancellor has given an undertaking not to extend VAT. That appears to imply that Gordon Brown will remain as Chancellor until 2030, which is perhaps another somewhat unreliable forecast.

Another reason given for refusing to calculate the potential revenue is that VAT only applies within the EU. If so, the alternative would be to apply a sales tax at 17.5% on all flights leaving UK airports.

Fortunately it is possible to do the calculation, admittedly on a rough and ready basis, oneself. The calculation is given overleaf, but can be skipped by non-mathematical readers. It shows that the revenue from imposing VAT on all flights from UK airports would be around £4 billion a year.

Duty free - a subsidy for air travel

In the days when the only way to cross the Channel was by sailing packet, travellers often took a bottle of wine to drink on the voyage but, if the sea was rough, did not always drink it all. The Customs officers, as a concession, allowed them to bring in, free of duty, one part-full bottle. This remained the basis of the concession until the 1960's when it was extended to one bottle of wine whether full or opened. Duty free at airports is now also applied, not only to drink and tobacco but also to VAT on the grounds that the goods are being exported. Customs have given up attempting to apply VAT on goods which air travellers subsequently re-import to the UK.

The EU sensibly abolished duty free on flights and boat trips within Europe. There was a huge lobbying campaign by the airlines. The Chief Executive of BAA warned that 30,000 jobs would be lost and the price of holidays would rise by up to 20%.[33] All these predictions proved false. It was a classic case study of why MPs and Ministers should be sceptical of the aviation lobby.

Duty free on flights outside Europe remains, costs the Exchequer about £0.4 billion a year,[34] and is a complete scam. It encourages drunkenness and air rage, runs counter to efforts to discourage smoking, takes business away from High Street shops, turns airports into shopping malls, reduces the revenue available for public services, and acts as a subsidy to air travel. There seems no reason why the Government should not abolish it immediately on all flights out of the UK.

Air passenger duty - a very small tax

When the air passenger duty (APD) was first introduced, in 1993, the Chancellor, Kenneth Clark, justified it because "air travel is under-taxed compared to other sectors of the economy. It benefits not only from a zero rate of VAT; in addition, the fuel used in international air travel, and nearly all domestic flights, is entirely free of tax."[35] How right he was!

Nevertheless APD, which brings in £0.9 billion a year, is small in comparison with the fuel tax and VAT exemptions. If these exemptions cannot be removed for some years, there seems no reason why the Government should not increase APD immediately. Conversely, if eventually aviation fuel is taxed and VAT imposed, there will be no need to retain APD.

The hidden costs

"The policies we will bring forward for civil aviation, ... will reflect our strategy for sustainable development. This means aviation should meet the external costs, including the environmental costs, which it imposes." So said John Prescott in his 1998 Transport White Paper.[36]

If this quote is read carefully it must mean that the new White Paper due to be published in 2003 will include substantial and immediate tax increases on aviation. Keep your seat belts fastened.

The European Environment Agency[37] has calculated the total external costs of all flights taking off from European airports in 1995 as 48 euro per 1000 passenger km. So we can work out the following tariff.

These figures represent the hidden costs of air travel; the costs imposed on the world by each return flight. They are a measure of the damage that each passenger does to the planet in terms of climate change, noise, and pollution. They show the amount of tax that should be charged in order to implement the Government's stated policy.

The figures above could be said to be on the high side because EEA, albeit based on their own scientific advice, use a higher figure for the cost of climate change than that used by DfT and DEFRA. On the other hand they do not include any contribution by air travellers towards the public services.

All parts of the world will suffer

At the Earth Summit in Johannesburg in September 2002 the Prime Minister said: *"We know that if climate change is not stopped, all parts of the world will suffer. Some will even be destroyed, and we know the solution - sustainable development. ... it means the world - the whole world - facing up to the challenge of climate change. ... Kyoto is right and it should be ratified by all of us, but Kyoto only slows the present rate of damage, to reverse it we need to reduce dramatically the level of pollution, and let us at least start to set that direction. ... there are painful decisions, vested interests* [you know who], *legitimate anxieties. But the facts remain, the consequences of inaction on these issues are not unknown, they are calculable. Poverty and environmental degradation, if unchecked, spell catastrophe for our world."*

The impact of aviation on climate change was spelt out by the Royal Commission on Environmental Pollution in a special report published in November 2002.[38] Aviation, because its forecast rapid rate of growth exceeds the rate of technological improvement, is the industry with the fastest growing contribution to global warming. Aircraft emissions at high altitudes are particularly damaging: this basket of pollutants, which includes NOx and water vapour, has about three times the radiative forcing effect on climate change than would be expected from aircraft CO_2 emissions alone.

At Kyoto in 1997 the nations of the world agreed to reduce greenhouse gas emissions by 5.2% by 2008/12. Aviation (except domestic flights) was excluded on the grounds that agreement had not been reached on how to allocate emissions over international waters. The UK Government has set a target of a 12.5% cut. Scientists have suggested that a 60% cut is necessary to stabilise CO_2 levels, and that was after taking into account improvements in aircraft fuel efficiency.[39]

International agreement may be reached at some point in the future to impose a global CO_2 tax on aircraft fuel, and this possibility is recognised by DfT. They suggest that the appropriate rate may be 100%.[40] That figure is based on their estimate of the damage costs of CO_2 and, as noted, is lower than that used by the European Environment Agency. A tax at 100% sounds high but it would be only about 18p a litre, compared to the duty on motor fuel at 45.8p.

Duty at 100% would, according to the government statisticians, reduce demand for air travel by about 10%. They then, however, produce an ingenious argument to prove it would have no effect at all. In 2000 the forecasts assumed a 1% a year fall in the price of air travel but, as a result of the unexpected arrival of the low cost airlines, this should be revised to 2% a year. The effect of the bigger price cut "would comfortably exceed the reduction in demand due to a CO_2 tax."[41] This is convenient: it comfortably obviates any need to revise the forecasts.

The effect, however, is to accept that CO_2 emissions will continue to grow at the rate originally forecast. For aviation, we remain firmly on course for "catastrophe for our world." Not very comfortable.

Although, as mentioned earlier, the cumulative economic benefit of new runways is added up over a period of 60 years, the effects of climate change are only cumulated over a period of 30 years. This curious lapse is more serious than it sounds since the damage costs of CO_2 are forecast to rise year by year.[42]

Other hidden costs

Concern is growing about the effects of air pollution around major airports. At Heathrow, or at Gatwick, a new runway would mean thousands of people affected by NO_2 in excess of EU limits. The same level of pollution would affect the far greater numbers who work at the airport. If nothing is done, the UK is likely to find itself in breach of mandatory EU rules, and liable to EU fines. That may well be sufficient to rule out a new runway at Heathrow or at Gatwick, but it does not absolve the airlines from paying the cost of the pollution caused by the use of existing runways. DfT dismiss this as negligible, because few people are admitted to hospital, but that is obviously an inadequate measure of the value of clean air.

Another hidden cost is the nuisance caused by aircraft noise. DfT calculate the cost of compensating local residents at around 36-40p per passenger at Heathrow, but below 5p at other airports.[43] That appears to be an underestimate. Calculations by AEF show that the cost may be at least twice as high.[44]

When airports are expanded, hidden costs include the destruction of landscape, wildlife, homes and communities, and heritage buildings. The consultation documents dismiss these as "best handled at each airport individually."[45] That might be true if the planning system were able to prevent such destruction. But it is not so: the forthcoming White Paper will lay down where runways are to be built, and will not be open to challenge at a local level.

All these hidden costs should in theory be included in air fares. The Chancellor, in a footnote to his pre-budget statement in autumn 2002, has announced that the Treasury will be holding talks with stakeholders on possible ways of doing so.

This concept of paying external costs causes some philosophical problems for environmentalists. If they were all to be included in the price of air fares, should air travel be permitted to expand without limit? The answer is no: some things should not be destroyed at any price. Motorists, even if they pay the necessary insurance premiums, are not allowed to kill pedestrians at will. In the same way rare flora or fauna, or heritage buildings, should not be destroyed except in the most exceptional circumstances. Where such damage is sanctioned, although it is not possible to put a price on such priceless things, some large notional cost should be charged.

Even though all these costs cannot be calculated precisely, what can be said with confidence is that air fares do not anywhere near reflect the full hidden costs of aviation. Air travel is artificially cheap, and the forecasts are artificially high.

DfT suggested, back in December 2000, that if the hidden costs of aviation were taken into account, the demand for air travel would drop by 3- 5% - equivalent to a tax of about £1 billion.[46] The airline lobbyists were overjoyed to be able to claim that they already paid their full external costs through APD, but the Royal Commission on Environmental Pollution kicked that into touch, saying that the estimate "fails to recognise the magnitude of the threat posed by climate change.... [and] significantly misrepresents the importance of aviation's growing contribution to climate change."

DfT have now raised their estimate of the hidden costs to 10%,[47] equivalent to slapping on extra tax of £2.3 billion a year. The Royal Commission, at their November 2002 press conference, upped the stakes, suggesting that air fares need to rise by at least £70 return to reduce the amount of global warming caused by flights.[48] That would be equivalent to around £6.3 billion a year.

Figures produced by the European Environment Agency suggest that the total external costs of UK aviation are around £6 billion a year.[49]

So if the hidden costs lie somewhere between £2.3 billion and £6.3 billion, and if *in addition* there is a good case for requiring air travellers to contribute to the public services, the suggestion made earlier in this booklet that aviation fuel should be taxed at a rate equivalent to £5.7 billion would seem fully justified.

£9 billion tax subsidy

We can now add up the extra tax revenue that would accrue to the Exchequer if aviation paid its full external costs, and if it paid a fair share of the cost of public services. This could be called the fair tax package.

The fair tax package

	£ billion per year
Fuel tax	**5.7**
VAT	**4.0**
Duty free	**0.4**
Deduct APD	**- 0.9**
Net tax subsidy	**9.2**

£9.2 billion a year is a measure of the present value of the tax subsidy for the aviation industry. No wonder fares are low.

The figures do not include any separate tax on external costs - that is included in the fuel tax. The calculations assume that demand remains unchanged (see below).

No new runways

In addition to their many other attributes, the Department for Transport has a great sense of humour. So when they devised a new computer model to predict the future of aviation they christened it SPASM.

A huge amount of information is stored in the model: where people live (in 455 UK Districts), how much they wish to fly now and in future years, the level of air fares, how much they value their time, and their cost of travel to various airports. Feed in a new runway at airport A, press the button and some time later the computer will print out an analysis of how many people will use airport A, and how this will affect airports B, C and D.

It is much more complicated than that because it also takes into account many other factors including the differences between business, leisure and low cost travel, when new routes become profitable, and when airlines may decide to use larger aircraft etc. The present rates of tax are assumed to continue unchanged.

It is the SPASM model which has produced most of the statistics presented in the consultation papers. Ministers, like most other people, will believe that anything produced on a computer must be true. But computer models are only as good as the assumptions on which they are based.

A group of environmental organisations - CPRE, the Aviation Environment Federation and Friends of the Earth - therefore asked DfT to run the SPASM model again, using different assumptions. The main new assumption was that aviation fuel was taxed at the same rate as motor vehicle fuel, and that VAT was imposed on all flights departing from UK airports.

To be precise, because computers like precise instructions, fuel tax was assumed to increase at five yearly intervals to reach the same level as motor fuel duty in 2025: 50% in 2005, 100% in 2010, 150% in 2015, 200% in 2020 and 230% (45.82p per litre) in 2025. VAT was also assumed to rise in steps: 5% in 2010, 10% in 2020 and the full 17.5% in 2025. Air Passenger Duty was assumed to be removed in 2020. The computer was also instructed to assume that demand was spread around the London airports, and not all concentrated on Heathrow.

The button was pressed and SPASM produced the results in February 2003. This is what they showed.

With the fair tax package, the number of passengers using UK airports would rise from 180 million in 2000 to around 315 million in 2030. This can be compared to the main official forecast of 500 million.

Heathrow would remain full, handling 85 million passengers a year. Gatwick would be busier than at present, handling 41 million on its existing runway. But Stansted would not be full, and would only be handling 26 million. Luton would have 10.6 million. Traffic at regional airports would be higher than at present, but substantially reduced compared to the official forecasts. Birmingham would have 30 million. Manchester at 51 million would at last have succeeded in its aim of overtaking Gatwick.

The computer model shows that there would be no need for any new runways. Not now. Not in 2015. Not in 2030. Not in the South East. Not anywhere in the UK.

Technical calculations

The experts who mind SPASM point out that these results depend on the assumption about price elasticity (how much less people spend on flying when the price goes up). The model assumes an elasticity of -1, but more on that anon. Demand, the experts also point out (somewhat implausibly), would be higher if the airlines paid some of the extra taxes out of their profits. It also makes a difference what rate is used to discount future years, but the conclusion that there would be no need for new runways is true whether one uses the discount rate previously used in the DfT forecasts, or the lower rate now recommended by the Treasury.

No allowance has been made, the SPASM minders say, for supply side effects. If you put a tax on aviation fuel, the aircraft manufacturers will design more fuel-efficient planes. That, of course, would be good for the environment but it would mean that air fares would be lower and the level of demand higher. A study by the consultants CE Delft has suggested that efficiency improvements might reduce the impact of fuel tax changes by 50%.[50] On the other hand the Royal Commission on Environmental Pollution are more sceptical, pointing out that old aircraft remain in service for many years, and that the technology of the gas turbine aircraft engine is relatively mature.[51] If we compromise on a figure of say 30 %, that would imply that demand would be 7% higher than 315 million.[52] Read on.

There would be no supply side effects for VAT: it would be difficult to design a VAT-efficient plane.

The SPASM model only relates to the UK. When the environmental groups suggested that VAT at 17.5% should only be imposed on departures and not on arrivals, the computer assumed that this meant half rate on return fares. Fair enough. But if all other countries were to impose VAT or a sales tax at the same rate, then the cost of return fares would rise by the full VAT rate. Air fares would be 8.75 % higher, and demand 8.75% lower, than the model predicted.

So it would seem reasonable to guess that the lower demand due to other countries imposing VAT may roughly cancel out the higher demand due to fuel efficiency improvements. We can stick with the new forecast of 315 million passengers a year in 2030.

A good future for aviation

315 million is still a 60 % increase above the present level. It would represent an absolute growth rate of 2% a year. With a happy serendipity it just about coincides with what most experts consider the maximum rate of future improvement in aviation technology, and thus might be accommodated without too much damage to the environment.

With a prospect of a 60% increase in the number of air passengers, the airline lobbyists are going to have a hard job. They can hardly say that the result of imposing fair taxation would be to stop people flying, or to kill off the aviation industry.

But they are not paid high salaries for nothing. Their standard line is that any tax on air travel would damage one of Britain's most successful industries. Rubbish. What is suggested here is that the tax changes need to be made either by the whole EU, or on a global basis as a result of international agreement. In which case there would be no harm to the competitive position of UK airlines. Indeed they could share in the continuing 2% annual growth.

No increase in air fares

As part of the SPASM re-run, DfT calculated that the effect of the proposed tax increases would be to increase fares for flights out of the UK by about 34% over the period from 2000 to 2030.

During that time, however, according to the DfT forecasts, the price of air travel will fall by 1% a year.[53] Allowing for compound interest that exactly matches the 34%.

So even after all the proposed tax increases, air fares for trips abroad would finish up no higher than in 2000. Of course air fares have fallen in the past three years, and the tax package would mean that over the next thirty years this fall might be reversed. That does not seem too high a price to pay for helping to save the world from the impact of climate change

Air fares for domestic flights might be a bit higher because VAT would be paid both ways. Similarly if other countries imposed VAT, the level of air fares might rise more than assumed. But, as discussed above, that is likely to be cancelled out by the reductions in fares due to improved fuel efficiency.

The result - no need for new runways, and no rise in air fares - can be expressed in another way. The huge official forecasts of future demand are predicated on the assumption of a steady fall in air fares. If this fall were to be cancelled out by a gradual increase in taxation so that fares remain roughly at the same level as in 2000, demand would increase at a more reasonable rate. No one would be significantly worse off.

Some people just don't believe that demand would actually be choked off by higher prices - whatever you do, they say, people will still go on flying. On domestic and near European flights air passengers might switch to rail, but there is no alternative for long distances - you can't bicycle across the Atlantic. So they don't believe the assumption that a 1% rise in prices would mean a 1% fall in demand (a price elasticity of - 1). May be. With even happier serendipity, however, it can be pointed out that if the tax increases match the forecast fall in prices, so there is no change in the level of air fares, there is no need to make any assumption at all about price elasticity.

A few paragraphs back it was stated that the revenue to be expected from imposing a fair tax package would be £9.2 billion - assuming no change in demand. It is now clear that there would be no reduction in demand. Indeed the predicted 60% increase in air travel would mean that by 2030 the annual revenue (at today's price level) could be expected to be over £14 billion.

In the past year there have been Shock! Horror! headlines in the tabloids. Alastair Darling and other Ministers have stated that if new runways are not built air fares will have to rise by around £100. That figure was based on calculations by the SPASM model of the increases in return fares that would be necessary to rein back demand in 2030 to the capacity of existing airports.[54]

The extra £100 would in many cases be no more than the hidden costs of each return flight. So it would actually be in line with Government policy. No shock!

Moreover, the £100 rise would be cancelled out by the forecast fall in prices. Take for example a flight from Heathrow priced at £300 return: by 2030 the DfT forecast is that the price will have fallen to £200. Adding on an extra £100 would leave the cost no higher than now. No horror!

What if taxes can't be increased?

It will never happen, say the worldly wise civil servants - political suicide, never get agreement in ICAO, EU governments won't agree, look at the strength of the airline lobby. Yet even if we were to accept that it may not be politically practicable to impose taxes on air travel, does it make sense to build runways to meet an artificial demand which would not exist if aviation paid a fair rate of tax?

The correct answer in economic theory is that public welfare will be maximised if no new runways are built, if the price of using existing runways is allowed to rise, and if the surplus 'rent' is creamed off by the Government for the public benefit. That is the case for airport slot auctions.

Heathrow and Gatwick are among the most congested airports in the world. Yet they have some of the lowest landing fees and airport charges in the world. BAA has argued that "these low levels actually encourage demand growth and compound the problems of insufficient capacity."[55]

One method of rectifying the situation would be to impose a levy on landing fees at congested airports. Like every other sensible idea, that would be ruled out by the Chicago Convention. A more promising solution would be to auction slots. (A slot is the right to take-off or land at a particular time. Under present rules, if an airline has a slot it has the 'grandfather right' to keep it forever.)

John Prescott has announced that it is Government policy to auction slots. In November 2000 he informed the EU that Member States should be allowed to auction newly created slots; that airlines should be allowed to trade existing slots; that the duration of grandfather rights should be reviewed; and that slots should be viewed as a "community good".[56] A report prepared by consultants for the Treasury in January 2001 showed that slot auctions were practicable, and how they could be arranged.[57]

Slot auctions would have substantial advantages. They would:

- bring in vast sums to help finance public services
- encourage the use of larger aircraft
- ensure higher load factors (fewer empty seats)
- increase competition and efficiency
- improve access, according to the CAA, from regional airports to Heathrow[58]
- reduce congestion and delays

- make the railways more viable
- remove any urgency in the need for new runways
- politically be much easier to implement than tax increases

Environmental groups at regional airports have expressed some concern that slot auctions at London airports would merely push more flights in their direction. Certainly slot auctions would provide an economic incentive to greater use of regional airports, but in fact Heathrow, Gatwick and Stansted would still be operating at maximum capacity and handling considerably more flights than at present.

How much money would regular slot auctions bring in? CAA calculations suggest a figure of £3-5 billion for Heathrow alone.[59] Sir Richard Branson has stated "We estimate that if slots at Heathrow and Gatwick were auctioned to the highest bidder, the Treasury could raise over £10 billion. No doubt the Chancellor is licking his lips."[60]

So, without being so optimistic as Branson, we can guess that at present slot auctions would bring in at least £5 billion a year. If, over the next 30 years no new runways were built, the value of slots would rise. The SPASM computer model shows that by 2030 slot auctions would be bringing in a further £6.7 billion.[61] Total revenue over £11 billion a year.

So there is a choice. Either impose a fair rate of taxation and bring in an extra £14 billion a year by 2030. Or auction slots and bring in around £11 billion. Either way it would be good news for the health service. Good news for education. Good news for everyone who cares about the public services. And good news for the environment.

Unfortunately, in an absent-minded fit of Euro-enthusiasm in 1993, the British Government agreed that the rules for slot allocation would be decided by the EU. So we cannot allocate slots to the highest bidder without the approval of a majority of EU nations; and, not surprisingly, most other countries are not keen to pay more to land at UK airports. For the past two years, since John Prescott's statement, the UK Government has been negotiating to be allowed to auction slots, but with no real sense of urgency or importance. Although the EU Commission recently commissioned a study on the subject, auctions are not on the agenda for the revised EU slot allocation regulation.

This unsatisfactory situation seems to be due to a curious lack of interest from Number 10 and from the Treasury. Far from licking his metaphorical lips, the Chancellor and his minions seem to have swallowed without mastication the aviation lobbyists' line that to tax air travel would not be socially inclusive, and that to tax holidays would amount to political suicide.

Socially inclusive?

Aviation at present is not socially inclusive. Anything but. The rich fly more than the poor. The top three social classes fly four times as often as the three lower classes.[62] According to a survey by the Office for National Statistics most of those who fly come from the prosperous South East, far fewer from less prosperous areas.[63] Most of those who fly are the able bodied without children. Families, the frail, the disabled and the old, fly much less.

Putting tax on air travel would be socially inclusive. The higher income groups would pay most, and the less well off would benefit when the proceeds were spent on improved public services. Moreover, as the Royal Commission has pointed out, taking action to prevent climate change would hit the richer nations but help the poorer nations.

The airline lobby say that "pricing people out of flying would hit low income passengers, such as families going on holiday, hardest."[64] Emotive, but misleading. As has been shown, the proposed tax increases are likely to be cancelled out by the forecast fall in air fares. So no-one would be priced out.

An alternative spin from the lobbyists is that tax on aviation would prevent the poor enjoying in future the pleasure of foreign holidays which at present they cannot afford. Yes, if air fares go on getting cheaper more people will be able to fly. But there is no evidence that the proportions will be any different: the rich may still fly four times as often as the poor, more will buy second homes abroad, and take more weekend breaks.

The present situation is unfair. Many less well-off families go on holiday in Britain in their cars, paying fuel duty and VAT on their petrol, paying VAT on their meal at the motorway cafe, and paying VAT on their bills at caravan sites and boarding houses. The children don't get into the theme park without paying VAT. The pub is not duty free. Why should holidays in Blackpool or Margate be taxed but not air trips to Bangkok or Marbella?

Political suicide?

The knee-jerk reaction of any politician, including the present DfT ministers, is that to impose substantial new taxes on aviation would be political suicide - look at the fuel tax protests of autumn 2000.

But would a gradual increase in taxation over a period of thirty years be unpopular? The survey by the Office of National Statistics found that in 2001 four out of five people would accept a 5% increase in the price of flights to cover environmental costs. And that was before they had read this booklet!

It would be possible to make a start now with some small changes which can be implemented by the UK Government acting alone. These include the abolition of duty free, increases in air passenger duty, VAT on domestic flights, duty on fuel for domestic flights, and taxes specifically related to local noise and pollution. None of these require international agreement, none are contrary to treaty obligations, and none would seem to amount to political suicide. No doubt the airline lobbyists would make a huge hullabaloo, but that is what they are paid to do.

Economic benefits nil

New runways, it is claimed, bring economic benefit to the nation, and must thus be in the national interest. That is why the CBI are supporting the airlines in their campaign for new runways. The net economic benefit to the nation of providing additional capacity in line with demand could, according to DfT, "be up to £15 billion in present value terms".[65] It sounds a lot of money, better than winning the lottery, too good for any politician to turn down.

The calculation of the benefits of airport expansion is done on the SPASM computer model. It is assumed that businessmen value their time at £42 an hour (rising to £80 in 2030) and that leisure passengers value their time at £7 an hour (rising to £13).[66] So if a new runway is built at an airport which is nearer to you, and saves you an hour's travel when you are off on holiday, the benefit to you is £7. Ask the SPASM model to add up all these benefits, total them over a period of sixty years, and deduct the construction costs of building new runways, and lo and behold that is the net economic benefit.

The calculation depends crucially on the assumed future price of air travel. Because of the shape of the demand curve, if the price of air travel rises (or falls less fast than assumed) the benefits rapidly disappear.

When the environmental groups asked DfT to re-run the SPASM model on the assumption of the fairtax package, they also asked that the computer should recalculate the economic benefits. The answers came churning out. There would be a small economic benefit in building a new runway at Heathrow, but only because it was shown that the airlines would pile into Heathrow, leaving other airports partly empty. Building a new runway at Heathrow, or at Gatwick, while there was still spare capacity at Stansted would obviously be politically unacceptable.

The computer was therefore instructed to assume that air traffic was spread around the London airports. It did not deign to produce any results for Gatwick, presumably because it is a law abiding machine and had been told by Alastair Darling that it would be highly undesirable to overturn the Gatwick legal agreement,[67] and that the Parliamentary and legal hassle in attempting to do so would cause it to blow a fuse.

It did, however, produce results for Stansted. The cost of building a new runway would be £2.15 billion. The economic benefit would be £1.12 billion. The net present value would be minus £1.03 billion. Changing the rate at which future benefits are discounted, in line with Treasury advice, produced a net present value of minus £0.40 billion.

Thus the economic benefit would be less than the cost of construction. If that would be true for any new runway at Stansted, it must be even more true for any new runway at Cliffe, or anywhere else in the UK.

If taxes were to be set at a fair level, the net economic benefit of building a new runway would be nil. Zero. Worse than that. It would be negative. Minus. As well as destroying countryside, heritage and communities, a new runway would actually make the nation poorer.

Which, of course, merely reflects the finding that the revised forecast level of demand means there is no need for any new runway.

Conclusion

Aviation should cover its hidden costs and pay a fair contribution towards providing public services. A fair level of tax would mean the same level of duty on aviation fuel as on petrol for cars, and VAT on all air travel.

These changes would need to be made, over the next thirty years, on a global, or an EU, basis. Concern about the impact of aviation on climate change is likely to grow. The case for change is strong. If Britain were to take a lead, it should not be impossible to achieve international, or at least European, agreement.

With fair tax, there would be no need to build any new runways, and no economic benefit in doing so. The fall in air fares forecast during the period 2000 - 2030 would cancel out the effect of higher taxes, so there would be little or no increase in the cost of air travel. No one would be worse off. Climate change damage would be greatly reduced. The aviation industry could continue to grow, but at a more sustainable rate of around 2% a year. Over £9 billion a year would be available for improving schools, hospitals or other public services.

All references to the DfT, unless otherwise stated, refer to the consultation documents on the Future Development of Air Transport in the UK. July 2002. For simplicity, references refer to the document for the South East (SE) but in most cases similar statements are repeated in the other regional documents

1 DfT - SE page 12

2 Office of National Statistics. www.statistics.gov.uk

3 DETR May 2000

4 Economic Appraisal. DfT. April 2002 page 15

5 Economic Appraisal. DfT. April 2002 page 17.

6 The Times. 5 November 2002

7 DfT - SE pages 34 - 36

8 Briefing Paper for MEPs. The Times 24 October 2002.

9 Response to the Future Development of Air Transport. 29 November 2002

10 Sunday Telegraph 19 May 2002

11 New York Times 10 October 2001

12 The Contribution of the Aviation Industry to the UK Economy. Oxford Economic Forecasting. November 1999.

13 Hansard 28 November 2002

14 Sunday Times 25 November 2001

15 DfT -SE Table 14.7

16 The Environmental Effects of Civil Aircraft in Flight. November 2002

17 The Times 11 January 2002

18 The Times 9 November 2002

19 Reported in the Daily Telegraph 21 June 2001

20 The Times April 2002

21 The Times 5 August 2002

22 Transport White Paper . Cm 3950. July 1998

23 Air Traffic Forecasts for the UK. DETR. May 2000

24 The Future of Aviation. DETR. December 2000

25 The Environmental Effects of Civil Aircraft in Flight. Page 30. November 2002.

26 PQ Hansard 21 October 2002

27 In 'Tax Free Aviation' (AEF December 2000) a different approach was used. This assumed that fuel tax should be imposed at half the rate on motor fuel in order to raise revenue, and then a separate tax should be imposed related to the external costs of aviation. The method used here is simpler.

28 Financial Times 28 May 2002

29 COM (2001) 370

30 Economic incentives to mitigate greenhouse gas emissions. CE.Delft. 2002

31 Information supplied by EU Vice President to Caroline Lucas MEP 4 December 2002

32 Environment News Service. 16 October 2002

33 Financial Times 11 September 1997. Guardian 12 September 1997

34 Based on BAA estimate of £15 per passenger.

35 Budget Statement 30 November 1993

36 CM 3950. DETR. July 1998

37 Environmental Signals 2001. www.eea.eu.int

38 The Environmental Effects of Civil Aircraft in Flight. 30 November 2002

39 Royal Commission on Environmental Pollution 22nd Report. Cm 4749. 2001

40 DfT - SE page 34

41 DfT - SE page 34

42 DfT - SE page 150

43 DfT - SE page 150, also Economic Appraisal page 35

44 Airport Watch briefing. www.airportwatch.org.uk/briefings/external costs

45 DfT - SE page 34

46 Valuing the External Costs of Aviation. DETR.
December 2000.

47 DfT - SE page 150

48 The Times. 30 November 2002

49 Based on EEA figure of 48 euro per 1000 passenger km, and DERA figure of 250 bn seat km used by UK airlines in 1999-00.

50 External Costs of Aviation. CE Delft February 2002

51 The Environmental Effects of Civil Aircraft in Flight. November 2002

52 The SPASM re-run was based on the assumption that the fuel tax would put up air fares by 23%.

53 DfT - SE page 34.

54 DfT - SE page 106

55 BAA. Response to consultation on Future of Aviation. April 2001

56 Hansard 9 November 2000

57 Report by DotEcon Ltd. January 2001. www.dotecon.com

58 CAA. Response to consultation on Future of Aviation . April 2001

59 CAA. Recommendations to the Competition Commission. February 2002. pages 17-18

60 The Times. 13 December 2000

61 Letter to the Author. 30 September 2002

62 Research by IPPR. Year 1999

63 Office of National Statistics. Omnibus Survey. February 2002

64 Flying responsibly into the future. Freedom to Fly. October 2002

65 DfT - SE page 17

66 SPASM Input Assumptions. DfT. July 2002

67 Hansard 28 November 2002

The Hidden Cost of Flying - Supplement: April 2003

Aviation and the Environment ; *Using Economic Instruments* was issued by the Treasury and the Department for Transport in March 2003. It is a welcome step in the right direction. At last the Treasury is turning its alpha mind to the issue of how much tax the airlines should pay. So far as it goes, which is not far, the new document confirms the calculations in the *Hidden Cost of Flying.*

The Treasury calculate the external costs of climate change caused by aviation as £1.4 billion in 2000, rising to £4.8 billion in 2030. The increase is mainly due to the fact that air travel is forecast to treble, and partly due to the fact that the cost of climate change is assumed to rise over time. Other external costs such as noise, local pollution and damage to countryside and heritage are said to be small by comparison.

The hidden costs included in this calculation are the impacts of global warming on agriculture, increased mortality, sea level rise, species loss, and health effects such as increased likelihood of malaria. Details are given in *Estimating the Social Cost of Carbon Emissions* by Richard Clarkson and Kathryn Deyes (DEFRA January 2002).

Clarkson and Deyes point out, however, that these figures are only sufficient to meet the UK's international obligations under Kyoto to reduce emissions by 5.2% (paragraph 9.13). If the Treasury wishes to meet the more ambitious target of a 20% reduction (let alone the IPPC target of a 60% reduction) a higher price needs to be put on carbon. One study suggests it would need to be £100/tC instead of £70/tC, ie 43% higher.

Taking into account also the annual increase since 2000, this would suggest that the figure of £1.4 billion should be increased to £2.5 billion in 2003.

Preventing catastrophe

The Treasury admit that the calculation "takes no account of uncertainties including the probability of: so-called 'climate catastrophe' (eg melting of the West Atlantic ice sheet, Gulf Stream suppression etc)". Nor does it include "the 'socially contingent impacts' of climate change (eg famine, mass migration etc)."

According to Tony Blair we should take these dangers seriously: "There are alarming changes in our atmosphere, in global temperatures, in weather patterns, in sea levels and in the protective ozone level. As a result, across the world millions face drought, flooding, disease." (Speech to the CBI. 24 October 2000).

These hidden costs are left out because the Treasury cannot measure them. Crossing a railway line in front of an oncoming train because you cannot exactly measure its speed may appeal to alpha minds but is generally not to be recommended. If the danger is probable or even possible, then according to the precautionary principle, we should take action to prevent it.

DEFRA suggest doubling the figure to provide a sensitivity range but admits that even this “does not cover the full uncertainty.” They point out that “Existing studies (of climate change costs) give little consideration to the possibility of climate catastrophes.” Also that, because some climate change events tend to become self re-inforcing, some studies show a “higher possibility of an extremely disastrous outcome than of a much more minor one.”

Therefore it would seem fair to suggest that the figure of £2.5 billion should at least be doubled. **This would suggest for the year 2003 a cost of climate change damage due to aviation of around £5.0 billion.** This does not take into account other external costs such as noise or local (ground level) pollution.

When fiscal equity is taken into account that would seem fully to justify taxing aviation fuel at the same rate as motor vehicle fuel (tax yield £5.7 billion).

Fiscal equity ignored

In the *Hidden Cost of Flying* it was argued that there is a need to ensure that aviation pays the same rate of tax as other industries (fiscal equity) as well as covering its external costs. But the new Treasury document makes no reference to fiscal equity.

The case for imposing tax on aviation fuel at the same rate as on petrol for cars depends partly on external costs and partly on fiscal equity. The case for applying VAT to air travel depends entirely on fiscal equity.

The Treasury document is full of invitations to suggest ‘instruments’ to reduce aircraft emissions. The alpha mind seems reluctant to recognise that the Treasury has the best instrument to hand: to remove the tax concessions which are fuelling the artificial growth in air travel. When a market is distorted, it is normally best to remove distortions rather than to try to control the results by regulation.

Brendon Sewill *April 2003*

www.cedelft.eu/en/publications/2145/economic-and-sustainability-impacts-of-an-aviation-tax

Economic and sustainability impacts of an aviation tax

This report presents an analysis of the economic and sustainability impacts of an aviation tax. These impacts were examined for three main variants, broken down into ten subvariants, for 2021 and 2030, against two background scenarios.

In all the variants the aviation tax has a modest positive impact on Dutch economic welfare, GDP and CO2 emissions. This holds for both background scenarios.

The impacts of the aviation tax are relatively modest. This is because the tax itself is likewise fairly modest (several percent of the average ticket price) and because of the serious capacity restrictions at Schiphol Airport, in particular. Without an aviation tax, these restrictions lead to higher profits for airlines. The tax will be paid for largely by the airlines from these higher profits.

As a result of the capacity restrictions, an aviation tax will not lead to fewer flights but to a shift in traffic segments (passenger/freight, OD/transfer, European/intercontinental destinations). This means the tax will have only a modest impact on CO2 and particulate emissions and noise.

Given the revenues accruing to government, in all the variants and scenarios the tax, in the form investigated, will increase overall economic welfare. These welfare gains stem mainly from some of the tax revenue coming from foreign airlines and passengers, and because depressed demand due to the tax will lead to alternative, non-aviation consumption expenditures (in the Netherlands) that are taxed.

A study on aviation ticket taxes

CE Delft

Committed to the Environment

A study on aviation ticket taxes

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CE Delft
Committed to the Environment

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Content

Summary

Aviation has a unique taxation regime that is characterised by a lower level of taxation than many other economic activities. The low-tax regime is supported by a number of interacting national, European, global and bilateral rules and agreements.

In order to still raise fiscal revenue from aviation, a number of countries have introduced aviation ticket taxes in the last decades. Invariably, these initiatives have been met by opposition from airlines and often opposed in courts, although in most cases, the taxes were judged to be lawful.

The aim of this study is to analyse which aviation ticket tax designs have held up in court and can therefore be considered as a template for new taxes. Moreover, the study analyses how and to which extent aviation ticket taxes can be used to internalise external costs of aviation, with a focus on climate impacts.

Legal cases against aviation ticket taxes

This study has analysed five legal cases against aviation ticket taxes in five different European countries. The cases argued that the taxes violated a number of laws, including:

- Article 15 of the Chicago Convention, prohibiting States to levy charges ‘in respect solely of the right of transit over or entry into or exit from its territory’;
- State Aid guidelines, because the plaintiffs argued that certain provisions of the taxes favoured some airlines or airports over others;
- the EU-US Open Skies Agreement, because plaintiffs argued that the aviation ticket tax was, in fact, a fuel tax and because it had an extraterritorial impact.

The analysis shows that:

- taxation of aviation activities per se is not prohibited by either the Chicago Convention or Bilateral Air Service Agreements;
- transfer and transit passengers may be exempted in order to avoid double taxation; this is not unlawful state aid;
- differentiation of taxes with regards to distance is permissible, but the differentiation should not interfere with the working of the internal market;
- an aviation ticket tax is not a fuel tax and hence restrictions on fuel taxes do not apply.

Consequently, an aviation ticket tax can withstand legal challenges if it is not linked to fuel consumption and if it does not differentiate rates within the EU, while it may exempt transfer and transit passengers.

Per flight taxes provide better emission reduction incentives for airlines than ticket taxes and could drive airlines to maximise the number of passengers and freight tonnage transported per flight. So far per flight taxes have not been introduced. As a consequence, little is known about possible legal obstacles to introducing a per flight tax, mainly because per flight taxes have not been tested in a court of law.

Options to enhance the internalisation of environmental externalities

Taxes have an impact on demand, so aviation ticket taxes will, by reducing demand for aviation, also reduce its environmental impacts. However, a ticket tax with a single rate is a rather blunt way to internalise externalities as it does not take the actual environmental impacts of a passenger on a specific flight into account. If taxes were differentiated with regards to the environmental impact, the transport system would become more efficient and an additional incentive to reduce the impacts would be provided.

The study analyses how climate externalities can be used as a basis for differentiation without risking that the tax is viewed as a fuel tax and taking into account that it is complicated to establish the fuel efficiency of an aircraft. Four proposals have been elaborated.

First, an aviation ticket tax, differentiated on the basis of the average lifecycle emissions of fuels that the airline has used in a previous period, would be one way to internalise external effects of CO_2 emissions. Passengers flying with airlines that have exclusively used fossil fuels would pay a higher tax rate than passengers flying with airlines that have used a share of sustainable low carbon fuels. Because the tax would be levied on the carbon content of the fuel and not on the amount of fuel, and because transfer passengers would be exempted, the tax cannot be considered to constitute a fuel tax.

Second, an aviation ticket tax, differentiated on the basis of distance to the destination, would also be a way to internalise the external impacts of CO_2 emissions. Currently, most taxes have two rates, one for intra-EU destinations and one for destinations further away, which does not take into account that a flight to a relatively nearby non-EU destination may cause half or less of the CO_2 emissions than a flight to a faraway destination. By increasing the number of distance bands, this variation in external impacts may be internalised.

Third, an aviation ticket tax, differentiated on the basis of certified NO_x emissions during landing and take-off (called LTO NO_x emissions), would be a way to internalise the external impacts of NO_x emissions, both in the LTO phase and in the cruise phase, where NO_x emissions have a climate impact. This is because LTO NO_x and cruise NO_x emissions are correlated.

Fourth, a share of the aviation ticket tax could be replaced by a NO_x climate impact charge related to the distance flown and the LTO NO_x emissions of the aircraft.

1 Introduction

1.1 Policy context

Aviation has a unique taxation regime. Airline tickets are generally exempt from VAT (domestic aviation is often subject to VAT on tickets), and no excise duty or VAT is levied on fuels (IMF and World Bank, 2013) (Keen, et al., 2013).[1] Also, aircraft are VAT exempt as upfront capital purchases in Europe as long as they are used by airlines for operations on international routes (EU VAT Directive 2006/112/EC). The taxation regimes are enshrined in bilateral air service agreements between countries which mutually prohibit taxation of aviation fuels for airlines flying between those countries and, in the case of VAT, in the EU VAT directive.

Aviation ticket taxes are widely deployed by countries around the world (see Section 2.2). The first EU Member state to do so was the UK, which introduced the Air Passenger Duty in 1994 as a way to broaden the tax base (IFS, 2008). In the same year, Norway introduced a passenger tax (OECD, 2005). Belgium, France, Ireland, Italy, Austria, The Netherlands, Germany and Norway have followed, and Sweden is currently considering the introduction of an airline climate tax (Reuters, 2016).

Not all the aviation ticket taxes that have been mulled were implemented, and some have been implemented but quickly abolished. In most cases, legal procedures were initiated against the taxes. Although these were generally not successful they did have the result of raising the barrier for introducing aviation ticket taxes by governments.

Apart from making up for the tax exemptions and raising fiscal revenue, aviation ticket taxes have an impact on demand by increasing the costs of flying. This can have an effect on aviation emissions and airport noise. Moreover, some countries have contemplated including a differentiation on environmental grounds in the tax rate, although to date this has not been implemented.[2]

In view of the above, Transport and Environment has requested CE Delft to study the possibility to develop EU guidelines for aviation ticket taxes in order to provide clarity about what is legally permissible and to see whether it is possible to design passenger carbon taxes that would not contravene the restriction on fuel taxes.

[1] Note that IATA (2005) asserts that aviation is highly taxed. In order to reach this conclusion, the report has had to classify infrastructure usage charges (e.g. landing fees that airlines pay to airports) as taxes, even though the level of the landing fees is often regulated to cover the costs of operating and maintaining the infrastructure (IATA, 2005).

[2] The UK (IFS, 2008),The Netherlands (CE Delft, 2008) and Germany are known to have considered differentiating the tax on the basis of aircraft NO_x emissions or noise.

1.2 Aim and scope of the study

The overall objective of the project is to develop elements of legal guidance for aviation taxes.

The project comprises two parts:
1. Develop elements of EU-level legislative guidance for aviation taxes to be implemented by Member States.
2. Analyse whether or how it could be legally feasible to introduce a climate change element in an aviation tax.

1.3 Outline of the report

Chapter 2 provides a definition of aviation ticket taxes and an overview of taxes in the EU and worldwide. Chapter 3 analyses five court cases against aviation taxes in five different EU Member States in order to identify which objections against the taxes have been judged to be legitimate and which have not. Chapter 4 progresses to find commonly accepted characteristics of aviation taxes. Chapter 5 explores whether and, if so, how climate externalities could be included in aviation ticket taxes. Chapter 6 concludes the report by providing an outline of legally permissible elements of aviation ticket taxes which internalise climate externalities.

2 Overview of aviation ticket taxes

Many EU Member States now implement aviation ticket taxes (CE Delft ; SEO, 2018). In the context of international agreements prohibiting the taxation of certain elements of a flight, such as the fuel used and flights themselves being levied a zero VAT rate, aviation ticket taxes are one way of levying a tax on the aviation sector. These taxes have been implemented in a number of countries.

This chapter presents a short overview of aviation ticket taxes in the EU and worldwide. First a definition will be given of aviation ticket taxes used in this report (Section 2.1), after which the worldwide use of ticket taxes will be sketched, showing that ticket taxes are not only implemented in the EU (Section 2.2).

2.1 Definition of aviation ticket taxes

Ticket taxes levy a tax on each origin-destination passenger departing from an airport in the country where the tax is applied, with the airline being responsible for collecting the tax and paying it to the government. The taxable event is therefore a departing passenger leaving on a commercial airline. Features of most ticket taxes are the exemptions for transfer and transit passengers, and flights for State or military reasons. Since freight transport carries no passengers, freight is exempt from this tax. Whether the tax is passed on to passengers depends on the pricing-decision of the airline. Since airlines are liable for collecting the tax and paying it, they can chose the degree to which they pass it on to the customer. In this report the meaning of taxes follows the definition of the International Civil Aviation Organization's: "a tax is a levy that is designed to raise national or local government revenues" (ICAO, 2000). This is in contrast to their definition of a charge: "a levy that is designed and applied specifically to recover the costs of providing facilities and services for civil aviation" (ibid.).

Since the ticket taxes were analysed from a legal perspective, case law was utilised to investigate which elements of the ticket tax could withstand legal challenges, and which elements could not. In cases which related to competition law the European Commission investigated distortions of the internal market, hence European case law was used for these cases. In cases where the tax itself was the source of the legal dispute because for instance it violated international air travel agreements, national case law was used.

2.2 Ticket taxes worldwide

In this report ticket taxes which have undergone legal challenges in the EU will be discussed. Ticket taxes are however implemented in various countries, also outside of the EU. In 2009 the International Air Transport Association (IATA) comprehensively listed all the ticket taxes in place in the various jurisdictions of the world. CE Delft and SEO (2018, ongoing) have updated this list, which will be published shortly. The 514 ticket taxes in total were further subdivided into domestic and international taxes (one country can have more than one ticket tax). The IATA definition of ticket taxes is the following: "Taxes which are collected at [the] time of ticket sale and which appear in the tax box of a ticket or which are included in the price of a ticket". These taxes are sometimes levied in return for a service, which does not fit our definition of a ticket tax, hence only the taxes which fit our definition will be summarised in Table 1. On the other hand some charges are levied without the expectation of a service in return, hence these are included in the table. The charges and taxes where it is not known whether they were levied in return for a service, such as the Spanish Departure Charge, will not be included in the table. This table illustrates the exhaustive list of ticket taxes in the EU, as well as some of the taxes implemented in non-EU countries.

Table 1 - Ticket taxes in the EU and worldwide

Country	Name of tax	Year of introduction[3]	Tax rate and distance groups (economy class)	Exemptions[4]
EU				
Austria	Air Transport Levy	2012	€ 7 EU flights, € 15 medium, € 35 long	Transit[5] and transfer[6] passengers
Belgium*	Ticket tax Zaventem	1995	12 frank (€ 0.3)	Unknown
France	Air Passenger Solidarity Tax	2006	€ 1 for economy domestic and EU flights, € 10 for first class domestic and EU flights, € 4 for long flights economy, € 40 for long flights first class	Transit passengers
	Civil aviation tax	1999	€ 4.31 for domestic and EU flights, € 7.75 per passenger to other destinations, € 1.29 per tons of freight or mail to any destinations	Transit passengers
Germany	Air Travel Tax	2011	€ 7.47 for EU flights, medium distances between 2,500 km and 6,000 km at € 23.32, longer distances € 41.99	Transit and transfer passengers
Hungary**	Air Departure tax	2005	€ 6-19.90 for international flights	Transit passengers
Ireland*	Air Travel Tax	2009	From 2012-2014 it was a € 3 rate for all flights	Transit and transfer passengers
Italy**	Embarkation Tax	1993	€ 3.48 for EU flights, €7.72 for longer flights	Transit and transfer passengers

3 In some cases the year of introduction is not included in the IATA list, hence in these cases the oldest year mentioned in the description was used.

4 Only exemptions for transit and transfer passengers will be listed since the range of exemptions is too large to include in Table 1.

5 Passengers who remain on the same flight during an intermediate stop.

6 Passengers who transfer to a different flight to reach their destination.

Country	Name of tax	Year of introduction[3]	Tax rate and distance groups (economy class)	Exemptions[4]
Lithuania**	Airport tax	2008	LTL 20-45 international flights depending on airport departure, LTL 10-20 for domestic flights	Transit passengers
Luxembourg	Passenger Service Charge	2002	€ 3 for all flights	Transit passengers
Netherlands*	Air Passenger Tax	2008	€ 11.25 for domestic and EU flights, € 45 for longer flights	Transit and transfer passengers
Romania**	Airport Departure Tax	2009	€ 2-7.20 for domestic flights, € 3-14.20 for international flights	Transit and transfer passengers
Slovakia**	Embarkation Tax	2009	€ 3.15-6.97 for domestic flights depending on airport, € 8.13-16.27 for international flights depending on airport	Transit passengers
United Kingdom	Air Passenger Duty	1994	£ 13 (€ 15) for domestic and EU flights, £ 75 (€ 88) for longer flights	Transit and transfer passengers
Non-EU				
Australia	Passenger Movement Charge	1995	$AUD 55 (€ 40) per passenger	Transit passengers
Brazil**	Embarkation Tax	2005	BRL 27-81 (€ 8-24)	Transfer passengers
Norway	Air Passenger Tax	2016	NOK 80 (€ 9) per passenger	Transit and transfer passengers
United States of America	Transportation Tax	1997	7.5% for domestic flights, $ 13.40 (€ 13) for international flights departing or arriving in the USA	Transit and transfer passengers
South Africa	Air Passenger Tax	2005	R120 (€ 9) for international departures	Transit and transfer passengers
Philippines	Travel Tax	1991	PHP 1620 (€ 30)	Other

Source: IATA, 2009.

* Abolished or zero-rated ticket tax.

** Unknown whether the tax is still in operation or not.

Some countries differentiate(d) the tax according to distance (e.g. UK, Germany and the Netherlands) while others levy a flat rate for international travel. For the EU countries the differentiation is often based on a single rate for all EU destinations, and higher rates for destinations outside of the EU (except Ireland and Belgium). From the table it is clear that ticket taxes have been applied on all inhabited continents: Europe, South-America, North-America, Asia, Oceania and Africa. Some ticket taxes have been in place since the early 90's, while others have been introduced more recently. The rates also vary, with the Norwegian rate being € 9 for all economy class, while the UK's duty can reach € 88 per passenger for long distance flights.

3 Legal cases on aviation ticket taxes

This chapter presents an analysis of five legal challenges against aviation ticket taxes in Europe. The cases are presented in chronological order, starting with the ticket tax Zaventem (Section 3.1), the UK's air passenger duty (Section 3.2), the Dutch aviation tax (Section 3.3), the Irish air travel tax (Section 3.4) and lastly the German air travel tax (Section 3.5).

3.1 Ticket tax Zaventem

3.1.1 Summary

The municipality of Zaventem introduced a ticket tax over the period 1996-2000. The tax was taken to court by Belgian companies for being in violation of Article 15 of the Chicago Convention. In 2005 the Belgian Council of State came to the conclusion that Article 15 was indeed violated.

3.1.2 Background

The Belgian municipality of Zaventem introduced a ticket tax on 18 December 1995 for all passengers departing from the municipality's territory, i.e. departing from Brussels National Airport in the municipality of Zaventem. The tax was 12 frank per departing passenger over the period 1996 to 2000. The tax would be levied retrospectively over the past year: the airlines would be charged 12 frank for each of their passengers departing from Brussels National Airport in the past year.

3.1.3 Grounds for opposing the tax

In May 2005 B.A.R. Belgium, Sabena and Lufthansa brought this tax before the Belgian courts for violating Article 15 of the Chicago Convention. The last sentence of Article 15 states that "No fees, dues or other charges shall be imposed by any contracting State in respect solely of the right of transit over or entry into or exit from its territory of any aircraft of a contracting State or persons or property thereon". Since no charges were allowed to be levied on an aircraft from a treaty country for merely flying over, landing or departing from a Belgian airport, the complainants argued that this Article was understood to have a broader definition than only prohibiting discrimination of foreign airlines relative to domestic airlines, which the municipality of Zaventem had argued. Furthermore the complainants argued that the tax was not compensated by any kind of service by the government, and it was therefore unjustified.

3.1.4 Results of court case

The Belgian Council of State agreed with the complainants that Article 15 should indeed be understood to mean that not only should foreign airlines not be discriminated against relative to domestic airlines, but that it also meant that no tariffs, dues or other costs can be levied on foreign airlines for merely flying over, landing or departing from a treaty country and that the tax is not connected to using the airport and airport facilities. The interpretation of Article 15 according to the Council of State is that “air transport services should operate in a sound and economic way”. The tax was therefore abolished.

3.2 Air Passenger Duty UK

3.2.1 Summary

The air passenger duty (APD) was introduced in 1994. After the rate was doubled in 2006 it was taken to court in 2007 by the Federation of Tour Operators for violating Article 15 of the Chicago Convention. The judge found that the tax was not in violation of Article 15.

3.2.2 Background

The Air Passenger Duty (APD) was introduced in 1994 and was levied on each passenger departing from an airport in the UK, excepting transit and transfer passengers (amongst others). The introduction of the tax was meant to increase tax revenues for the UK government since it was not possible to do so via VAT (Seely, 2012a). Initially passengers were charged £ 5 for flights within the EU, and £ 10 for flights to other destinations. The distance bands are presently split according to the distance of a country’s capital from London, with the exception of Russia which is split east and west of the Urals. The APD has been adjusted multiple times, and as of 1 April 2017 it will charge £ 13 for reduced rate[7] flights (i.e. economy class) up to 2,000 miles (3.218,69 km) and £ 75 for longer flights. The APD additionally differentiates between standard rates (£ 26 EU flights, £ 146 other) and higher rates (£ 78 EU flights, £ 438 other), with the higher rate applying to aircraft of 20 tonnes or more equipped to carry fewer than 19 passengers (i.e. business or leisure jets), and the standard rate applying to all passengers who do not fall into the other two groups (i.e. first class in aircraft carrying more than 19 passengers).

3.2.3 Grounds for opposing the tax

On 6 December 2006 the Chancellor of the Exchequer decided to double the APD from £ 5 to £ 10 in the EU, and from £ 10 to £ 20 everywhere else. The increase would come into effect on 1 February 2007, giving aircraft operators 7 weeks to adapt their prices. Following this decision the Federation of Tour Operators, which represents the majority of the UK’s larger outbound operators, claimed that the APD was in violation of the Chicago Convention Article 15, and that the increase was also unlawful. The APD is payable by the operator of the aircraft, however when a flight has been purchased by a tour operator the APD is passed on to it by the aircraft operator. The passing on of the APD to customers of tour operators is however constrained by the Package Travel Regulation, and according to the claimants this made it legally and practically impossible to change prices in published brochures after a tour package had been purchased. Furthermore some tour operators had included ‘no surcharge guarantees’ in the conditions of their contract, making it impossible to pass on

[7] Lowest class of travel available on the aircraft.

the increase in the APD to their customers if this increase occurred after the contract was finalised. Even in the case where the tour operators could pass on the increase, they could not do so for the customers whose holidays would begin less than 30 days after the announcement of the increase, which was stipulated by the Package Travel Regulation. Another requirement was that operators absorb the first 2% of any increase in prices, and because the increase in the APD would in most cases be below 2% of the entire package, the tour operators would mostly bear the entire financial burden of the increase.

Usually after an increase in the APD rate, tour operators would be given time to adjust their brochures to reflect the new rates because they typically sell tour packages months in advance. For previous increases in the APD, the change would come into effect between 9-12 months after the announcement of the increase. Tour operators would therefore not face the above mentioned problems caused by the Package Travel Regulation in combination with a sudden increase of the APD. According to the tour operators the doubling of the APD was retrospective as aircraft operators would have to return to the customers in order to recover the increase, who bought tickets before the doubling was announced and who would fly after the doubling came into effect. The government argued that the above issues had been taken into account with regards to the APD increase coming to effect earlier than usual.
The first step in the case was an application for judicial review before the High Court.[8] Only if the judicial review was granted could the substantive hearing follow. The results of the court case will not deal with the legality of the increase since this is not relevant to the rest of the report, but will only focus on the alleged violation of Article 15 of the Chicago Convention.

3.2.4 Result of court case

As with the Zaventem case, the source of the dispute arises from the interpretation of the last sentence in Article 15 of the Chicago Convention: “No fees, dues or other charges shall be imposed by any contracting State in respect solely of the right of transit over or entry into or exit from its territory of any aircraft of a contracting State or persons or property thereon”. The claimants argue that the sentence includes taxes like the APD and so prohibits them. While the defendants argue that the sentence is restricted to charges, and not taxes like the APD. Since the Chicago Convention has been officially translated into numerous languages, some of the translations unknowingly exacerbated the ambiguity of the above quoted sentence, with the French translation of “fees, dues or other charges” being “*droits, taxes ou autres redevances*”. A translation expert testified before the court that the French use of the word *taxe* does not refer to taxes in the English sense, but rather translates to a compulsory levy to finance a particular public service. The Spanish and Russian translations on the other hand do unambiguously refer to a tax. The claimants relied on the French, Spanish and Russian translations of Article 15 to support their claim, while the defendants instead placed a greater weight on the English text.

The judge came to the conclusion that the decision to omit the word “taxes” in the sentence in the English text implies that “dues” therefore do not carry this meaning, otherwise “taxes” would have been included in the sentence. In its entirety Article 15 should rather be interpreted as an anti-discrimination provision, since the judge found that the meaning of the words “in respect solely of the right of transit over or entry into or exit from its territory of any aircraft of a contracting State or persons or property thereon” were clear, irrespective of the language of the official translation. According to the judge it

[8] Judicial review is a type of legal case where the legality of administrative decision making, including the levying of taxes, can be challenged.

meant that a fee, due or other charge levied on the right to enter a country, or the right to leave or transfer over it, would discriminate in favour of a national airlines relative to a foreign one. This is not the case if the fee, due or charge is levied on take-off, irrespective of the destination, and including destinations within the country since this does not lead to the discrimination of foreign airlines. The APD was therefore not in violation of Article 15 and a full substantive hearing was not granted.

3.3 Dutch Aviation Tax

3.3.1 Summary

The tax was investigated for unlawful State aid due to the exemption on transfer and transit passengers. The Dutch court found this not to be the case since the selectivity criterion of State aid was not met. The European Commission also concluded that there was no indication of unlawful State Aid. Lastly the Dutch court found that the tax did not contravene the Article 15 of the Chicago Convention. The tax was set to 0 on 1 July 2009 to allow airlines to recover from the 2008 crisis, and on 1 January 2010 it was formally abolished.

3.3.2 Background

The Dutch aviation tax was introduced on 1 July 2008 whereby airlines departing from a Dutch airport were charged directly with respect to every departure of a passenger according to the tax. The tax rate was € 11,25 for intra-EU flights of no more than 3,500 km or 2,500 km for a final destination outside the EU, and € 45 for all other flights. The radius of 3,500 km covers all destinations in Europe, except Member States' overseas territories. Exemptions were given to transfer and transit flights, as well as freighter aircraft since no passengers are transported. The basis for the dispute was the exemption of levying the tax on transfer and transit passengers. On 6 February 2008 the Maastricht Aachen Airport (MAA) company filed a complaint along with Ryanair against the Dutch government with regards to the tax, and requested the tax be suspended until the European Commission had investigated the likelihood of unlawful State aid and the Dutch courts had determined whether the tax was in conflict with Article 15 of the Convention on International Civil Aviation.

3.3.3 Grounds for opposing the tax

MAA and Ryanair argued that Amsterdam Airport Schiphol and Air France/KLM unduly benefitted from the exemption on transfer and transit passengers as well as freight transport since these undertakings have a relatively high proportion of such passengers and flights, leading to unlawful State aid. The Maastricht Aachen airport does not serve transfer and transit passengers. The complainants also argued that the tax was in conflict with Article 15 of the Chicago Convention. This last dispute is based on the following sentence from Article 15: "No fees, dues or other charges shall be imposed by any contracting State in respect solely of the right of transit over or entry into or exit from its territory of any aircraft of a contracting State or persons or property thereon." MAA and Ryanair used this part of Article 15 to argue that any form of taxation which is independent from the costs of using the airport and its facilities should be prohibited (KiM, 2011). However the Dutch government argued that Article 15 should rather be seen as a ban on discrimination whereby airlines from other countries should not be treated differently from the country in which the airport is situated.

3.3.4 Results of court case

The court in the Hague ruled in favour of the Dutch government that the selectivity criterion which would lead to unlawful State aid was not supported since the tax exemption was applied on a general basis to all Dutch airports and all transfer and transit passengers. Furthermore the court stated that almost all taxes have the inadvertent effect of benefitting one company more than the other, hence the argument that some airports profit more from the exemption than others did not hold.

The court shared the Dutch governments reasoning for the exemption of transfer and transit passengers: since the Dutch government had imitated the ticket taxes of France and the UK, it also imitated the exemption to these passengers which would avoid the double taxation of passengers departing from France and the UK and transferring through the Netherlands. It also found that the tax was not in conflict with the Chicago Convention Article 15 since the above quoted sentence is ambiguous with regards to the prohibition of any form of taxation on aircraft. The court found that “charges” were not an all-encompassing grouping under which taxes should fall, and that ICAO (International Civil Aviation Organization) unambiguously stated in a 1999 policy document that fiscal issues were not comprehensively dealt with by the Chicago Convention. The court argued that Article 15 should rather be understood as a ban on discrimination. A ticket tax is possible as long as airlines from other convention countries are treated the same as domestic airlines.

The Commission also investigated whether the tax led to unlawful State aid. Even though the tax favoured certain undertakings and distorted trade between Member States, the selectivity criterion could not be proven and the State aid was deemed legal. This was due to the fact that the measure fulfilled the exemption criterion for selectivity: “the selective nature of a measure may be justified by the nature or general scheme of the system” (EC, 2011). In comparison to the reference system, which is the taxation of air passenger transport, transfer and transit passengers are justifiably exempted from the tax since the avoidance of double taxation falls within the logic of the relevant tax system. Furthermore the Commission has recommended the exclusion of transfer and transit passengers from European flight taxes (EC, 2005).

3.4 Irish Air Travel Tax

3.4.1 Summary

The Irish Air Travel Tax was judged to amount to unlawful State aid since the lower tax rate benefited domestic airlines relative to other airlines who had to pay a higher tax. The differential tax rate was consequently amended to a flat rate. The tax was also investigated for illegal State aid with regards to the exemption of transfer and transit passengers, however the European Commission dismissed this. The tax was reduced to zero in 2014 by the Irish government.

3.4.2 Background

From 30 March 2009 until April 2014 airlines departing from an Irish airport were charged directly with respect to every departure of a passenger according to the air travel tax for aircraft carrying more than 20 passengers and not used for State or military purposes. The intention of the tax was that it would be passed on to passengers through the ticket price, even though the airline operators had to pay it. Initially the tax was dependent on the distance between the airports of departure and arrival, with a rate of € 2 in the case of a flight from an airport to a destination no more than 300 km from Dublin airport, and € 10 for longer distances. Transit and transfer passengers were exempted from the tax.

3.4.3 Grounds for opposing the tax

In July 2009 the Commission received a complaint from Ryanair criticising several aspects of the air travel tax implemented by Ireland. Ryanair claimed that the lower tax rate mainly benefited airlines operating the majority of their flights to destinations no more than 300 km from Dublin airport, such as Aer Arann. Furthermore according to Ryanair the non-application of the tax to transit and transfer passengers constituted unlawful State aid to the advantage of the airlines Aer Lingus and Aer Arann, because those companies had a relatively high proportion of passengers and flights in those categories. This last complaint is similar to Section 3.3 in the Dutch ticket tax case, where the Commission investigated whether the exemption of transfer and transit passengers from paying the tax led to unlawful State aid.

Owing to complaints lodged by Ryanair with the Commission the air travel tax was investigated for possible unlawful State aid, which was incompatible with the internal market since the tax discriminated between domestic and intra-EU flights[9]. The lower rate was justified according to the Irish government for domestic flights, however the Commission did not share this view. First due to the fact that departing flights would lead to the same negative externalities for Irish citizens regardless of their destination. Second because the tax was not differentiated according to the actual distance of the flight, but rather on the basis of the distance between Dublin airport and the destination. Since all destinations within 300 km from Dublin would be charged the lower rate, some flights departing from Ireland would be traveling further than 300 km but were only subject to the lower tax rate. This would be the case for flights from Cork to Liverpool, since the distance from Dublin to Liverpool is around 230 km, meaning the lower rate applied, while the distance from Cork to Liverpool is around 410 km, hence the tax is not differentiated according to the actual distance of the flight in this case. Third, it could not be shown that the price of tickets for domestic flights was necessarily lower than that of flights to other destinations in the EU. The Irish authorities had initially argued this last point for the purpose of differentiating rates to introduce an element of proportionality in the level of the tax relating to distance, since it was assumed that prices are normally lower for shorter distanced flights. Lastly the Irish authorities argued that if the lower tax rate is deemed as unlawful State aid it should still be declared to be compatible with the internal market as *de minimis* aid.

3.4.4 Result of the legal challenge

To determine whether the State aid was unlawful, the Commission examined if the low tax rate was a selective measure, if it conferred an advantage to domestic airlines, if it made use of state resources and was attributable to the state (imputability), and if it led to an adverse effect on competition and trade between Member States. Next the decision making process of the Commission in this case will be highlighted to reveal how it came to a decision on whether unlawful State aid had been given or not. A summary of the decision is described at the end of this section.

[9] Commission decision of 25 July 2012 on State aid case SA.29064.

To establish whether a measure is selective, the Commission had to assess whether the low tax rate favoured certain flights in comparison with others in a comparable factual and legal situation. To do this the relevant tax system of reference had to first be identified, which in this case was the taxation of air passengers departing from airports situated in Ireland. Second the Commission had to determine whether the tax measure constituted a derogation (an exemption of a rule or law) from the identified reference system. In this case the reference system was the higher rate of € 10 per passenger, and not the € 2 rate, since 85-90% of flights departing from an Irish airport paid the higher tax rate. This implied that the € 2 rate was an exemption from the reference system. Third the Commission investigated whether this exemption was justified by the nature of the scheme. The Irish authorities had justified the lower tax rate to introduce an element of proportionality in the level of the tax relating to distance, since it was assumed that prices are normally lower for shorter distance flights. The Commission found this to be unjustified as the price of tickets of domestic flights was not necessarily lower than for flights to other destinations in the EU, hence the lower tax rate could not ensure its objective of ensuring proportionality of the tax in relation to flight distance. Due to the above reasons the Commission argued that the lower tax rate of € 2 per passenger was therefore unwarranted for flights to domestic destinations and seemed to be a selective measure, which falls under the definition of unlawful State aid under Article 107(1) of the Treaty.

The lower tax rate also provided an advantage to airlines which operated the low-rate routes since their costs would have been higher had they paid the higher tax rate.
This meant that these airline, being Irish airlines such as Ryanair, Aer Lingus and Aer Arann, were supported in competing with other airlines in intra-EU markets, and the Commission concluded that this therefore led to an advantage for these airlines. This advantage corresponded to the difference between the € 10 tax and the € 2 tax over the period 30 March 2009 and 1 March 2011 (the period when the tax was differentiated), meaning the Irish airlines received a benefit of € 8 per passenger over this period for domestic flights and some flights to the UK. With regards to state resources and imputability (under control of the state) the lower tax rate meant that the Irish government received fewer tax revenues, meaning it was effectively paying for this measure. The measure was also imputable to the Irish government as the lower rate had been decided by it. With regards to the effect of the lower tax rate on competition and trade between Member States, the airlines benefitting from the lower rate were relieved from higher costs relative to their competitors while these costs should have been borne. This improved their economic situation relative to competitors who did not fly the routes subject to the lower tax rate, hence distorting competition, which could be directly related to aid granted by the Irish government.

The Commission consequently argued that the tax discrimination led to unlawful State aid to the airline operators that had operated the routes benefitting from the reduced tax rate, which was incompatible with the internal market. Clearly a tax which does not differentiate between domestic flights (lower rate) and EU flights (higher rate) will not be deemed as unlawful State aid. Ireland amended the law in 2011 to not discriminate airlines according to the distance travelled, introducing a single rate of € 3 per passenger for all flights.

With respect to unlawful State aid arising from the exemption of the tax for transfer and transit passengers the Commission found that this was not a selective measure, and consequently it could not be classified as unlawful State aid. Section 3.3 already discussed this type of complaint for the Netherlands.
In all the Irish ticket tax was found to lead to unlawful State aid due to the differentiation of the tax rate within the EU since Irish airlines would benefit from the lower tax rate relative to other European airlines, distorting competition. On the other hand the

exemption of the tax for transfer and transit passengers was not found to have resulted from unlawful State aid.

3.5 German Air Travel Tax

3.5.1 Summary

American Airlines filed suit against the German air travel tax for violating a number of treaties and agreements. The complaints were all dismissed by the Fiscal Court of Hesse. Some of the supposed violations were: the violation of national sovereignty; unlawful discrimination of a foreign airline; charging of a fee or tax on an aircraft from a Chicago Convention signatory country; unilateral restriction of traffic volumes; unfair and unequal conditions for competition; unlawful charge on fuel; lack of price-setting freedom; heavier tax burden US airlines; unconstitutional consumption tax.

3.5.2 Background

Since 1 January 2011 the German Air Travel Tax (*Luftverkehrsteuer*) has been in place for flights departing from German airports, including domestic and international flights, regardless of carrier nationality. The tax is differentiated according to the distances from Frankfurt am Main to the largest commercial airport in the destination country: for short distances up to 2,500 km the tax per passenger is € 7.47[10] for EU flights as well as flights to Morocco, Tunisia, Turkey, Cyprus and Russia; medium distances between 2,500 km and 6,000 km at € 23,32; and long distances of over 6,000 km are subject to a € 41,99 tax per passenger. Similar to the Irish and Dutch aviation taxes, transfer and transit passengers are exempted from the tax. However the tax is still levied on passengers who arrive in Germany from abroad and fly to a destination within Germany.

3.5.3 Grounds for opposing the tax

On 19 March 2012 American Airlines filed suit against the air travel tax since it violated the principal of national sovereignty and several international agreements such as the Chicago Convention of 1944, the EU-USA Open Skies Agreement[11] of 2007, and the Friendship, Commerce and Navigation Treaty[12] between the Federal Republic of Germany and the USA of 1954.
According to American Airlines the tax violates the principle of national sovereignty, which is seen as a general rule of international law, and it also violates national sovereignty by taxing acts in foreign territories (Articles 1, 11 and 12 of the Chicago Convention, and Article 7 of the EU-USA Open Skies Agreement). It was also claimed that Chicago Convention Articles 11 and 15 were violated, since the plaintiff argued that the tax unlawfully discriminates against foreign airlines by levying an inappropriate graduation of tax rates (i.e. group divisions according to distance led to discrimination). In particular it was argued that Article 15 supposedly prohibits signatories from charging fees or taxes for its territory merely for the right of transit, entry, or departure of an aircraft from a signatory country.

[10] Which is increased by an additional 19% VAT for domestic travel.

[11] This agreement aims to promote among others an international aviation system between the two blocs based on competition and minimal government interference, as well as promoting security.

[12] This is a treaty of general relations between the two countries, fixing rules on governing day-to-day relations between the countries.

With regards to the EU-USA Open Skies Agreement, American Airlines argued that the tax leads to the following violations: the unilateral restriction of traffic volumes (Art.3(4)); unfair and unequal conditions for competition since the tax discriminates against foreign airlines by imposing cost-intensive additional requirements (Art. 2); it is an unlawful charge on fuel used in international aviation (Art. 11); and price-setting freedom is no longer protected (Art.13). Also the plaintiff views that there was a breach of the Friendship, Commerce and Navigation Treaty because the tax does not treat host country nationals equally as it differentiates according to nationality. Another violation is that it imposes a heavier burden on US airlines than on airlines from other countries in similar conditions.

3.5.4 Result of court case

The Fiscal Court of Hesse dismissed all the complaints. First the tax does not violate the principle of national sovereignty since a state has the right to levy a tax on something which is realised outside its territory as long as the effects caused by the tax do not affect the territorial sovereignty of another state. Second the supposed conflict with Article 1 of the Chicago Convention, that the airspace of the US is violated, was not found by the court since signatories of the Chicago Convention confirm that each *state* holds the exclusive sovereignty over the airspace above its territories, and so this does not hold for organisations like airlines. Third, Article 11 of the Chicago Convention states that air traffic regulations should be applied without distinction of nationality by signatory countries, which was found not to be violated since the tax does not make a distinction as to the nationality of the aircraft. Fourth the tax does not violate Article 15 of the Chicago Convention since it is not a fee because “it is not consideration for a benefit that can be individually attributed to the airlines”. Neither is Article 24 of the Chicago Convention contravened by the tax, which states that aircraft flying to, from, or across the territory of another signatory country must be held temporarily duty-free, subject to the customs regulations of that country, and that fuel and regular equipment (amongst others) are exempt from customs duty, inspection fees, or similar national charges and fees.
In particular the court found that the tax is not a duty on fuel used in international air traffic since it is neither directly nor indirectly linked to the fuel introduced to the customs territory aboard an aircraft or contained on board when it exits the territory.

With respect to the EU-USA Open Skies Agreement, the limitation in traffic volume due to the tax did not lead to a violation since there was no unilateral limitation of air traffic in the charging of the air transport tax. The court ruled that the tax is also not a fuel consumption tax since it does not tax the consumption of fuel and the amount of tax paid is not determined by the quantity of fuel consumed on a flight. Even though the tax rate is higher for more distant countries, distance is only loosely associated with the tax rate since it is divided into three discrete groups and it is only one of the two assessment factors (the other is passenger numbers). Therefore a short flight with many passengers may lead to a higher amount of tax paid with low fuel consumption than a long flight with few passengers and high fuel consumption. The court also did not find that the tax violated the plaintiff’s right to freely design its pricing structure as the airline could decide itself whether to pass through the tax to passenger tickets or not.

Based on the Friendship, Commerce and Navigation Treaty (Article 11(1)) the court ruled that there was no violation of the requirement to treat host country nationals equally as the tax does not differentiate by the nationality of the airline. For flights to the US the tax is the same for German as well as US airlines. The tax also does not violate Article 11(3) which states that there should be no discrimination against foreign airlines due to the country-based graduation of tax rates (distance division into three groups). American Airlines had argued that this graduation led to the unequal treatment of US airlines relative to for instance Russian airlines flying to Russia under similar conditions, since the tax rate could be higher for US airlines for the same distance. Hypothetically this could occur because flights to Russia are charged based on the distance to Moscow (the lowest tax rate), while the destination may be in the Far East, in which case the distance is much larger. On the other hand a US airline will always pay the highest tax rate to fly to the US. However, because only a tiny proportion of flights depart from Frankfurt to the Far East in Russia, the Court found that Russian airlines are not in a “like situation” with the plaintiff American Airlines and it therefore found that American Airlines was not discriminated against.
The simplification arising from the division into three groups is justified according to the court as it leads to minimal administrative effort and the assumption that most flights are destined for the largest commercial airport in the destination country is an accurate one.

4 When are aviation ticket taxes lawful?

Several lessons can be learnt from the above cases with regards to the legality of a ticket tax and it withstanding legal challenges. Firstly, of the five cases, four dealt with Article 15 of the Chicago Convention, with three cases adjudging there to be no violation with respect to a ticket tax (The Netherlands, Germany and the UK), and one where a violation was found (Zaventem). It should be noted that the Zaventem case was one of the first to challenge the viability of the ticket tax with regards to Article 15. This however had no consequence for later cases which challenged the ticket taxes since all survived the complaint of a violation of Article 15. The Zaventem case took place in 2005, the UK one in 2007, the Dutch case in 2008, and the German one in 2012, so if the judgement had carried more weight one could have expected the other cases to have followed with a similar conclusion.

Furthermore the Dutch case revealed that ICAO was aware of the fact that the Chicago Convention did not prohibit taxes and that ICAO had unambiguously stated in a 1999 policy document that fiscal issues were not comprehensively dealt with by the Chicago Convention. In the British case the judge clearly ruled that Article 15 was meant to prohibit discrimination, and not to prohibit a tax altogether. The case of Zaventem was also mentioned in the UK case, where the British judge who presided over the case of the APD stated that the reasoning behind the Zaventem judgement was flawed. For example the Belgian Council of State argued that the tax was aimed specifically at flying out of the *district* of Zaventem, when in actual fact Article 15 refers to the territory of a nation. The judge stated that "While according its decision all due respect, I regret that it does not lead me to alter my above conclusion [that the tax does not violate Article 15]". Bisset (2013) also finds that no in-depth analysis was provided for the decision of the Belgian Council of State. In light of this criticism, and because the majority of cases came to a similar conclusion about the non-violation of Article 15, the Zaventem result can rather be seen as an exception. It can therefore be assumed that a ticket tax on passenger departures should be safe from successful legal challenges with respect to Chicago Convention Article 15. This means that levying a ticket tax, without considering its features in relation to Article 15, is legally possible.

Second, the next most common aspect of the ticket tax to be challenged was the exemption of transfer and transit passengers (Irish and Dutch cases). The exemption was found to justifiably avoid double taxation and fall within the logic of the relevant tax system (see Section 3.3.4). This is not a surprising conclusion since the Commission had recommended the exclusion of transfer and transit passengers from European flight taxes in a 2005 staff working paper. An exemption of transfer and transit passengers should therefore withstand legal challenges.

Third, the differentiation of the ticket tax according to different distance groups is possible if this takes into account the workings of the EU's internal market. The Irish case (Section 3.4) revealed that this differentiation can be challenged successfully if airlines in the EU are perceived to receive unlawful State aid. In particular the Irish tax applied different tax-rates to airports within the EU. This is in contrast to the German, Dutch and UK taxes which were differentiated on the basis of distance but ensured that all EU destinations were within the same distance group. The Irish tax was consequently amended to a flat-rate, however another option could have been to follow the differentiation of the Netherlands, UK and Germany with a lower rate for EU flights, and a higher rate for flights outside of the EU.

Fourth, the German case showed that the ticket tax was not directly or indirectly linked to fuel consumption. A tax on fuel aboard a flight entering a country with a ticket tax is expressly prohibited by Article 24 of the Chicago Convention, while many bilateral air service agreements further restrict any kind of tax on fuel. The court found that the tax is not a duty on fuel used in international air traffic since it is neither directly or indirectly linked to the fuel introduced to the customs territory aboard an aircraft or contained on board when it exits the territory.

This analysis shows that an aviation ticket tax can withstand legal challenges if it is not linked to fuel consumption, if it exempts transfer and transit passengers, and if it does not differentiate rates within the EU. Nor can it be successfully challenged for being a tax.

Table 2 - Summary of court cases analysed in this report

Country with ticket tax	Belgium	UK	The Netherlands	Ireland	Germany
Plaintiff	B.A.R. Belgium, Sabena and Lufthansa	Federation of Tour Operators	Maastricht Aachen Airport and Ryanair	Ryanair	American Airlines
Legal grounds opposition ticket tax	Art. 15 Chicago Convention	Art. 15 Chicago Convention, First Protocol (A1P1) to the European Convention on Human Rights, Art. 49 of the European Treaty	Art.15 Chicago Convention; State aid due to exemption transfer passengers benefitting transfer hubs like Schiphol	State aid due to tax differentiation benefitting Irish airlines	Numerous violations of Chicago Convention, EU-USA Open Skies Agreement and Friendship, Commerce and Navigation Treaty
Result of case	Ticket tax abolished	All complaints dismissed	All complaints dismissed	Imposition of ticket tax legal as long as does not violate EU competition rules by differentiating between EU destinations	All complaints dismissed
Part of tax amended	Abolished	None	None	Distance element was removed	None
Tax status	Abolished	In place	Abolished	Set to Zero	In place

5 Legality of per flight taxes

In this section we investigate the legality of levying taxes on a per flight basis. A per flight tax based on the maximum take-off weight and distance flown (preferred by the UK government of 2008 (Seely, 2012b) incentivises airlines to maximise the number of passengers and freight transported, thereby better targeting emissions. Other advantages relative to a ticket tax are that it broadens the tax base and the scope of targeted emissions since transit and transfer passengers and freight flights can be taxed, and that other environmental factors such as aircraft noise can also be included as a component in the tax.

Per flight taxes have however not yet been introduced anywhere, and have therefore not been legally challenged. Still, the legality of this tax has been mentioned in proposals by the UK government to reform the Air Passenger Duty to a per flight tax, and indirectly in the judgement on the German Air Travel Tax.

5.1 Air Passenger Duty reform

In 2007 the UK's Pre-Budget Report committed to replacing the APD with a duty payable per flight (HM Treasury , 2007). In the following Pre-Budget Report in 2008 this plan was shelved and the APD was to be reformed to include more distance bands (HM Treasury, 2008).
The main reasons given for this decision were the foreseen disruption and costs to transitioning to a new tax (Seely, 2012c) and the risk of the UK losing its status as a transit hub for international flights (IFS, 2010). Clearly, no legal obstacles were mentioned.

In 2011 there was again a proposal to reform the UK's APD from a ticket tax to a per flight tax, with the goal of improving the incentive of the tax to cut carbon emissions (Seely, 2018). In the government's later consultation report on this proposed change it stated the following:

> "Aviation is a global industry bound by international agreements. The UK is a signatory to the 1944 ICAO Chicago Convention and has Air Service Agreements (ASAs) with over 150 countries. Many stakeholders have expressed concerns about the legality and feasibility of introducing a per flight duty under current international rules. The Government wishes to proceed with consensus in this area and will not introduce a per flight duty in place of APD at the present time, but nevertheless will continue working with our international partners to build understanding and support for this approach in the future." (HM Treasury, 2011)

Former Chancellor Osborne also stated the following in 2011 during a parliamentary debate: "Let me be straight with the House: we had hoped that we could replace the per passenger tax with a per flight tax. We have tried every possible option, but have reluctantly had to accept that all are currently illegal under international law. So we will work with others to try to get that law changed." (Parliament UK, 2011)

Unfortunately the exact legal reasons for this decision are not publicly known. Seely (2012c) refers to the decision made in 2008 and argues that there are "…legal restrictions on the direct or indirect taxation of the quantity of fuel used on international flights" owing to the Chicago Convention. A per flight tax correlates better with CO_2 emissions and fuel consumption than a ticket tax, an advantage with respect to incentivising emission reductions, but this may cause legal issues in terms of Article 24 of the Chicago Convention.

The reference to Article 24 of the Chicago Convention as a legal obstacle in introducing a per-flight tax probably refers to its first sentence, which reads: “Aircraft on a flight to, from, or across the territory of another contracting State shall be admitted temporarily free of duty, subject to the customs regulations of the State”.

In the Federation of Tour Operators case (detailed in Section 3.2 of this report), part of the judgment turned on whether “taxes” were in the prohibition in Article 15 of the Chicago Convention which states: “No fees, dues or other charges shall be imposed by any contracting State in respect solely of the right of transit over or entry into or exit from its territory of any aircraft of a contracting State or persons or property thereon”.
The claimants in that case argued that Article 15 includes taxes like the UK APD and so were prohibited. However, the judge dismissed this claim on the basis that the decision to omit the word “taxes” in Article 15 implies that “dues” do not carry a meaning which includes “taxes”. Therefore, it could be supposed that in analysing Article 24 which prohibits only “duty” on aircraft, “taxes” that were imposed on the basis of take-off weight and distance flown would not violate Article 24. This is because “duty” refers to a type of customs tax and indeed, in reading the full sentence in Article 24 that is clear: “Aircraft on a flight to, from, or across the territory of another contracting State shall be admitted temporarily free of duty, subject to the customs regulations of the State”, where customs are specifically referred to. If the drafters of the Chicago Convention had intended to ban all taxes, duties and charges on aircraft then that language would have been included.
As only “duty” was included and only “temporarily” but with the proviso that the aircraft must comply with all the customs regulations of the State, Article 24 must be interpreted as another anti-discrimination provision to ensure that foreign aircraft do not face duties which do not apply to domestic aircraft. There would be no discrimination in the case of a fee levied on the basis of maximum take-off weight and distance flown and therefore no reason to suppose such a tax would fall foul of Article 24.

5.2 Judgement on German Air Travel tax

As was described in Section 3.5, the Fiscal Court of Hesse judged on a number of complaints made by American Airlines about the German Air Travel Tax, one of which was that the tax violated Article 24 of the Chicago Convention. The court found that the tax was not in violation of this article because it is not a duty on fuel used in international air traffic since it is neither directly nor indirectly linked to the fuel introduced to the customs territory aboard an aircraft or contained on board when it exits the territory.

This may mean that a per flight tax which correlates with fuel consumption could be in violation of this article. However, since Article 24 refers to fuel on board when the aircraft arrives in a jurisdiction, a more thorough legal analysis would be required to draw a firm conclusion.

The Court also dismissed American Airlines claim based on Article 11 of the EU-US Open Skies Agreement that the German air travel tax was an unlawful charge on fuel used in international aviation. Article 11 states;

> Customs duties and charges
> 1. ***On arriving in the territory of one Party***, aircraft operated in international air transportation by the airlines of the other Party, their regular equipment, ground equipment, fuel, lubricants, consumable technical supplies, spare parts (including engines), aircraft stores (including but not limited to such items of food, beverages and liquor, tobacco and other products destined for sale to or use by passengers in limited quantities during flight), and other items intended for or used solely in connection with the operation or servicing of aircraft engaged in international air transportation shall be exempt, on the basis of reciprocity, ***from all import restrictions, property taxes and capital levies, customs duties, excise taxes, and similar fees and charges*** that are (a) imposed by the national authorities or the European Community, and (b) not based on the cost of services provided, provided that such equipment and supplies remain on board the aircraft.

This article exempts aircraft on a reciprocal basis *from all import restrictions, property taxes and capital levies, customs duties, excise taxes, and similar fees and charges* which leaves open the question as to whether an environmental tax such as a per flight tax is covered by the above provision which in any case only applies to arriving aircraft. The 2007 Protocol to the Open Skies Agreement also deals with environmental measures being introduced and would also need to be taken into account.

5.3 Conclusion

Per flight taxes provide better emission reduction incentives for airlines than ticket taxes and could drive airlines to maximise the number of passengers and freight tonnage transported per flight. So far per flight taxes have not been introduced. One of the reasons for this is that such an introduction may lead to legal issues.

Little is however known about the possible legal obstacles to introducing a per flight tax, mainly because this has not been tested in a court of law. The judgement of the Court of Hesse and the UK government's statements in 2011 seem to point towards legal issues arising if taxes like ticket taxes or per flight taxes is directly or indirectly linked to fuel consumption. However, the decision in the UK APD case shows that Article 24 of the Chicago Convention prohibits only customs duties and not general environmental taxes and therefore a per flight tax would not be prohibited on those grounds. This issue requires more legal analysis.

6 Possibilities to internalise climate externalities in aviation ticket tax

6.1 Introduction

There are currently two existing policy instruments that internalise the external climate impacts of aviation, the EU ETS and ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The former requires airlines to surrender EU Allowances for emissions on intra-EEA flights; the latter will require airlines from 2020 onward to surrender allowances for the sector's emissions above the 2020 level. Both only internalise a share of the external climate costs. To the extent that the EU allowance price reflects the social cost of carbon, the EU ETS internalises the CO_2 costs of intra-EEA flights, assuming that airlines pass on the opportunity costs of freely allocated allowances as economic theory would suggest. However, the EU ETS does not internalise the non-CO_2 climate externalities and most research shows that the social cost of carbon is much higher than the EUA price due to over-allocation (CE Delft, 2018).

CORSIA[13] will internalise the external costs of the flights within the system to a lesser extent than the EU ETS because for each unit of CO_2 emitted, only a share has to be offset. Hence the marginal cost increase due to CORSIA is smaller than the offset price (which may be lower than the social cost of carbon). Moreover, CORSIA only addresses the CO_2 impacts, just like the EU ETS.

One way to internalise external costs is to differentiate charges or taxes on the basis of environmental impacts. In the aviation sector, this is common practice in landing fees, which many airports differentiate according to the noise level of the aircraft or to the time of day of landing or take-off. Some airports also differentiate charges according to LTO NO_x emissions of aircraft. This section explores whether aviation ticket taxes can be differentiated on the basis of climate externalities.

The first issue that will be analysed is the monetary value of the climate externalities of aviation (Section 5.2). second, several designs of aviation ticket taxes will be developed which have the potential to internalise a share or all of the climate externalities (Section 5.3).

6.2 Estimations of the external climate costs of aviation

The external costs of the climate impacts of aviation are the largest category of external costs for this transport mode (CE Delft, INFRAS & Fraunhofer ISI, 2011). Estimates of the external costs crucially depend on two factors: the social costs of carbon and the GWP of non-CO_2 climate impacts.

[13] The Carbon Offsetting and Reduction Scheme for International Aviation, which aspires to make the growth in airline emissions carbon-neutral from 2020 onwards.

We use three estimates of the social costs of carbon, in line with CE Delft 2014: € 10, € 78 and € 155. The low value was chosen to reflect the EU Allowance prices. The higher values are the high and medium estimates of carbon prices that would be needed to stay in line with a 2 degrees aim.

The sum of the global warming potential (GWP) of all climate-relevant emissions of aviation is assumed to be 1.3 times the GWP of aviation CO_2, in line with (Lee, et al., 2010).[14]

The total climate externality has been scaled to the EU28 level on the basis of fuel sales.

Table 3 presents the external climate costs associated with flights departing from EU airports in 2015. They range from € 1.3 billion to € 19 billion, depending on the assumption of the CO_2 price. This translates into € 2, 14 or 26 per passenger on average (again, depending on the damage costs of CO_2). Of course, passengers flying long distances or in relatively inefficient aircraft create relatively more externalities than passengers flying short distances on efficient aircraft.

Table 3 - External climate costs of aviation in the EU28, 2015

	CO_2 price		
	Low	Medium	High
CO_2 price (EUR/ton)	10	78	155
Non-CO_2 multiplier	1.3	1.3	1.3
External climate costs aviation, (million €)	1,311	10,173	19,035
External climate costs aviation, (€/pax)	2	14	26

Source: This report on the basis of CE Delft, 2014.

6.3 Possible designs of aviation ticket taxes that internalise external climate costs

This section presents four possible designs of aviation ticket taxes that internalise external climate costs.

The following considerations have been used in drafting the list:

1. Apart from CO_2 emissions, aviation has other climate impacts which include:
   - emissions of NO_x (overall warming effect);
   - formation of contrails and induced cirrus clouds (overall warming effect);
   - emissions of sulphate particles (cooling effect).

   Of these, the emissions of NO_x have the largest impact in terms of RF.

2. The fuel efficiency of an aircraft, and hence its CO_2 emissions, depends not only on the aircraft type but also on the distance flown (because taking off requires much fuel and because fuel is needed to carry fuel). Different aircraft types are optimised for flying different distances. Hence, any ranking of aircraft according to fuel-efficiency is problematic (CE Delft, 2008).

[14] This value excludes induced cirrus cloudiness, which is the most uncertain impact and also one that is not directly related to emissions or fuel use but to perturbances of the atmosphere.

3. Aviation taxes may be legally challenged when there is a 'direct and inseverable link between the quantity of fuel held or consumed by an aircraft and the pecuniary burden on the aircraft's operator' (ECJ, 2011). Note that the ECJ ruled that the EU ETS did not create such a link because airlines receive free allowances and because the price of allowances varies.

Consideration 1 suggests that the differentiation should be on the basis of CO_2 or NO_x emissions of aircraft. Because of consideration 2, we do not consider it to be possible to differentiate the tax on the basis of the fuel-efficiency of aircraft. Because of consideration 3, a fuel tax is ruled out.

Still, an inclusion of a climate change element in an aviation ticket tax would not have an inseverable link with the quantity of fuel used if the aviation ticket tax is differentiated according to the life cycle carbon emissions of the fuels used. This would mean that passengers on airlines which use sustainable low-carbon fuels would have a lower tax rate.

Another way to include a climate change element in an aviation ticket tax would be to differentiate it according to distance. While this may not be legally permissible for intra-EU flights, there appear to be no objections against setting multiple distance bands for flights to non-EU destinations.

Inclusion of a NO_x element in an aviation ticket tax would never have an inseverable link with the quantity of fuel used because the amount of NO_x emitted depends on the type of engine as well as on the fuel flow rate.

One of the ways in which a NO_x element could be included in an aviation ticket tax is to differentiate the tax on the basis of certified LTO NO_x emissions of the aircraft engines. LTO NO_x emissions are shown to be well correlated with cruise NO_x emissions, which have a climate impact (CE Delft, 2008). Such a differentiation would have the advantage that it only depends on one parameter, but the disadvantage that the differentiation does not take into account the distance flown, even though the distance, or actually the amount of fuel, determines the amount of NO_x emitted.

Another way to include a NO_x element would be to calculate a part of the tax as an LTO NO_x charge with a distance factor, which is one of the best options to internalise the climate impact of cruise NO_x according to CE Delft et al. (2008).

The next section discusses how a carbon or a NO_x element can be included in an aviation ticket tax.

6.3.1 Possible designs of aviation ticket taxes that include the external costs of CO_2 emissions

Differentiation of the aviation ticket tax according to the carbon emissions of the fuel used

An aviation ticket tax can be differentiated according to the life cycle carbon emissions of the fuels used. It would then no longer have an inseverable link to the amount of fuel used for at least two reasons. First, aviation ticket taxes are generally only levied on origin/destination (OD) passengers and not on transfer passengers. This means that the revenues of the tax vary with the share of OD passengers and are therefore not directly linked to fuel consumption. This argument is valid for all aviation ticket taxes. The second argument is specific to a tax that is differentiated on the basis of the life cycle carbon emissions. Because fuels have different life cycle carbon emissions, the tax is not differentiated on the amount of fuel used but rather on the quality of the fuel.

The tax could be designed as follows:
- A differentiated tax would be levied on OD passengers.
- Since the tax will be levied upon the purchase of a ticket, when the fuel that the aircraft will use may not be known, the differentiation could be based on the average lifecycle carbon emissions of fuels used by the airline in the year (or another time period) before the sale of the ticket.
- The differentiation could be designed as a discount on the tax rate for airlines that have lower average lifecycle carbon emissions of fuels used than the emissions of fossil fuels.
- The calculation of the average lifecycle carbon emissions of fuels used could be based on the share of advanced biofuels or other sustainable low carbon fuels, which airlines might monitor under their EU ETS or potentially future CORSIA obligations. These fuels could either be assigned a zero emission factor (as in the EU ETS) or a higher one. The higher value can be based on information provided by the supplier, who is obliged to calculate the lifecycle emissions under the FQD.

As an example, the tax level on a flight from Frankfurt to Barcelona could be set as follows: if the normal tax rate is set at € 14 per one-way flight, based on the average climate impact per passenger (see Table 3). Suppose also that 75% of the impact is related to carbon (the inverse of the non-CO_2 multiplier in Table 3), so that the CO_2 element in the tax amounts to € 10.8. When the airline uses 30% sustainable low carbon fuels which have 80% lower lifecycle CO_2 emissions than fossil fuel, the CO_2 element is reduced to € 8.2 so that the new tax rate is € 11.4.

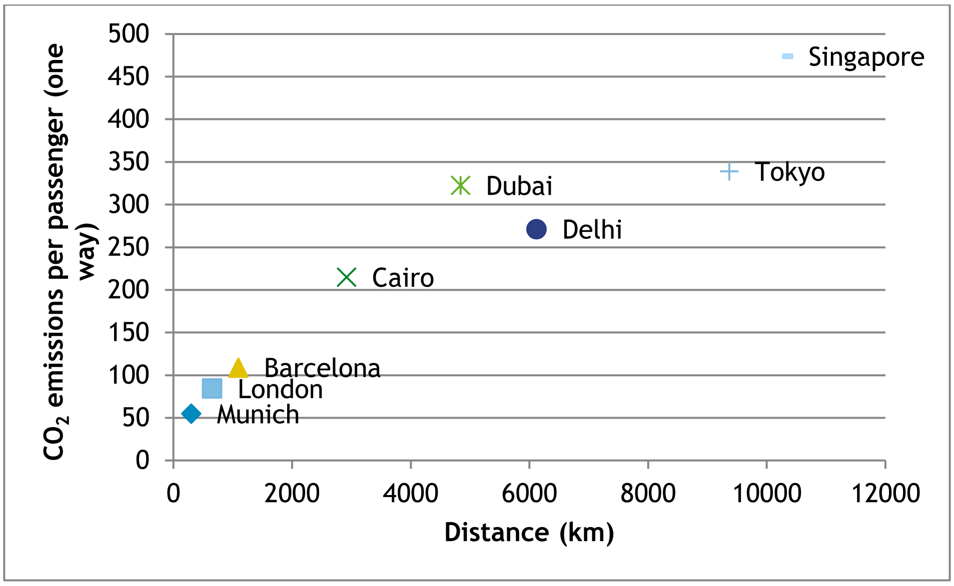
Such a tax would act as an incentive to use fuels with lower life cycle carbon emissions than fossil jetfuel.

Differentiation according to distance flown

An aviation ticket can be differentiated according to distance for flights to destinations outside the EU (a differentiation of tax rates on intra-EU flights may be problematic legally, as concluded in Chapter 4).

Flight distance is roughly correlated with emissions, as shown in. The correlation is not perfect due to the use of different aircraft types, amongst others.

Figure 1 - Emissions on flights from Frankfurt



Source: ICAO Carbon Emissions Calculator.

In Figure 1, flights to non-EU destinations have CO_2 emissions ranging from 215 kg/pax to 474 kg/pax for a one-way trip. It would make sense to set several distance bands to account for the fact that longer flights may have a climate impact that is more than twice as high as shorter flights.

The tax could be designed as follows:
- A differentiated tax would be levied on OD passengers.
- The tax would have one rate for intra-EU flights, and distance-dependent rates for flights to non-EU destinations, e.g. in bands of 1,000 km.
- Based on the limited number of observations in Figure 1, the average increase in emissions per 1,000 km amounts to 30 kg CO_2. Note that this is only a rough estimate and the correlation between distance and emissions should be analysed in more detail when choosing to introduce a differentiated tax.
- Assuming the central carbon price of Table 3, the tax rate should increase by approximately € 2,30 per 1,000 km to account for the additional carbon emissions.

6.3.2 Possible designs of aviation ticket taxes that include the external costs of NO_x emissions

Differentiation of the aviation ticket tax on the basis of certified LTO NO_x emissions

An aviation ticket tax can be differentiated on the basis of certified LTO NO_x emissions. This would incentivise air lines to buy engines with lower LTO NO_x emissions, but since LTO NO_x emissions and cruise NO_x emissions seem to be aligned in most current technology cases, policies that would reduce LTO NO_x would also reduce cruise NO_x (CE Delft, 2008).

The tax could be designed as follows:
- A differentiated tax would be levied on OD passengers.
- Using the non-CO_2 multiplier in Table 3, 23% of the tax[15] would be attributed to NO_x, and this share would be differentiated by multiplying it with the normalised LTO NO_x emissions per seat of the aircraft.
- CE Delft (2008) shows that the normalised values range from 0.04 to 1.00 for single-aisle aircraft with a mean value of 0.17.

Addition of an LTO NO_x charge with a distance factor to an aviation ticket tax

As a way to address the climate impacts of NO_x emissions of aircraft, CE Delft et al. (2008) proposes a charge based on the certified LTO NO_x emissions of the engines of the aircraft and the distance flown. Mathematically, the charge would be:

$$C_{i,j} = \alpha_{ClimNOx} \times \beta_i \times LTONOx_i \times D_j$$

Where:
- $C_{i,j}$ is the charge for aircraft i on mission j in €.
- $\alpha_{ClimNOx}$ is the charge level in € per unit of mass, set at the monetary value of the climate impact of NO_x (in €).
- β_i is the co-efficient of correlation between LTO NO_x emissions times a distance factor and cruise NO_x emissions of aircraft i (per unit of distance).
- LTO NO_{xi} is the mass of the LTO NO_x emissions of aircraft i (in mass units).
- D_j is the distance of mission j (in distance units).

All of these parameters can be quantified, although some of them may still have a considerable level of uncertainty:
- $\alpha_{ClimNOx}$ could be related to the CO_2 price by taking the global warming potential over a 100-year time horizon (GWP100) of aviation NO_x emissions. GWP100 is commonly used in climate policy to calculate the CO_2-equivalence of emissions of other compounds. Although there is still debate about the GWP100 of aviation NO_x, Lee et al. (2010) reports that it is likely be in the range between -2 and 63.
- ß has been calculated for 10 different aircraft types in CE Delft et al. (2008), where it ranged from 0.04 to 0.08.
- LTO NO_x emissions can be taken from the ICAO Aircraft Engine Emissions Databank (ICAO, 2018).
- D_j can either be taken as the great circle distance between the airport of departure and the airport of arrival, or aligned with distance bands of the aviation ticket tax.

In this case, rather than differentiating the aviation ticket tax, a charge on top of the tax base rate would make more sense because a differentiation would require calculating an average impact which could be cumbersome.

[15] The non-CO_2 multiplier is 1.3, of which 1 is CO_2 and 0.3 non-CO_2. 0.3/1.3 = 23%.

7 Conclusions

This report set out to analyse under which conditions aviation ticket taxes would hold up in legal proceedings and how a climate change element could be introduced as a way to internalise the external climate costs of aviation.

While many aviation ticket taxes have been challenged in legal proceedings, most taxes have been judged to be in conformity with the law. In particular, most judgements agree that:
- taxation of aviation activities per se is not prohibited by either the Chicago Convention or Bilateral Air Service Agreements;
- transfer and transit passengers may be exempted in order to avoid double taxation; this is not unlawful state aid;
- differentiation of taxes with regards to distance is permissible, but the differentiation should not interfere with the working of the internal market;
- an aviation ticket tax is not a fuel tax and hence restrictions on of prohibitions of fuel taxes do not apply.

Consequently, an aviation ticket tax can withstand legal challenges if it is not linked to fuel consumption and if it does not differentiate rates within the EU, while it may exempt transfer and transit passengers.

Per flight taxes provide better emission reduction incentives for airlines than ticket taxes and could drive airlines to maximise the number of passengers and freight tonnage transported per flight. So far per flight taxes have not been introduced. As a consequence, little is known about the possible legal obstacles to introducing a per flight tax, mainly because this has not been tested in a court of law.

The environmental impacts of aviation taxes as well as the efficiency of the transport system can be improved by internalising the external costs of aviation through differentiation of the tax.

Four ways to internalise climate impacts of aviation via taxes are legally feasible.

1. An aviation tax can be differentiated on the basis of the average lifecycle emissions of fuels that the airline has used in a previous period. This would be a way to internalise external effects of CO_2 emissions. Passengers flying with airlines that have exclusively used fossil fuels would pay a higher tax rate than passengers flying with airlines that have used a share of sustainable low carbon fuels. Because the tax would be levied on the carbon content of the fuel and not on the amount of fuel, and because transfer passengers would be exempted, the tax cannot be considered to constitute a fuel tax.

2. An aviation tax can differentiated on the basis of distance to the destination, which would also be a way to internalise the external impacts of CO_2 emissions. Currently, most taxes have two rates, one for intra-EU destinations and one for destinations further away, which does not take into account that a flight to a relatively nearby non-EU destination may cause half or less of the CO_2 emissions than a flight to a faraway destination. By increasing the number of distance bands, this variation in external impacts may be internalised.

3. An aviation tax can be differentiated on the basis of certified NO_x emissions during landing and take-off (called LTO NO_x emissions). This would be a way to internalise the external impacts of NO_x emissions, both in the LTO phase and in the cruise phase, where NO_x emissions have a climate impact.

4. Fourth, a share of the aviation tax could be replaced by a NO_x climate impact charge related to the distance flown and the LTO NO_x emissions of the aircraft.

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A Relevant Chicago Convention Articles

A.1 Chicago Convention Article 15

"Every airport in a contracting State which is open to public use by its national aircraft shall likewise, subject to the provisions of Article 68, be open under uniform conditions to the aircraft of all the other contracting States. The like uniform conditions shall apply to the use, by aircraft of every contracting State, of all air navigation facilities, including radio and meteorological services, which may be provided for public use for the safety and expedition of air navigation.

Any charges that may be imposed or permitted to be imposed by a contracting State for the use of such airports and air navigation facilities by the aircraft of any other contracting State shall not be higher:

a As to aircraft not engaged in scheduled international air services, than those that would be paid by its national aircraft of the same class engaged in similar operations, and

b As to aircraft engaged in scheduled international air service, than those that would be paid by its national aircraft engaged in similar international air services.

All such charges shall be published and communicated to the International Civil Aviation Organization: provided that, upon representation by an interested contracting State, the charges imposed for the use of airports and other facilities shall be subject to review by the Council, which shall report and make recommendations thereon for the consideration of the State or States concerned. No fees, dues or other charges shall be imposed by any contracting State in respect solely of the right of transit over or entry into or exit from its territory of any aircraft of a contracting State or persons or property thereon."

A.2 Chicago Convention Article 24

"a. Aircraft on a flight to, from, or across the territory of another contracting State shall be admitted temporarily free of duty, subject to the customs regulations of the State. Fuel, lubricating oils, spare parts, regular equipment and aircraft stores on board an aircraft of a contracting State, on arrival in the territory of another contracting State and retained on board on leaving the territory of that State shall be exempt from customs duty, inspection fees or similar national or local duties and charges. This exemption shall not apply to any quantities or articles unloaded, except in accordance with the customs regulations of the State, which may require that they shall be kept under customs supervision.

b. Spare parts and equipment imported into the territory of a contracting State for incorporation in or use on an aircraft of another contracting State engaged in international air navigation shall be admitted free of customs duty, subject to compliance with the regulations of the State concerned, which may provide that the articles shall be kept under customs supervision and control."