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Developing a Sustainable Framework for UK Aviation: Scoping Document - Consultation deadline 20th October 2011

Thank you for the opportunity to respond to this consultation. This response is submitted by the Local Authorities' Aircraft Noise Council (LAANC) on behalf of two dozen Local Councils comprising Boroughs, Unitary Boroughs, London Boroughs, County and Parish Councils serving a wide area around Heathrow Airport. The Constitution of LAANC covers environmental issues as well as noise and represents a very large community many of whom have direct contacts with Heathrow.

The following responses were discussed and endorsed at the last meeting of LAANC Executive Committee on 14th October 2011.

Our comments are referenced to the relevant section in the consultation. So far as is possible our comments respond to the questions set out on the proforma response attached as Appendix 1.

As requested in the consultation, evidence in support of the council's comments is also attached. These are appended as Appendices 2-5. For the ease of reference a list of Contents is supplied.

LAANC fully supports the policy of the Coalition Government for no further expansion at Heathrow either by means of an additional runway capacity, removal of the current 480,000 air transport movements (atms) cap or by the introduction of new operations such as mixed mode. We believe that these policy statements should be a cornerstone of the new Aviation Framework.

LAANC also acknowledges that Heathrow Airport contributes significantly to the economy of south west London as a whole. However, Heathrow operations impact significantly over a wide area of London and the Home Counties. Despite promises made during the Heathrow Terminal 5 public inquiry, the reality is that little progress has been made by the airport operator over the last 10 years to secure improvements in key areas. These are air quality, noise, congestion on road networks and public transport infrastructure.

The previous government failed to address the need to update social surveys and assessment techniques which has traditionally been used to underpin policy in relation to aircraft noise. The result is now that much of the UK scientific data on this subject are now out of calibration, being at variance with more recent studies that have been undertaken in other EU states.

LAANC supports the Government's aim to make airports better not bigger. LAANC believes this is a sensible approach particularly as the evidence is that it cannot be assumed (if the UK is to meet Carbon reduction targets) that UK aviation can continue to grow unrestrained. LAANC has commissioned its own review of climate change and the results of this study confirm this view. We trust you find our comments useful in regard to informing the development of the Sustainable Aviation Framework.

Cllr Malcolm Beer

Malcolm Beer

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The Local Authorities Aircraft Noise Council Response to Sustainable Aviation Framework

List of Appendices

Appendix 1 - Proforma Response Form

The aviation sector	
5.1 How does the aviation sector as a whole benefit the UK? Please consider the whole range of aviation activities including, for example, air freight, General Aviation and aerospace.	LAANC agrees that the aviation sector is an important source of employment and productivity in the UK. However caution needs to be applied in so far as the overall activity of the sector has led to the rapid expansion of foreign leisure flying from the UK. This expansion has come at a price to both the UK economy and to the environment.
5.2 What do you consider to be the aviation sector's most important contributions to economic growth and social well-being?	Employment in its widest sense - to include the development of aviation support services plus movement of high value freight both imports and exports. However these contributions do not appear to be any more important than those from other UK industries that provide goods and services. It would therefore seem wrong to praise the aviation sector for stimulating the wider economy in the good years, or to blame it for the downturn in the bad. In both cases, aviation appears to simply reflect what happens generally in the economy. The fastest growing section of the aviation sector is leisure travel (from the UK). However in economic terms this runs at an annual deficit which is a drain on the country's resources. It results in an ever increasing financing requirement and cost to the Treasury. The current economic times highlight the question of whether this increasing deficit is sustainable. Whilst it is accepted that, people value overseas leisure travel as an expression of their well-being, it is likely that UK residents who take multiple leisure flights abroad do not associate with the true financial cost to the country as a whole. when taking such trips
5.3 Are some sub-sectors of aviation more important than others? If so, which and why?	LAANC believes that the business sector is more important for UK plc than Leisure. Business passengers fly in search or fulfilment of a business contract. Leisure passengers fly on their own initiative and whilst they may be important for the tourist sector, it needs to be remembered that the UK has run an ever-widening trade deficit in tourism since the 1960s. Consumer spending on tourism can be re-directed readily to the purchase of other goods and services, including UK-based

	leisure activities that do not require aviation intermediaries Business passengers are therefore likely to be more important for the UK economy as a whole in terms of positive contribution than are leisure passengers. LAANC believes that the fact that business passengers terminating at Heathrow account for approximately 20 per cent of all passengers understates their importance to the UK economy compared with the other categories of passenger. For the purposes of this question, it is suggested that the principle matter to be addressed is the extent to which Heathrow's finite capacity is now catering for leisure rather than business passengers Note: (Leisure passengers accounted for 46.6 million (71 per cent) of Heathrow's 65.8 patms. in 2009, with business passengers accounting for 19.2 million passengers (29 per cent). Source CAA
5.4 How do you think the global aviation sector will evolve in the medium and long term (twenty to fifty years)? What do you expect to be the most significant changes?	LAANC is of the view that growth will be led from Asia. The World Economic Forum predicts annual growth of 5% per annum for the next 10 years. Much of this growth will arise from future growth in the number of leisure passengers. In the UK most flights from Heathrow and other principal UK airports are for leisure purposes; including - the most recent phenomenon - frequent short-haul breaks by the same consumers within one year. It has been this growth in the number of leisure passengers that has caused existing capacity problems for UK airports and air space. Hitherto leisure passengers have been confined largely to the developed economies The developed economies are expected to continue to get richer and even faster growth rates are expected in the developing economies, against a background of continued growth in world population. The appetite for and affordability of leisure flying can therefore be expected to extend to many millions more consumers in future than at present.
5.5 How, and within what constraints, can aviation growth occur as technological developments and improved operating procedures reduce CO_2, pollutant emissions and noise impacts?	LAANC is firmly of the view that so far as Heathrow is concerned the airport has reached its maximum capacity so far as air transport movements are concerned and no further growth should be permitted. According to the evidence supplied by the Heathrow airport operator and accepted by the T5 inspector, there is around 30% unused passenger carrying capacity (current 65m pax - 90mpax max) Policy at Heathrow should therefore permit

	growth in the numbers of passengers per movement at Heathrow but not growth in the number of movements. At other UK airports future growth should be contingent on the aviation industry sharing the benefits of technology both with those immediately affected by its activity and the global environment. For example advances in noise performance of future aircraft types should be used to reduce noise burden on communities rather than simply providing a mechanism for growth. Where sustainable growth can be permitted, in future, it must include provision for sufficient headroom for resilience (as opposed to theoretical maximum operational capacity) within existing infrastructure at airports that are constrained by runway capacity. The trend for substantial growth in leisure travel will increasingly come up against the constraints of climate change and local impacts such as noise and pollution. Evidence at Appendix 5 of this response cautions that little reliance should currently be placed upon new technology satisfying the climate change constraints. The scope and timescale for future improvements - and whether the improvements are likely to be substantial or only marginal - are unclear. The risk is that reductions in adverse environmental impacts per aircraft will be offset, in part or in whole, by an increase in the total number of movements in order to accommodate future growth.
5.6 How should decision-makers address trade-offs or competing interests, where these occur both (a) between different aviation objectives, e.g. CO_2 emissions versus local noise reduction, and (b) between aviation and other sectors, e.g. airspace use versus renewable energy objectives, or the use of land for maintaining a viable network of smaller airfields versus housing development?	Locally noise continues to be the priority issue together with ensuring compliance with statutory air quality standards. However for the purposes of constructing a national framework for aviation LAANC considers that CO2 emissions will be the key driver for determining the extent to which future growth in aviation is sustainable. As regards conflict between different aviation objectives, this should be decided in favour of the option which offers the greatest benefit; and in favour of the more important objective where the benefits are equal. But in both cases compensating action should be taken where the "lost" option would result in a noticeable deterioration. For example, if improved aircraft design would reduce CO2 emissions to a marked degree but would increase noise emissions to a marked degree, the design should be adopted on the grounds that combating global warming is more important than reducing local noise impacts. But the increased noise per movement would have to be compensated for by tightening the

	overall noise restrictions at airports.
5.7 Should some aspects of UK aviation be considered to be of strategic national interest (e.g. certain airports, air traffic control)? If so, based on what criteria?	In view of the congestion at airports in south east England, there is a case for strategic management of the region's main airports (Heathrow, Gatwick, Stansted, Luton and London City) as well as "Near London" Airports such as Southend, Ashford, Biggin Hill and Manston The purpose should be to make the best use of the runways and their shared airspace as a common resource for the South East, while delivering real improvements to the local environments. Certain regulatory functions are international and the development of these need to be handled in the international forum by the Government and its agents - for example, climate change, noise pollution, safety, taxation and shared use of air space.
5.8 How might the cost of regulation to the aviation sector be reduced, while achieving the Government's objectives of promoting sustainable aviation, improving the passenger experience at airports, and maintaining high standards of safety and security for passengers and freight?	LAANC questions that regulation can be done on the cheap if it is to be effective. However there are options for paying for this. For example the costs could be paid for out of the VAT on aviation fuel – if VAT was collected.
International connectivity and hub airports	
5.9 How important are air transport connections – both international and domestic – to the UK at both national and regional levels?	It is important that the UK has good air transport connections to support business and commerce. Support and development to be prioritised for new routes in the far east. These routes should if need be have priority in terms of potential growth when considered along side the continued expansion of existing European routes by low cost carriers. The needs of business should be a key feature in the prioritising. The use of a connection in terms of volume of traffic and the type of traffic (e.g. business or leisure, transfer or point-to-point) are pertinent to the importance of the connection.
5.10 As long as people and goods can easily reach their desired destination from the UK, does it matter if they use a foreign rather than a UK hub airport?	No - we believe that most passengers would prefer to fly direct to their ultimate destination, if given the choice, as direct flights should be cheaper and quicker than transferring at an intermediate airport. Meeting that preference should be the objective of the aviation industry, particularly for popular destinations. Where transfers may be necessary for less popular destinations, it is not important whether the transfer takes place at a UK airport or an overseas airport.

	There are doubts about whether Heathrow meets either determinant now, still less in the future (see response to Question 5.13 below).
5.11 Are direct connections from the UK to some international destinations more important than others? If so, which and why?	Yes – those from the major trading capitals of the world.
5.12 How will the UK's connectivity needs change in the light of global developments in the medium and long term (twenty to fifty years)?	There will be a need for better connectivity from the regions of the UK direct to the major trading capitals of the world An increasing number of destinations will not require a UK hub airport to assemble passengers and will be able to support direct flights from the UK. Developing countries will build their own hubs to accept UK direct flights and then dissemble the passengers within the region
5.13 What are the benefits of maintaining a hub airport in the UK?	LAANC believes the benefits accrue mainly to the aviation industry in terms of retail sales from transit passengers. With respect to Heathrow passengers often face many hours of waiting in transit lounges for connecting flights and arguably would be better off by ignoring the transit flight promoted by the big airlines and opting for a direct flight. Consumer choice would be improved by being able to easily connect from European cities to regional UK airports direct. LAANC is also of the view that transfer traffic in its own right may be loss-making for the airlines themselves. This is because firstly fares have to be cut to compete with a direct service and to compensate for the inconvenience of changing at a hub. Secondly, costs are higher for airlines as they pay twice for landing fees and handling costs when passengers and baggage change aircraft.
5.14 How important are transfer and transit passengers to the UK economy?	LAANC does not believe transit and transfer passenger are important to the UK economy. This view is supported by an ex CEO of British Airways (Bob Ayling) who argued that the value to the economy from passengers stopping to catch flights to other destinations is minimal - little more than the price of a cup of coffee each in many cases. (Evening Standard of 16 June 2008) There are millions of pounds currently lost to the exchequer by failing to include transfer passengers in the UK APD tax. The decision not to include transfer passengers in the APD scheme is unfair on the rest of the travelling public.
5.15 What are the relative merits of a hub versus a point-to-point airport?	LAANC sees little merit in promoting hub airports over point to point operations. In the UK it appears that most commercially successful airlines have rejected the hub model and fly passengers direct to their destinations from a number of UK airports. LAANC believes the "Heathrow hub" model is

	being sustained from pressure by the airport operator which has in the past been incentivised by government to increase the number of flights and passengers it can move through Heathrow The lack of capacity at Heathrow means that the full benefits that are claimed for hub airports are not being realised. Heathrow is providing services to ever fewer destinations in order to serve the most popular destinations more frequently. An option would be to cut back on the frequency of services to the most popular destinations in order to serve emerging markets. Heathrow has become a second order hub increasingly serving the international transfer (leisure) market at the expense of local passengers. LAANC believes the best option for Heathrow would be to abandon its strategy in favour of more direct services, with the focus on meeting local demand. If coordinated effectively, the demand at all south east England's main airports (Heathrow, Gatwick, Stansted, Luton and London City) should be sufficient to ensure that most international destinations are served by at least one of those airports.
5.16 Would it be possible to establish a new 'virtual' hub airport in the UK with better connectivity between existing London and / or major regional airports? Could another UK airport take on a limited hub role? What would be the benefits and other impacts?	Yes - LAANC believes this potentially could result in better use of existing runway and airport provision to serve London. Gatwick has in the past served as a second hub airport for London. The provision of a dedicated rail transfer link between Gatwick and Heathrow should be investigated.
Regional connectivity and regional airports	
5.17 Can regional airports absorb some of the demand pressures from constrained airports in the south-east? What conditions would facilitate this?	LAANC believes this is an option, for new runways in the south east.. There is spare capacity at regional airports and there is a need to widen their passenger catchment areas and improve access. LAANC believes that airlines are unlikely to provide more direct services unless it is made clear in the framework that there will be no new runways in the southeast The exemption from air passenger duty also stimulates transfers to Heathrow and is a disincentive to more direct services from other regions.

5.18 What more can be done – and by whom – to encourage a switch from domestic air travel to rail?	There is room for improvements in rail services in general the net benefits of high speed" rail should be re-evaluated alongside those relating to improvements overall in range of rail services linking the south east with London and the rest of the UK Passengers on inter-city trains must be guaranteed seats. And the price of fares on inter-city aircraft and trains needs to be brought more in line with each other.
5.19 How could the benefits from any future high speed rail network be maximised for aviation?	Most benefit would accrue by ensuring that UK arrivals can transfer easily from the London system (and at a competitive price) to rail services direct to main midland and northern cities. This would potentially enable the aviation industry to promote new more profitable long haul networks.
5.20 How can regional airports and the aviation sector as a whole support the rebalancing of the economy across the UK?	Although LAANC believes this is probably better done by rail, recent evidence in the UK support a view that growth of regional airports can provide economic benefit locally apart from where the main existing economy is tourism. Each region of the UK needs to stand alone and develop its own transport network. Business organisations in other regions need to encourage airlines to provide more direct services - particularly to the more popular destinations with fewer connecting flights to the South East.
Making better use of existing capacity	
5.21 To what extent do UK airports meet the needs of their customers? How might those needs be more effectively met within existing capacity? What is the right balance between competition and regulation?	The needs of their neighbours are also important and should be considered as well as their customers. From a London perspective the needs of business customers would be better served if Heathrow concentrated on being the business airport for London, providing a world class service.
5.22 Can we extract more capacity out of the UK's existing airport infrastructure? Can we do this in a way which is environmentally acceptable? To what extent might demand management measures help achieve this?	At Heathrow. the capacity of the airport in terms of atms is fixed at 480,000. LAANC notes the commitment by the government not to overturn this cap and LAANC believes a statement confirming this should be one of the cornerstones of the new Aviation Framework. In 2010 Heathrow only used about 78% of estimated maximum carrying capacity. Currently load factors are around 74%.

	Reforming the slot allocation procedures at Heathrow would introduce competition and increase load factors. In order to make the best use of capacity at Heathrow, the new aviation framework needs to identify: • What the capacity of Heathrow is when operating in segregated mode and within the existing limits on the annual ATMs both as an annual figure and as an hourly figure during the sixteen-hour day. • How much of that capacity needs to be reserved - if any - to increase resilience at Heathrow (see response to Question 5.24 below) • What scope there is for increasing the number of passengers per ATM by: (a) fuller use of passenger capacity in existing aircraft; (b) introducing aircraft with larger passenger capacity; and (c) a combination of (a) and (b). • What scope there is for improving airline schedules and for better control on the arrival time of air traffic for spreading demand more evenly across each hour between 0700-2300 Air passenger duty should be extended to transfer passengers, particularly non-UK residents flying to Heathrow en-route between two overseas airports.
5.23 How can we support Heathrow's hub status within the constraints of its existing capacity? Can we do this in a way which is environmentally acceptable?	Heathrow should be encouraged to turn away from trying to compete with other European Hub Airports and focus on fewer flights, not more. Heathrow should turn away from the hub airport model towards flying passengers direct to their destinations. Instead of operating at 97% capacity, the airport should accept a lower operating capacity together with a proper market for trading slots. This would enable it to provide a better rather than bigger service. A transparent slot trading market would enable airlines holding slots which are difficult to work economically to cash in their historic investment at Heathrow and move to another airport. With fewer flights, Heathrow could focus on punctuality and service.
5.24 How important is increased resilience at the UK's major airports to reduce delays? How best could resilience be improved with existing capacity, e.g. how might trade-offs between existing capacity and resilience play a role in this?	At Heathrow TEAM (and TEDs) are short term ways of temporarily increasing resilience, but only with the unacceptable loss of alternation respite. They are therefore not supported in the long term. LAANC believes that in policy terms the best way forward at all the major UK airports. • fuller use of passenger capacity in existing aircraft; • introducing aircraft with larger passenger capacity;

	• revised schedules to spread peak demand into spare capacity at other times of the day; • better management of the arrival times of aircraft approaching Heathrow airspace.
5.25 Could resilience become an issue at regional airports? If so, how might this be avoided?	Every airport needs resilience so each should be kept within its capacity.
5.26 Could existing airport capacity be more efficiently used by changing the slot allocation process, for example, if the European Commission were to alter grandfather rights? If so, what process of slot allocation should replace it?	The continued practice or airlines running flights with nearly empty aircraft out of Heathrow demonstrates that something needs to be done. It is not clear whether a viable alternative to grandfather rights for the allocation of slots has been identified at national or European Union level. The European Union should be asked to consider what measures could be adopted in the short term to promote the most efficient use of slots allocated by grandfather rights, particularly the application of the "use it or lose it" rule and rules on the reallocation of surrendered slots under the EU regulation on slot allocations [1]. The "use it or lose it" rule focuses entirely on whether an aircraft movement takes place at the allotted slot time, regardless of the number of passengers. As a result, the best use is not being made of Heathrow's capacity because the airlines are not carrying the number of passengers per movement that was envisaged at the time of the Terminal Five Public Inquiry. Changes to the EU "use it or lose it" rules should be sought so as to promote the largest number of passengers in the smallest number of movements. The scope for this efficiency would be greatest on routes to the most popular destinations that have several arrivals and departures per day The slot reallocation rules should also be amended to include the setting of capacity and environmental conditions for reallocated slots. For example, if the slot is intended to serve the most popular destinations it could be a condition that the airline acquiring the slot will operate a higher number of passengers per movement (in absolute and relative terms) than the previous slot holder; and that the aircraft operating in the slot will operate to the lowest

[1] Council Regulation (EEC) No 95/93 of 18 January 1993 on common rules for the allocation of slots at Community airports

	gaseous and noise emission standards that are commercially available when the slot is reallocated. The extent to which airport operators could already male such amendments should be investigated. There could also be a requirement for those services to use aircraft with the largest passenger capacity and to fill the capacity in each movement to not less than a specified percentage. By increasing the number of passengers in each movement to the most popular destinations, this reform should reduce the number of daily movements to the most popular destinations and free up slots for new entrant airlines.
5.27 What provision, if any, should be made for regional access into congested airports?	New slots to be offered to direct regional connecting routes first.
5.28 What provision, if any, should be made for General and Business Aviation access into congested airports?	The level of access is a commercial decision but fees and charges should not unfairly work against GA and business aviation services that seek to provide direct connecting services.
5.29 What is the role of airspace design and air traffic management in making better use of existing capacity?	It is not clear whether and to what extent there is scope for improvement in South East England under existing arrangements. Aircraft should be discouraged from racing to arrive in London airspace ahead of schedule, which causes additional congestion in the stacking with no compensating benefit. A study of whether the duplication in the number of destinations served by London's five main airports (Heathrow, Gatwick, Stansted, Luton and London City) helps or hinders better use of airspace capacity. Where possible, the development of 4D technology should be supported to enable the best use to be made of capacity. However, the development of advanced aids should not solely be about maximising capacity. LAANC believes that new technology such as 4D PRNAV offers the possibility to reduce the noise burden of overflying by for example removing stacks around the London area.
Climate change impacts	LAANC has commissioned a review of climate change implications for UK aviation. This work is Appended to this response as Appendix 5
5.30 What do you consider to be the most significant impacts of aviation, including its non-CO_2 emissions, on climate change? How can these impacts best be addressed?	The effect on the upper atmosphere. This is still not recognised in the EU ETS scheme. LAANC believes that there must be an understanding that if the UK is to meet its carbon reduction goals aviation growth may need to be restrained. It is inequitable that the aviation industry should be permitted to expand unrestrained at the expense of every other UK industry and transport mode.
5.31 What role should aviation play relative	Use of alternative energy when on the ground.

to other sectors of the economy in reducing greenhouse gas emissions in the medium and long term?	Undertake all flights in a way that provides the optimum balance between noise and emissions – even if this means that journey times increase. Audit waste production and minimise
5.32 How effective do you believe the EU ETS will be in addressing the climate impacts of aviation? Should the UK consider unilateral measures in addition to the EU ETS? If so, what?	Hardly at all. LAANC believes that the ETS will simply allow "business as usual' for the airlines. The reason for this is that it has been estimated that that the cost to the aviation sector will be the equivalent of a one-cent per litre tax on aviation fuel which is currently untaxed in the EU. The effect on ticket prices is likely to be less than a 1 per cent increase in average fares across the EU. The UK should be pressing for an EU wide scheme for taxing aviation fuel. The EU currently sets minimum fuel duty rates within the community for road transport and it should do the same for aviation.
5.33 What is the best way to define and quantify the UK's share of the CO_2 emissions generated from international aviation?	Any flight which has an origin and destination in the UK should be part of the UK's CO2 emissions. The use of many different Carbon calculators is currently confusing for consumers. UK consumers should be able to compare a 'typical' flight over a given destination so as to see which aircraft / airlines will the best CO2 emissions irrespective of the efficiency of the plane or number of seats Provision of more accurate emissions data would enable passengers to choose the lowest carbon flight. Ready access to CO2 data has the potential to create a market for low-carbon flights, with airlines adopting more efficient planes with denser seating configurations. The UK government should seek through ICAO to ensure consistency between carbon calculators.
5.34 What is the potential for increased use of sustainable bio fuels in aviation and over what timeframe? What are the barriers to bringing this about?	Not great in our view as there is increasing concern over the use of finite land resources for bio fuel growth when there is unmet need in many parts of the world for use of the land for food growing. This subject is covered in depth as part of the LAANC review on Climate Change which forms Appendix 5 of this response.
5.35 What mechanisms could the Government use to increase the rate of uptake of sustainable bio fuels in the aviation sector? In particular, how can we accelerate the successful development of second generation bio fuels?	LAANC believes that the scope for the use of bio fuels is limited and that its development should be overseen internationally. LAANC does not support the development of bio fuels which require the use of farmland that could otherwise be used for food crop growing.
5.36 Which technologies (e.g. for aircraft and air traffic management) have the most potential to help reduce aviation's CO_2	Flight optimisation techniques - which will enable individual flights to be optimised for speed / height and emissions.

emissions (noting potential trade-offs with local environmental impacts)?	Development of a future airspace strategy (FAS) The use of turbo prop aircraft for flights within the EU
5.37 What more could be done to encourage the aviation industry to adopt new technology to reduce its climate change impacts?	The cost of fuel is already providing some incentive to do this. If fuel duty were to be levied on aviation fuel this would provide even greater incentive for airlines to adopt new technology
5.38 What more can the UK aviation industry do to reduce the climate change impact of its ground operations and surface access to and from the airport (which can also help reduce local environmental impacts)?	Maximise Ground Power and plug in air conditioning when aircraft are loading.
5.39 What scope is there to influence people and industry to make choices aimed at reducing aviation's climate change impacts, e.g. modal shift, alternatives to travel, better information for passengers, fuller planes, airspace management (which can also help reduce local environmental impacts)?	In the short term as slots become more difficult to obtain this will naturally have the effect of persuading airlines to upgrade their fleets to larger more modern aircraft, which will be more efficient both in terms of noise and emissions. Also please see our comments at section 5.33 above re: access to carbon calculators at point of sale.
Local impacts	
5.40 What do you consider to be the most significant impacts – positive and negative - of aviation for local communities? Can more be done to enhance and / or mitigate those impacts? If so, what and by whom?	The positive is the employment and everything that follows – housing and health. This is good, if not overwhelmed by negative impacts of noise, poor air quality, congestion, overheating of the economy, pressure on schools etc.
5.41 Do you think that current arrangements for local engagement on aviation issues, e.g. through airport consultative committees and the development of airport master plans, are effective? Could more be done to improve community engagement on issues such as noise and air quality? If so, what and by whom?	There is now an Noise Action Plan (NAP) for Heathrow and it is welcomed that the airport has set itself targets. However LAANC believes that the responsibility for production of future Noise Action Plans should be devolved to a consortium which includes local authorities as well as Defra and DfT. By Contrast the Heathrow Airport Master Plan is still draft form. LAANC believes this is a missed opportunity to set performance targets across a range of airport activities. These targets could be monitored over time not only by the HACC but also by an independent aviation regulator. At Heathrow, consultation with the operator is generally considered to be unsatisfactory; the latest consultation on "operational freedoms" particularly so. . LAANC believes that the HACC would be more effective if community representatives

	were invited to sit on the appointments panel for the HACC Chairman and officers On a purely local point the acoustics at the Heathrow HACC meetings are inadequate for the press/public area, so it does not encourage community engagement.
5.42 Do you think that current arrangements for ensuring sustainable surface access to and from airports, e.g. Airport Transport Forums and airport surface access strategies, are effective? Could more be done to improve surface access and reduce its environmental impacts? If so, what and by whom?	No. - more could be done to improve connectivity between London's airports. Research needs to be undertaken in order to formulate a master plan for better connecting airports in London and the south east to each other as well to the national rail network. Each of the London airports should be asked to provide their ideas for doing this.
5.43 What are your views on the idea of setting a 'noise envelope' within which aviation growth would be possible, as technology and operations reduce noise impacts per plane? What do you consider to be the advantages and disadvantages of such an approach?	Within the context of a framework for future growth LAANC rejects the idea of a conventional noise envelope at Heathrow, where the 480,000 Air Transport Movements (atms) cap must stay. There is therefore by definition no opportunity for growth in atms, at the airport - only a growth in passenger numbers should be considered. , At the Heathrow Terminal 5 inquiry, evidence was presented that demonstrated the need for a cap on numbers as well as compliance with noise contour levels. This evidence has been summarised and is attached at Appendix 2 to this response LAANC would however support the concept of a Reducing Noise Envelope (RNE). Our ideas for this are set out at Appendix 2 of this submission. Nationally LAANC believes that it is essential that the Government completes the ANASE study as part of its framework for sustainable aviation. Without robust dose response data it is difficult to see how a conventional Noise Envelope can be fairly implemented anywhere. This is particularly relevant as the evidence from recent EU and UK studies (ANASE) clearly indicates that annoyance from aircraft noise is now reported as levels lower than previously thought.
5.44 Is it better to minimise the total number of people affected by aircraft noise (e.g. through noise preferential routes) or to share the burden more evenly (e.g. through wider flight path dispersion) so that a greater number of people are affected by noise less frequently?	Yes - but burden sharing is only likely to be effective if combined with an absolute cap on numbers – such as the Heathrow 480,000 atm cap. Any distribution or spreading of noise should not result in an overall increase in noise (due to increases traffic)
5.45 What is the best way to encourage aircraft manufacturers and airlines to continue to strive to achieve further reductions in noise and air pollutant	Tax breaks for environmentally compliant craft. Deadlines - Heathrow NAP objective to encourage quietest .

emissions (notably particulate matter and NOx) through the implementation of new technology?	A Tax regime which discriminates against noisy engines and rewards for fuel efficient / quieter types.
5.46 What are the economic benefits of night flights? How should the economic benefits be assessed against social and environmental costs?	LAANC urges the Department should consider the findings of the recent CE Delft report (HACAN) which indicate that so far as London Heathrow is concerned there is no overall economic benefit to UK plc once the environmental and health disbenefits of night flights are properly considered.
5.47 How can the night flying regime be improved to deliver better outcomes for residents living close to airports and other stakeholders, including businesses that use night flights?	The only practicable option for delivering a better outcome is a night curfew at Heathrow. The night curfew should be designed to achieve a total ban on scheduled aircraft movements between the hours of 23::00 to - 07:00 save for medical and / or national emergencies
5.48 Should extended periods of respite from night noise be considered, even if this resulted in increased frequency of flights before or after those respite periods.	This will vary from airport to airport but at Heathrow there should no scheduled movements between 23:30 and 07:00. The average of 16 flights per night (nqp) plus typically 45 in the shoulder period that would be affected could be rescheduled to arrive after 07:00 hrs.

Appendix 2 Evidence - Noise Envelopes

Question / Paragraph 5.43
What are your views on the idea of setting a 'noise envelope' within which aviation growth would be possible, as technology and operations reduce noise impacts per plane? What do you consider to be the advantages and disadvantages of such an approach?

What follows are views on a daytime noise envelope. LAANC believes that night noise from Heathrow operations is currently unacceptable and is dealt with separately in this response. In any event the concept of a night time noise envelope has been previously considered and rejected by the DfT as part of a previous night flight consultations at Heathrow.

Policy Context for the Development of a Noise Envelope

The development a noise management mechanism should reflect international, national and local noise policies for example:

- The noise directive 49/2002/EC, indicating that noise levels should be reduced.
- The European Environment Agency document "Good practice guide on noise exposure and potential health effects", November 2010 advises that at a noise level of 55 L_{den} 27% of people are highly annoyed.
- WHO health related noise criteria are 50dB(A) daytime external (to protect the majority of peopled from being moderately annoyed).
- The UK's long term position on noise is outlined by the Noise Policy Statement for England 15 March 2010. It sets out the "long term vision of government noise policy, to promote good health and a good quality of life through the management of noise. "Ref defra website[2]

Historically the Government has taken the view that that the onset of community annoyance is at 57 dB $L_{Aeq,16hr}$. The Councils believe that this is no longer the case based on the work undertaken by the EEA and further demonstrated by the evidence presented on this matter (also appended as evidence to this response) by Mike Rickaby (LB Hillingdon).

Noise Envelope and Aviation Growth

Question 5.43 is predicated on allowing aviation growth to occur within a noise envelope. The Councils believe that Heathrow's operation exposes too many people to significant levels of daytime noise. Therefore technological improvements should benefit the community that surrounds Heathrow so that less people are exposed to such levels.

The overall aim of a conventional noise envelope within a framework for growth can only be to facilitate increases in numbers of atms. For reasons stated in our covering response this is not currently a proposition that the Councils can agree to.

Noise Envelope as a Mechanism for Improving the Noise Environment.

A noise envelope could however be employed as a mechanism to monitor and enforce an i**mprovement** in the daytime noise environment.

[2] http://www.defra.gov.uk/environment/quality/noise/npse/

In this context a model noise envelope system could be designed to:

- Reduce levels of air noise experienced by the community. Such improvements would be significant, continuous and have a trajectory towards the target noise levels set out in WHO guidance on Community Noise.
- Drive technological improvements e.g. silent aircraft initiative.
- Take into account changes in the aircraft fleet for example retirement of the nosiest types of aircraft.
- Be future proofed to ensure that any technological changes in other areas of aircraft design do not compromise improvements of noise performance[3].
- Have sanctions available if envelope is breached.
- Recognise the numbers of aircraft and the amount of noise individual aircraft make.
- Be meaningful i.e. not so great that it gives the industry a headroom "to pollute into".
- Provide an all encompassing monitoring tool for the BAA NAP.

Currently there is no consensus with regard to the onset of the effects of noise at lower levels. Opinions are somewhat polarised with the local authorities and community groups being of the opinion that greater numbers of people than is currently accepted are affected by both the level of aircraft noise and the numbers of flights that pass overhead.

What cannot be disputed is:

- Noise levels closer to the airport boundary are higher due to the proximity of the aircraft.
- That higher levels of noise produce greater levels of annoyance.

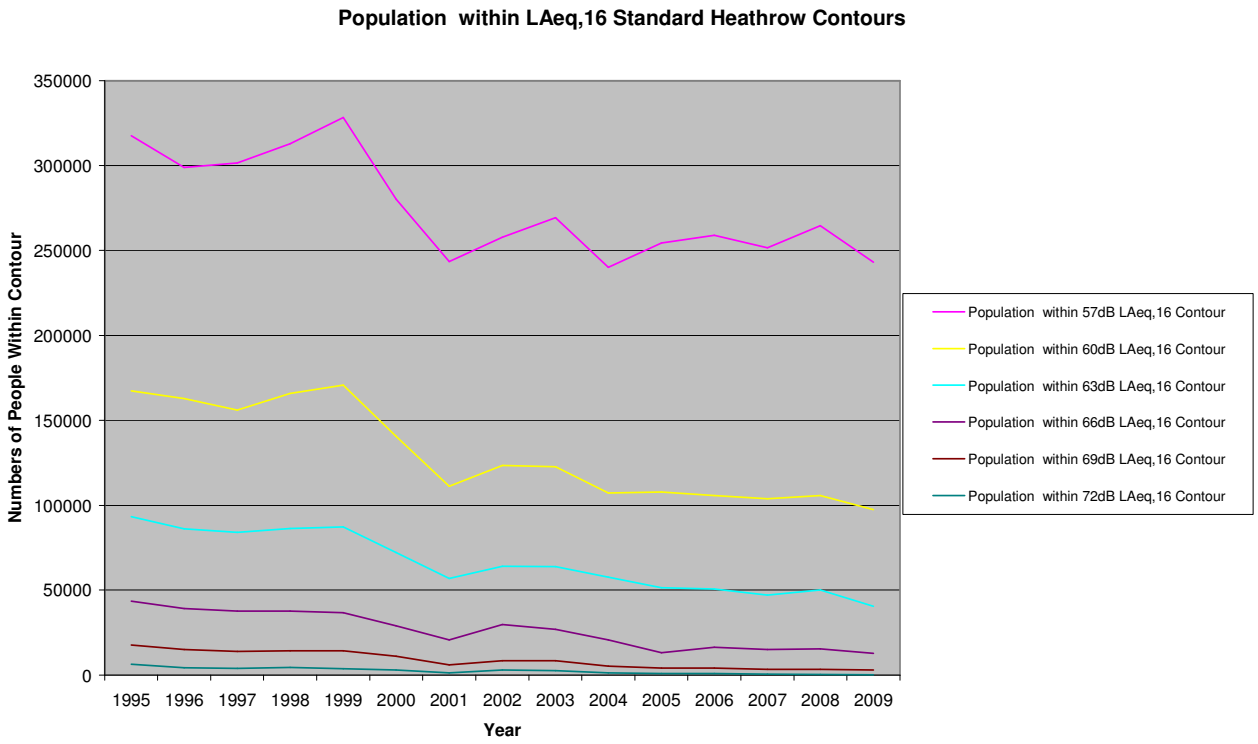
The Aim of the LAANC Noise Envelope (RNE)

In order to circumvent any disagreement on the onset of annoyance or health effect the Councils propose the following noise envelope.

The aim of this noise envelope is to reduce the numbers of people who are exposed to **high levels** of aircraft noise. This would be a phased tightening of the envelope during the time span of the scheme. Our scheme envisages that "Numbers of population exposed to noise" would be used as the benchmark criterion instead of the traditional noise contour area. Thus it is possible to produce a Reducing Noise Envelope (RNE). Reduction in the numbers of people exposed to high level of aircraft noise would result in a commensurate reduction in the number of people exposed to lower levels of noise see Graph 1 below.

[3] A380 design was driven by noise performance. If it was being designed today its design would be driven by the need to reduce greenhouse gas emissions.

Graph 1



Graph 2 shows the number of people who have been exposed to noise levels specifically above 69 and 72dB,$L_{Aeq,16hr}$ by year.

Table 1. Examples of Noise Controls Available to Facilitate a Reducing Noise Envelope at Heathrow.

Variable	Control Method
Numbers of aircraft	Controlled by planning condition,
Types of aircraft	Controlled by airlines and ICAO phase out arrangements,
The way aircraft are flown	ICAO, local agreement,
Location of the community receiving the noise impact	Planning (new). Buy people out (existing),
Times of operation or times a noise envelope is in force	Government / BAA control
The level of noise emitted by each aircraft.	Aircraft Manufactures

Conclusion

LAANC maintains that a conventional rigid noise envelope is not an appropriate noise control mechanism at Heathrow. However a Reducing Noise Envelope (RNE) based on reducing the numbers of people exposed to high levels of aircraft noise could be a useful policy tool to inform the Government's new aviation policy.

Appendix 3 - Update of Noise Dose Response Data

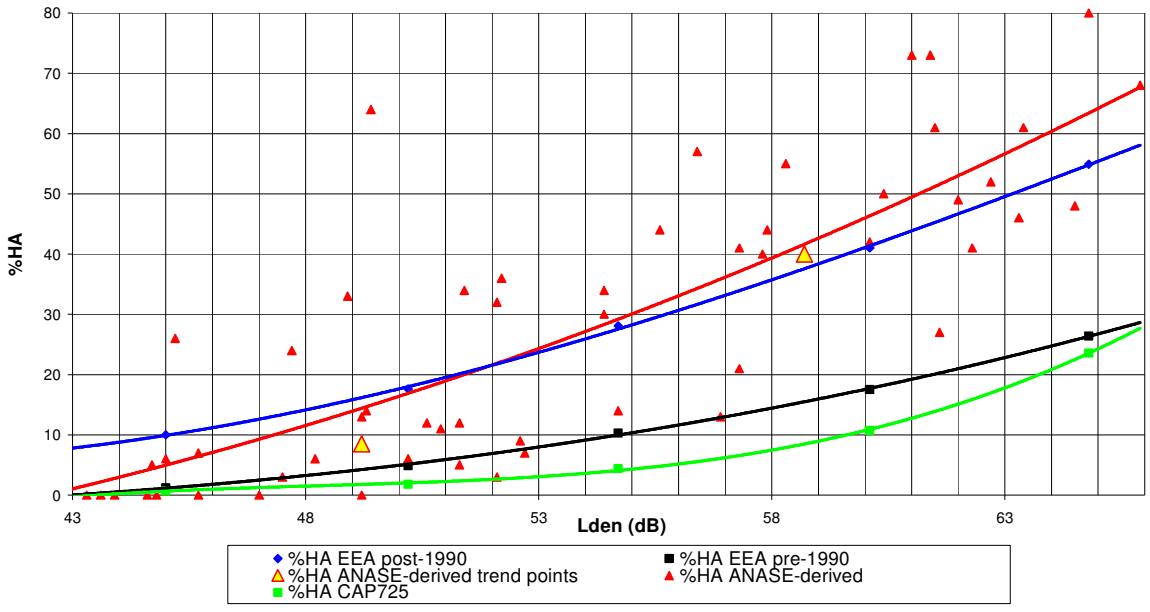
Introduction

This paper presents evidence that there is a useful correlation between the aircraft noise annoyance studies reported in a recent European Environment Agency (EEA) report and the UK Government's ANASE study. Both sets of studies have found a significant shift in that aircraft noise now causes annoyance at lower levels than it did previously. The significance of this, in relation to the current framework scoping consultation, is that it provides some support for the use of the ANASE findings in the development of future aviation policy. This is important, as without this support, the ANASE findings have been set aside. However, until the ANASE issue can be resolved, the conclusion is that the EEA findings should be accepted for the development of future aviation policy, in relation to annoyance. There remains an important caveat to this, in that the EEA evidence itself needs to be improved by including the significance of flight numbers in any noise annoyance assessment. Only once this is resolved can the question of acceptable aviation capacity be addressed fully. So, in spite of the various study deficiencies, the message remains clear, that aircraft noise now causes annoyance at lower levels than it did previously, and this issue must be addressed in any future aviation policy.

EU and UK models for aircraft annoyance

The recent European Environment Agency report [1] is a good practice guide intended to assist policy makers and competent authorities in understanding and fulfilling the requirements of Directive 2002/49/EC [2], commonly referred to as the Environmental Noise Directive, relating to the assessment and management of environmental noise. It summarises the latest European view on issues such as exposure-response relationships and thresholds for health endpoints (annoyance, sleep disturbance, cardiovascular effects and cognitive impairment). Individual annoyance relationships with the noise metric Lden are given for road, rail and aircraft noise.

Figure 1: Comparison of EU and UK aircraft noise annoyance models



HA = "Highly annoyed"

The EEA report gives a previously used European aircraft noise annoyance relationship based on studies carried out prior to 1990. This is the same relationship as given in the 2002 EU Position Paper [3]. The relationship gives an estimate of the percentage of persons highly annoyed at a given Lden noise exposure.

The EEA report mentions studies showing a trend change in annoyance around 1990, and gives an updated European annoyance relationship based on aircraft noise studies carried out after 1990. These were all European studies (Switzerland, Germany, Netherlands) regarded as more appropriate for the EU than the pre-1990 studies, which were mainly carried out in the USA and Australia.

Figure 1 gives the results for the pre-1990 and post-1990 studies in terms of percentage highly annoyed in relation to Lden. It can be seen that levels of annoyance at a given noise level are much higher for the post-1990 studies than for the pre-1990 studies. The analysis given in Figure 1 is confined to the range of noise levels in the ANASE study (40.9 to 64.2 dB $L_{Aeq,16h}$).

At 59 dB Lden, for example, the relationship adopted for the pre-1990 studies in Figure 1 gives 16% highly annoyed. In the case of the post-1990 studies, the relationship adopted gives the same percentage highly annoyed at around 49 dB Lden.

Thus, the EEA report suggests that levels of annoyance (expressed as percentage highly annoyed) that occurred at 59 dB Lden in the pre-1990 studies occurred at around 49 dB Lden in the post-1990 studies, a reduction of around 10 dB Lden.

The Government's aviation policy uses 57 dB $L_{Aeq,16h}$ as the level of daytime noise marking the approximate onset of significant community annoyance. This level is based on the Aircraft Noise Index Study (ANIS) [4] carried out in the UK in the 1980s.

The CAP725 document [5] produced by the Civil Aviation Authority in 2007 outlines methodologies for environmental assessment of an airspace change proposal. It gives an aircraft noise annoyance response relationship for calculating percentage of people highly annoyed using $L_{Aeq,16h}$ noise levels. The relationship is based on the Schultz curve produced in 1978 [6]. The document states that the ANIS results exhibit the same general trend as the aircraft studies in the Schultz analysis. The EU annoyance relationships use the Lden noise metric rather than the $L_{Aeq,16h}$ noise metric used in the UK.

Analysis of data [7,8] relating to Heathrow airport in 2006 shows that Lden is typically around 1.7 dB higher than $L_{Aeq,16h}$. This 1.7 dB adjustment has been used to convert $L_{Aeq,16h}$ to Lden to give the CAP725 annoyance relationship shown in Figure 1.

The Attitudes to Noise from Aviation Sources in England (ANASE) study [9] reported in 2007 that annoyance with a given level of aircraft noise is much higher than when the ANIS study was carried out. The ANASE study made a direct comparison with the ANIS study in terms of "mean annoyance" with aircraft noise. This showed that the level of mean annoyance found at 57 dB $L_{Aeq,16h}$ in the ANIS study was found in the ANASE study at a level of just over 50 dB $L_{Aeq,16h}$, a reduction of just less than 7 dB $L_{Aeq,16h}$.

The Government accepted that the ANASE study demonstrated that annoyance with a given level of aircraft noise is higher than found in the ANIS study. However, on advice contained in an independent peer review report [10], the Government decided that the detailed findings of the ANASE study should not be relied on.

Most of the analysis in the ANASE report related to "mean annoyance", and trend lines were fitted to graphs of mean annoyance versus $L_{Aeq,16h}$. Figure 7.2 of the ANASE report gave a graph of

percentage "at least very annoyed" versus $L_{Aeq,16h}$, but no trend line was fitted to the plotted data points. In the ANASE study, responses from respondents were recorded using an annoyance scale of (i) "Extremely annoyed", (ii) "Very annoyed", (iii) "Moderately annoyed", (iv) "Slightly annoyed" and (iv) "Not at all annoyed". The annoyance scale did not include a response of "Highly annoyed" as used in the EEA and CAP725 reports so comparison of the results of the different studies is not straightforward.

However, section 6 of the ANASE peer review report [10] assumes that the ANASE term "at least very annoyed" is equivalent to the term "highly annoyed" used in other studies. This assumption allowed the peer reviewers to deduce (apparently by eye) two trend points for the plotted ANASE data points. The two ANASE trend points given in the peer review report are 8.5% highly annoyed at 47/48 dB $L_{Aeq,16h}$, and around 40% highly annoyed at 57 dB $L_{Aeq,16h}$. These trend points relate to the corrected version of ANASE report Figure 7.2 given in the Erratum dated 1st November 2007 contained in the ANASE final report dated October 2007. This paper therefore tentatively plots the ANASE data, but makes plain that the ANASE values for "highly annoyed" have been derived.

The two ANASE derived trend points are plotted in Figure 1, after converting $L_{Aeq,16h}$ to Lden by adding 1.7 dB, derived from Heathrow data for 2006. Using the same assumptions that (i) the ANASE term "at least very annoyed" is equivalent to "highly annoyed" in other studies, and (ii) Lden can be estimated from $L_{Aeq,16h}$ by adding 1.7 dB, the results derived for all ANASE sites have been plotted in Figure 1. That figure also shows a third order polynomial trend line fitted to the ANASE derived results. The relatively poor agreement between the plotted data points and the fitted trend line ($R^2 = 0.667$) reflects the spread of the data points, but this is not unusual in social surveys of this kind.

It is important to note that Figure 1 shows that the annoyance levels at a given noise level are much higher for the EEA post-1990 studies than for the EEA pre-1990 studies. For example, percentage highly annoyed at 57 $L_{Aeq,16h}$ (approximately equivalent to 58.7 dB Lden) is more than doubled from around 15% for the pre-1990 studies to around 37% for the post-1990 studies.

It can be seen from Figure 1 that the annoyance levels for the UK's CAP725 relationship are generally lower than given by the EEA pre-1990 studies relationship, and much lower than given by the EEA post-1990 studies. This implies that continued use in the UK of the CAP725 annoyance relationship will seriously underestimate levels of aircraft annoyance. The ANASE trend line is generally similar to the EEA post-1990 studies relationship, and certainly in much better agreement with the EEA post-1990 studies relationship than is the CAP725 relationship.

The Government rejected the detailed findings of the ANASE study and continues to rely on the ANIS, Schultz and CAP725 aircraft noise annoyance relationships, even though these relationships are based on social surveys carried out more than 25 years ago. It seems doubtful that these relationships remain in calibration for current public attitudes, flight numbers, aircraft fleet mixes and aircraft noise characteristics. The EEA report supports this doubt on the continued validity of these relationships. This is because the EEA report suggests that levels of annoyance at a given noise level are much higher than suggested by previous European guidance. Furthermore, these EEA findings of much higher levels of annoyance seem to be replicated by the results of the recent ANASE study.

Objectives and findings of the ANASE study

The ANASE study was commissioned by the Government in 2001 in order to update the ANIS study of 1982 which led to $L_{Aeq,16h}$ noise index being adopted by the Government for measuring aircraft noise.

The ANASE report recognises that the amount of air traffic has increased significantly since 1982 whilst the sound levels generated by individual aircraft events have been significantly reduced as older, noisier aircraft have been replaced by more modern aircraft types with quieter engines and much improved climb performance. It is also recognised that attitudes to aircraft noise may have been changed due for example to the general growth in personal income, higher expectations of a peaceful living environment and less tolerance of environmental intrusion.

The main findings of the ANASE study are reviewed below against the study objectives.

Objective 1: Re-assess attitudes to aircraft noise in England

The study found that the annoyance level of respondents increased as the noise indicator $L_{Aeq,16h}$ increased, and that a large proportion of measured variation in annoyance can be accounted for by $L_{Aeq,16h}$.

However, for a given $L_{Aeq,16h}$, there is a range of reported annoyance indicating that annoyance is not determined solely by the amount of aircraft noise as measured by $L_{Aeq,16h}$. The main additional influences on the level of annoyance were found to be respondent's household income and socio-economic group.

The study found that for the same amount of aircraft noise, measured by $L_{Aeq,16h}$, people were more annoyed in 2005 than they were in 1982.

The study showed that people are much more sensitive to aircraft noise at night (particularly around midnight and the early hours thereafter). In contrast, people are least sensitive to aircraft noise in the morning and early afternoon. Ideally, therefore, a noise indicator for aircraft noise should reflect these times of day sensitivities. In contrast, $L_{Aeq,16h}$ does not reflect weighting for sensitivities by time of day.

Objective 2: Re-assess their correlation with the $L_{Aeq,16h}$ noise index

The study considered whether $L_{Aeq,16h}$ is the appropriate measure of aircraft noise for predicting annoyance.

The study found that while $L_{Aeq,16h}$ continues to be a good proxy for measuring community annoyance at a given point in time, the relationship between $L_{Aeq,16h}$ and annoyance is not stable over time.

Because of this, use of $L_{Aeq,16h}$ to predict future levels of annoyance may be misleading. In particular, where numbers of aircraft are increasing significantly, the ANASE results suggested that under-prediction of annoyance is likely.

The study recognised that the $L_{Aeq,16h}$ noise index incorporates a mathematical trade-off of 10 between event noise level and number of noise events[4], which means that each doubling or halving of the numbers of aircraft noise events counts as equivalent to a 3 dB increase or decrease in average noise levels[5]. The results from the study suggested that the $L_{Aeq,16h}$ noise indicator gives insufficient weight to aircraft numbers, and a relative weight of 20 appears more supportable from the evidence than the relative weight of 10 inherent in $L_{Aeq,16h}$.

[4] LAeq,T = SEL + 10LogN – 10LogT, where SEL is event noise level (dB) for N events in T seconds

[5] 10Log(2/1) = +3dB and 10Log(1/2) = -3dB

Objective 3: Examine willingness to pay to remove aircraft noise

The study was required to examine (hypothetical) willingness to pay in respect of nuisance from aircraft noise, and whether attitudes might be affected if cash transfers or, for example, noise insulation grants were made available. The study found that aircraft event noise level, aircraft type, time of day and personal characteristics (in particular household income) influence annoyance and willingness to pay.

Aircraft noise action plans

The EEA report [1] provides the dose-effect relationships intended to be used to assess the effects of noise on populations as required by the Directive [2]. Section 6 of the EEA report suggests that the lower noise thresholds for mapping are intended to delimit the area where noise is "considered to be a problem". These thresholds are noise levels above which health effects start to occur.

The EEA report accepts that use of the current threshold levels for noise mapping of 55 dB Lden and 50 dB Lnight is understandable as a first step because of the large scale noise mapping required. However, the report points out that Member States are free to choose their own noise thresholds from where to start action planning, and the Lden threshold for noise mapping of 55 dB Lden does not take into account differences that exist between different noise sources. These differences are illustrated in Table 6.1 of the EEA report giving respective percentages highly annoyed at 45, 50 and 55 dB Lden for road, rail and aircraft noise. Table 6.1 of the EEA report is reproduced here (in part) as Table 1.

Table 1: Transportation noise annoyance (reproduced from EEA report)

	Percentages of highly annoyed		
Lden	Road	Rail	Aircraft
55 dB	6%	4%	27%
50 dB	4%	2%	18%
45 dB	1%	0%	12%

The EEA report states that while 55 dB Lden is a "fair" threshold for rail noise, use of 55 dB Lden for other noise sources leads to an underestimate of the actual burden.

Table 1 gives the percentage highly annoyed at 55 dB Lden for rail noise as 4%, while the percentage highly annoyed at 45 dB Lden for aircraft noise is given as 12%. This means that to achieve annoyance levels approaching that regarded as "fair" for rail noise, the threshold for aircraft noise may have to be lower than 45 dB Lden. In fact, Section 2 of the EEA report gives 42 dB Lden as a general noise threshold above which annoyance effects start to occur or rise above background.

It would therefore appear that the EEA report implies that the threshold for noise mapping where aircraft noise is considered to be a problem should be significantly lower than 55 dB Lden as currently used.

Conclusions

The EEA report recognises that levels of annoyance with aircraft noise are much higher for post-1990 studies than for pre-1990 studies.

This paper compares the results for different annoyance models over the range of noise levels in the ANASE study (40.9 to 64.2 dB $L_{Aeq,16h}$). Analysis in this paper shows that annoyance levels predicted by the UK's CAP725 relationship are generally lower than given by the EEA pre-1990 relationship, and much lower than given by the EEA post-1990 relationship.

In contrast, the analysis shows that the much higher annoyance levels in the EEA post-1990 studies seem to be replicated by the ANASE study. Despite this, the Government continues to rely on the ANIS, Schultz and CAP725 aircraft noise relationships derived from social surveys carried out more than 25 years ago.

Until the issues of the ANASE study are addressed, it is suggested that Government policy should be based on guidance in the EEA report, including the specified relationship between annoyance and aircraft noise level.

Although the EEA report gives increased levels of aircraft noise annoyance, it does not address all the objectives of the ANASE study. These objectives include the suitability of $L_{Aeq,16h}$ as an indicator of community annoyance, the importance of numbers of aircraft flights, the relative importance of different times of day, and determining willingness to pay to reduce annoyance from aircraft noise. Further work is necessary to address these objectives.

It is concluded that there is an urgent need for updated guidance from the Government on the annoyance relationship for aircraft noise, and the threshold level at which aircraft noise is considered to be a problem.

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Appendix 4 Evidence on the Health Effects of Night Flights

5.46 What are the economic benefits of night flights? How should the economic benefits be assessed against social and environmental costs?

The Effect of Nocturnal Aircraft Noise on Health: a Review of Recent Evidence.

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Report prepared for the London Borough of Hounslow

August 2011

Draft 1

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ABBREVIATIONS & GLOSSARY

95%CI 95% confidence interval demonstrating the estimated range of an odds ratio
DALYS Disability adjusted life years: measure used in the World Health Organisation Burden of Disease methodology
dBA a measure of sound level in decibels, A-weighted to approximate the typical sensitivity of the human ear
ECG Electrocardiography: records heart rhythm
EEG Electroencephalography: records brain waves
EMG Electromyography: records muscle activity
EOG Electroculograph: records eye movements
LA_{eq16} average sound pressure level for a specified period (in this example 16 hours) in dBA units
L_{Amax} Maximum sound pressure in dBA units
LC_{pk} measurement of peak sound pressure level over a specified period
OR odds ratio
PSG Polysomnography: records biophysiological changes that occur during sleep
SEL Sound exposure level

EXECUTIVE SUMMARY

SCOPE OF THE REVIEW

This literature review was carried out to inform the London Borough of Hounslow's response to the Department for Transport's 'Developing a Sustainable Framework for UK Aviation: Scoping Document' (Department for Transport, 2011), which forms a platform and consultation for debate about the future development of aviation in the UK. Whilst aviation plays a significant role in economic growth in the UK, this has to be balanced with effects on climate change and the quality of life of local communities. This consultation seeks debate and opinion about night flying regimes around Heathrow, Gatwick and Stansted airports. In response, this literature review focuses on nocturnal aircraft noise exposure, summarising current evidence for effects of nocturnal aircraft noise exposure on human health. Effects for both adults and children are described.

NON-AUDITORY EFFECTS OF NOCTURNAL AIRCRAFT NOISE

Overall, evidence for an effect of aircraft noise exposure on human health has strengthened in recent years, as more methodologically robust studies have been carried out. Methodological advancements have included the use of larger epidemiological community samples, as well as better characterisation of noise exposure. This has enabled recent studies to begin to differentiate the effects of nocturnal aircraft noise exposure (usually defined as 23.00-07.00 hours) from the effects of daytime aircraft noise exposure (usually defined as 07.00-23.00 hours). Two main pathways for how nocturnal aircraft noise exposure could influence health have been postulated. Firstly, noise can cause sleep disturbance, which could lead to fatigue, annoyance, low mood and impaired performance the next day. Secondly, nocturnal noise exposure may have a direct effect by activating biological systems which could have long-term effects on health: e.g by increasing heart rate or altering cortisol responses.

NOCTURNAL AIRCRAFT NOISE, HYPERTENSION & CORONARY HEART DISEASE

Evidence for an effect of aircraft noise on coronary heart disease has increased in recent years. A range of outcomes ranging from self-reported hypertension and medication use, to more objective measures of blood pressure, as well as incidence of myocardial infarction and ischaemic heart disease have been examined. Overall, as well as there being consistent evidence for a small but significant impact of aircraft noise exposure on cardiovascular risk and disease, this research area is

one of the few that can draw specific conclusions about the effect of nocturnal aircraft noise exposure.

The European Union funded HYENA study (Hypertension and Exposure to Noise near Airports) (Jarup *et al.*, 2008), a large community study of samples from around 7 major European airports including London Heathrow, found that a 10 dBA increase in nocturnal aircraft noise exposure was associated with a 14% increase in odds for hypertension, which was defined as a systolic blood pressure ≥140 or a diastolic blood pressure ≥90 or a diagnosis of hypertension by a physician in conjunction with use of antihypertensive medication. No effect was found for day-time aircraft noise exposure. Overall, the findings of the HYENA study indicate specific effects of nocturnal aircraft noise exposure on hypertension, as well as suggesting that residents around London Heathrow airport may be more vulnerable to the effects of noise compared to those from other European countries. Similarly, the European Union funded RANCH project (Road traffic and Aircraft Noise exposure and children's Cognition and Health) of 9-10 year old children living near London Heathrow and Amsterdam Schiphol found that day-time and nocturnal aircraft noise exposure at home was associated with systolic and diastolic blood pressure (van Kempen *et al.*, 2006). Taken as whole, the evidence for hypertension and coronary heart disease would support preventive measures to reduce nocturnal aircraft noise exposure.

NOCTURNAL AIRCRAFT NOISE & SLEEP DISTURBANCE

There is consensus that nocturnal aircraft noise is associated with sleep disturbance. However, the measurement of sleep disturbance is challenging: no one measure is considered accurate or reliable, thus, a broad range of sleep outcomes have been examined, ranging from weaker subjective outcomes such as self-reported sleep disturbance, to more objective measures such as polysomnography (PSG), which records biophysiological changes that occur during sleep, and actigraphy, which measures sleep disturbance based on body movements.

There is sufficient evidence from laboratory and community studies that aircraft noise disturbs sleep in adults, as evidence by an increased number of awakenings, increased length of awakenings, reduced short-wave sleep and Rapid Eye Movement sleep, as well as effects on subjective self-reported sleep quality. There is also consensus that nocturnal noise exposure causes direct biological responses such as changes in heart rate and blood pressure, which could also influence health in the longer-term. Whilst this evidence supports regulatory policy for night-time noise exposure, it must be acknowledged that a few studies do not find an effect of aircraft noise on sleep disturbance. The majority of evidence in this field comes from cross-sectional studies which are

unable to examine the long-term health effects of aircraft noise disturbed sleep or mechanisms for effects. There is a lack of knowledge concerning the effects nocturnal aircraft noise on children's sleep outcomes. To date few studies have examined changes in sleep disturbance associated with either a reduction or increase in nocturnal noise caused by changes in airport operations and evidence from such studies is equivocal.

Whilst there remain some gaps in knowledge, there is thought to be sufficient data available to define defining limit values and guidelines for nocturnal noise exposure. The World Health Organisation Europe 'Night Noise Guidelines' (NNG), are the result of deliberations of international experts, which aim to provide clear guidance for planners and policy makers within Europe. The working group agreed that there was sufficient evidence that nocturnal noise exposure was related to self-reported sleep disturbance, medication use, and self-reported health problems and that there was some evidence along with biological plausibility for effects of nocturnal noise exposure on hypertension, myocardial infarctions, and depression. The NNG state that the target for nocturnal noise exposure should be 40 dB $L_{night,\ outside}$, which should protect the public as well as vulnerable groups such as the elderly, children, and the chronically ill from the effects of nocturnal noise exposure on health. The NNG also recommend the level of 55 dB $L_{night,\ outside}$, as an interim target for countries wishing to adopt a step-wise approach to the guidelines.

NOCTURNAL AIRCRAFT NOISE & STRESS HORMONES

It has been postulated that aircraft noise exposure could influence the stress hormones adrenaline, noradrenaline and cortisol, which are released by the adrenal glands in situations of stress. Studies in this field have demonstrating conflicting results, most likely because these hormones can be extremely difficult to study. The most compelling evidence for effects of aircraft noise effects on adult endocrine responses seen to date comes from a sub-study of the HYENA study, which found an effect of nocturnal, as well as 24 hour and day-time aircraft noise exposure on increased morning cortisol for women but not men (Selander *et al.*, 2009). Analyses also suggested that this effect was stronger in the London Heathrow sample compared with other European countries. Further studies on the effects of nocturnal aircraft noise exposure on endocrine responses in both adults and children are required. It should also be noted that there remains a lack of understanding about how long-term activation of the endocrine system links to health impairment and also about whether endocrine responses can habituate to noise exposure.

NOCTURNAL AIRCRAFT NOISE & ANNOYANCE

Annoyance is the most widespread response to noise and describes negative reactions such as disturbance, dissatisfaction, and irritation. Overall, there is consistent evidence that aircraft noise annoyance responses around major European airports have increased in recent years. In terms of London Heathrow airport specifically, there is evidence from methodologically strong studies that day-time aircraft noise annoyance is higher than that observed around other English airports (Le Masurier *et al.*, 2007), as well as evidence that both day-time and nocturnal aircraft noise annoyance is higher than that observed around other European airports (Babisch *et al.*, 2009). Taken as a whole, the evidence suggest that the population around London Heathrow may be especially vulnerable to annoyance responses, which would have implications if aircraft noise exposure were to increase due to changes in airport operations.

NOCTURNAL AIRCRAFT NOISE & COGNITIVE DEVELOPMENT

Overall, evidence for the effects of aircraft noise exposure on children's cognition has strengthened in recent years, showing effects of day-time or 24 hour aircraft noise exposure on children's reading comprehension and memory. To date, few studies have focused specifically on the effects of nocturnal aircraft noise exposure on children's cognitive performance. Recent secondary analyses of the London Heathrow sample of children from the RANCH project compared the effects of day-time aircraft noise exposure at school with nocturnal aircraft noise exposure at home on cognitive performance (Stansfeld *et al.*, 2010). This study found that whilst nocturnal aircraft noise exposure at home was associated with impaired reading comprehension and recognition memory, nocturnal aircraft noise exposure had no additional effect on these outcomes, once day-time exposure at school had been taken into account. These findings suggest that the school should be the main focus for the protection of children against the effects of aircraft noise on cognitive performance.

NOCTURNAL AIRCRAFT NOISE, PSYCHOLOGICAL MORBIDITY & WELL-BEING

Studies of aircraft noise exposure and psychological health have used day-time or 24 hour noise exposure metrics making it hard to establish the effects of nocturnal aircraft noise exposure, per se. Psychological ill-health has been examined using a range of outcomes including psychiatric diagnoses, the number of psychological symptoms, medication use, as well as questionnaire assessments of well-being and quality of life. Overall, the evidence for both adults and children suggests that aircraft noise exposure is probably not associated with serious psychiatric disorder, but that there may be effects on psychological symptoms, well-being, and quality of life. However, this conclusion is largely drawn from studies of day-time aircraft noise exposure and evidence in relation to nocturnal aircraft noise exposure is lacking. There may be a stronger link to psychiatric

disorder for nocturnal noise exposure and further contemporary studies need to explore this issue in large scale longitudinal studies using standardised interview measures of psychiatric disorder.

CONCLUSION

This review indicates that nocturnal aircraft noise exposure is potentially associated with considerable public health impact for residents living near major airports. Evidence for an effect of nocturnal aircraft noise exposure on human health has strengthened over the past decade and there is good and robust evidence for an effect of nocturnal aircraft noise exposure on hypertension, sleep disturbance, and noise annoyance. This evidence is sufficient to support preventive measures such as policy, guidelines, and limit values for nocturnal aircraft noise exposure in communities near airports. The need for a preventive approach is further strengthened by the evidence from several recent studies which indicate that the population around Heathrow airport may be particularly vulnerable to effects of nocturnal aircraft noise on health. Night-time flying regimes around London Heathrow airport need to balance the economic benefits against the protection of public health and quality of life in the surrounding area.

1 INTRODUCTION

1.1. SCOPE OF THE REVIEW

This literature review was carried out to inform the London Borough of Hounslow's response to the Department for Transport's 'Developing a Sustainable Framework for UK Aviation: Scoping Document' (Department for Transport, 2011), which forms a platform and consultation for debate about the future development of aviation in the UK. Whilst aviation plays a significant role in economic growth in the UK, this has to be balanced with effects on climate change and the quality of life of local communities. This consultation seeks debate and opinion about night flying regimes around Heathrow, Gatwick and Stansted airports. In response, this literature review summarises the current evidence for effects of aircraft noise on human health, focusing specifically on effects for nocturnal aircraft noise exposure.

This is a narrative review, focusing on key studies in the field conducted over the past decade, summarising recent developments in knowledge. The literature has been identified from searches of electronic databases including PubMed, IngentaConnect, Science Direct, Google Scholar, and the Acoustical Society of America Digital Library, as well as through searches of reference lists of papers, and searches of specific journals including 'Noise and Health' and the 'Journal of the Acoustical Society of America', as well as conference proceedings such as INTERNOISE and ICBEN (International Commission on the Biological Effects of Noise). This strategy has been supplemented by the research teams' knowledge of existing reports and publications. The literature is predominantly drawn from Europe and the USA, with a focus on UK-relevant publications, where possible. The review focuses on studies of aircraft noise exposure, where possible, but does draw on findings of other noise sources such as road traffic noise, where the evidence may be relevant.

This review considers the characterisation of noise exposure in these studies and then reviews the findings of epidemiological studies which focus on the role of chronic nocturnal aircraft noise on hypertension and coronary heart disease; sleep disturbance; stress hormones; annoyance; cognitive development; and psychological morbidity and

well-being. The review additionally considers evidence from laboratory studies, where this adds further to our knowledge and understanding of nocturnal noise effects on health. Studies of adults and children are included.

1.2. BACKGROUND TO THE RESEARCH FIELD

The direct effect of sound energy on human hearing is well established and accepted (Babisch, 2005, Kryter, 1985). Auditory impairments are typically seen in certain industrial occupations, hence protective legislation requiring hearing protectors to be worn. In contrast, non-auditory effects of noise on human health are not the direct result of sound energy. Instead these effects are the result of noise as a general stressor: thus the use of the term noise not sound: noise is unwanted sound. The non-auditory effects of noise are less well established and accepted than auditory effects. Overall, evidence for an effect of aircraft noise exposure on human health has strengthened in recent years, as more methodologically robust studies have been carried out. Methodological advancements in the field have included the use of larger epidemiological community samples as well as better characterisation of noise measurement and better measurement of health. Studies have also examined exposure-effect relationships, and have attempted to identify thresholds for noise effects on health which can be used to inform guidelines for noise exposure. There has also been a better assessment of confounding factors: noise exposure and health are often confounded by socioeconomic position; individuals living in poorer social circumstances are more likely to have poorer health, as well as be exposed to noise. Therefore, measures of socioeconomic position need to be taken into account when examining associations between noise exposure and health. Evidence from longitudinal studies is also beginning to emerge and a few recent studies have differentiated nocturnal aircraft noise exposure from day-time aircraft noise exposure to examine the specific health effects associated with exposure during different parts of the day.

It is increasingly been thought that the night-time period, when the organism physically recovers from daytime load and when brain restoration takes place, may be particularly important with respect to noise-induced health effects (Babisch, 2011). Nocturnal aircraft noise could affect health in two ways. Firstly, by a direct effect on biological systems, such as increasing heart rate, awakenings and sleep quality, as the individual responds to stimuli in the environment (HCN, 2004). Activation of some

biological responses could have long-term effects on physical and mental health (Hume, 2011a). Secondly, sleep disturbance could impact on well-being, causing annoyance, irritation, low mood, fatigue, and impaired task performance (HCN, 2004).

2 THE ASSESSMENT OF NOISE EXPOSURE

Studies of noise effects on health typically use established metrics of external noise exposure, which indicate the average sound pressure for a specified period using dBA as the measurement unit (dBA is the unit of A-weighted sound pressure level where A-weighted means that the sound pressure levels in various frequency bands across the audible range have been weighted in accordance with differences in human hearing sensitivity at different frequencies). The introduction of the European Union's Environmental Noise Directive Metrics (END) (Directive 2002/49/EC, 2002) has further led to a more standardised approach within the research field to the measurement and characterisation of noise exposure.

The metrics typically used are:

- L_{Aeq16} which indicates noise exposure over a 16 hour daytime period usually 07.00-23.00. This same time period is also sometimes represented by L_{day} which indicates noise exposure over a 12 hour day-time period, usually 0700-19.00 and $L_{evening}$ which indicates noise exposure during 4 hours of the evening, typically 19.00-23.00.
- L_{night} which indicates noise exposure at night usually 23.00-07.00.
- The END uses the metric L_{den} (day-evening-night level) which combines the L_{day}, $L_{evening}$ and L_{night} measures to indicate average noise exposure over the 24 hour period, with a 5dB penalty added to the evening noise measure and a 10dB penalty added to the night-time noise measure to account for the greater sensitivity of people to evening and nocturnal noise exposure .

In contemporary studies these metrics are usually modelled using standard airport noise modelling systems, using Geographical Information Systems to present the data, whilst fewer studies measure noise exposure in the community, which can be less reliable if measurements cover short time-periods. A few recent studies have also examined exposure to maximum noise levels (e.g. L_{Amax}), as in pathophysiological terms it is not known whether the overall 'dose' of noise exposure is important in

determining effects on health or whether peak sound pressure events or the number of noise events might be important. This issue is of increasing importance given that the number of noise events for aircraft and road traffic noise are increasing, while noise emission levels per event are falling.

Studies of the non-auditory effects of noise exposure typically use the term ‘noise’ to refer to the individual’s exposure to sound. The term noise is used, regardless of whether the exposure is high or low: the term noise implies that the sound exposure is unwanted and that it is an environmental stressor. This tradition is maintained throughout this literature review.

3 NOCTURNAL AIRCRAFT NOISE EXPOSURE & HEALTH EFFECTS

3.1. Hypertension & Coronary Heart Disease

Studies examining the effects of aircraft noise on coronary heart disease (CVD) and coronary risk factors in adults have used varying outcome measures, ranging from self-report measures of hypertension and medication use to more objective measures of blood pressure as well as prevalence and incidence of myocardial infarction and ischaemic heart disease. Methodologically robust studies also take important confounding factors associated with coronary heart disease such as age, gender, smoking, and body mass index into account.

A meta-analysis of evidence in this field found that whilst evidence for effects of aircraft noise exposure on cardiovascular risk has increased in recent years , few studies have specifically examined night-time aircraft noise exposure (Babisch, 2006). Thus, evidence for effects of night-time aircraft noise exposure has to be gleaned from studies using either day-time or 24 hour aircraft noise metrics. For example, one meta-analysis found that a 5 dBA L_{Aeq16} rise in aircraft noise was associated with a 25% increase in risk of hypertension compared with those not exposed to aircraft noise (Van Kempen *et al.*, 2002). Further, an effect of aircraft noise on incidence of myocardial infarction has been demonstrated for individuals exposed to >50 $L_{Aeq24\ hours}$, with stronger associations found for older subjects (Eriksson *et al.*, 2007). Aircraft noise has also been associated with death from myocardial infarction in the very large Swiss National cohort Study with a dose-response relationship for both level and duration of exposure. Moreover, this association was not explained by confounding factors such as education, area socioeconomic status or particulate air pollution (Huss *et al.*, 2010). Results were similar when comparing day time or night time exposures.

Recent years have seen studies begin to quantify the specific effect of night-time aircraft noise exposure on cardiovascular health. A large-scale study of the

prescription data of 809,379 people around Cologne-Bonn airport demonstrated an effect of nocturnal aircraft noise exposure (based on a 6-month average exposure between 03.00-05.00 hours) on the use of anti-hypertensive drugs and cardiovascular drugs, especially when prescribed in conjunction with anxiolytic drugs (Greiser *et al.*, 2007). However, this study has several methodological limitations: no data about individual level confounding socioeconomic and health factors such as income, homeownership, length of residency, health status, and existing illness were included in the analyses.

The European Union funded HYENA study (HYpertension and Exposure to Noise near Airports) assessed the relationship between aircraft and road traffic noise near airports and the risk of hypertension (Jarup *et al.*, 2008), differentiating the effect of aircraft noise exposure in the day-time and night-time. This study measured the blood pressure of 4681 people aged 45-70 years who had lived for at least 5 years near one of 7 major European airports (Heathrow, London; Schiphol, Amsterdam; Tegel Berlin, Arlanda, Stockholm; Bromma, Stockholm. Malpensa, Milan, and Elephterios Venizelos, Athens). The study found a significant exposure-response relationship between night-time aircraft noise exposure (L_{night} defined as 2300-0700 hours) and risk of hypertension (defined as a systolic blood pressure ≥140 or a diastolic blood pressure ≥90 or a diagnosis of hypertension by a physician in conjunction with use of antihypertensive medication), after adjustment for major confounding factors including gender, age, education, physical activity levels, alcohol intake, and body mass index. A 10dBA increase in night-time aircraft noise exposure was associated with a 14% increase in odds for hypertension. Aircraft noise exposure during the day (L_{Aeq16} defined as 0700-2300 hours) was not associated with hypertension. These findings did not differ by gender or across the 6 countries examined. The authors speculate that there could be an effect for nocturnal but not day-time aircraft noise exposure as nocturnal aircraft noise may influence hypertension by causing acute physiologic responses that may affect restoration during sleep. However, there may also be a methodological explanation as aircraft noise exposure is based on place of residence making it possible that nocturnal aircraft noise had less exposure misclassification than day-time aircraft noise exposure which assessed the period when people were more likely to be absent from their homes.

A further HYENA paper examined associations between aircraft noise exposure and medication use, assessing a range of common prescriptions: anti-hypertensives, antacids, anxiolytics, hypnotics, antidepressants, anti-asthmatics; finding an effect of nocturnal aircraft noise on anti-hypertensive use, but only for the UK and the Netherlands samples (Floud *et al.*, 2011). In the UK, a 10dB increase in nocturnal aircraft noise was associated with a 34% increase in odds of taking anti-hypertensives. This paper also found an effect for anxiolytic medication in all 6 countries, with a 10 dBA increase in nocturnal aircraft noise being associated with a 27% increase in odds of taking anxiolytic medication. Anxiolytics are used to treat anxiety but are also prescribed for sleep problems.

The HYENA study is methodologically strong, using aircraft noise exposure from 2002 to assess health outcomes assessed 5 years later, adjusting for a range of confounding factors. With its large sample from around London Heathrow airport, the HYENA study has direct policy relevance for the UK. However, one limitation of the HYENA study is that it is cross-sectional: it is therefore possible that the poorer health outcomes and the medication use may have preceded the noise exposure (Floud *et al.*, 2011). However, taken as a whole, the results of the HYENA study indicate specific effects of nocturnal aircraft noise exposure on hypertension, and on anti-hypertensive use, and the findings suggest that the UK sample may be particularly vulnerable to these effects: the UK sample shows stronger associations between nocturnal aircraft noise and health, based on aircraft noise exposure in 2002 around London Heathrow airport, than those observed in the other European countries. This does not seem to be explained by the number of night-flights, as Amsterdam Schiphol and Elephterios Venizelos, Athens airports have a similar, if not slightly higher number of night-flights compared with London Heathrow (EUROCONTROL, 2009). The HYENA study concluded that preventive measures should be considered to reduce night-time noise from aircraft (Jarup *et al.*, 2008).

As aircraft noise exposure shows an association with cardiovascular disorders such as hypertension, it has also been hypothesised that associations may be observed with stroke, which is another ischaemic outcome. A population-based cohort study of over 57,000 people in Denmark found that the incidence rate ratio for stroke increase by

14% for a 10dB L_{den} increase in road traffic noise (Sørensen *et al.*, 2011). Death from stroke was not associated with aircraft noise exposure in the Swiss National Cohort Study although further study is needed of haemorrhagic as well as ischaemic stroke separately (Huss *et al.*, 2010). Whilst this is an emerging field of study, stroke is a fairly rare outcome in the population, making robust studies of associations only possible on studies involving tens of thousands of participants.

Evidence for effects of noise on coronary risk factors in children has been mixed, which may be due to a number of methodological problems including lack of control for confounding factors such as parental blood pressure, socioeconomic status, age, and body composition; differences in study design; and methodological differences in the assessment of blood pressure and noise exposure (Paunovic *et al.*, 2011). However, overall, studies show a tendency towards a positive relationship between aircraft noise exposure and blood pressure in children (Paunovic *et al.*, 2011). The sub-study of RANCH project around Amsterdam Schiphol and London Heathrow airports found an effect of aircraft noise during the daytime at home (L_{Aeq16}), as well as nocturnal aircraft noise exposure ($L_{Aeq\ night}$) on systolic and diastolic blood pressure for 9-10 year old children but no effect for day-time aircraft noise at school (L_{Aeq16}) (van Kempen *et al.*, 2006). These findings suggest that it may specifically be aircraft noise exposure during the night that affects children's blood pressure. However, these findings need replication in different settings and samples before more definite conclusions can be drawn about the effects of nocturnal aircraft noise exposure on children's blood pressure. It is also worth noting that most studies that find an effect of aircraft noise on children's blood pressure find relatively small differences in blood pressure measurements, which are well within the normal range (Paunovic *et al.*, 2011): whether such changes in blood pressure have long-term consequences for health is not well understood for this age group.

Overall, as well as there being consistent evidence for a small but significant impact of aircraft noise exposure on cardiovascular risk and disease, this research area is one of the few that can draw specific conclusions about the effect of nocturnal aircraft noise exposure. The findings of the HYENA study indicate specific effects of nocturnal aircraft noise exposure on hypertension, as well as suggesting that residents around London Heathrow airport may be more vulnerable to the effects of noise

compared to those from other European countries. Taken as whole, the evidence for hypertension and coronary heart disease would support preventive measures to reduce nocturnal aircraft noise exposure.

3.2. Sleep Disturbance

Overall, there is evidence for an effect of nocturnal aircraft noise on sleep disturbance from community based studies of noise exposed populations (HCN, 2004, Hume, 2011a, Miedema and Vos, 2007). However, some reviews conclude that the evidence is inconclusive and contradictory (Jones, 2009, Michaud *et al.*, 2007), which could be explained by methodological differences between studies of noise effects on sleep disturbance (Clark and Stansfeld, 2007).

The measurement of sleep disturbance is challenging, as no one physical or psychological measure is considered accurate or reliable with the exception of polysomnography, which is expensive and not suitable for large field studies. Studies have examined a broad range of sleep disturbance outcomes, ranging from weaker subjective outcomes such as self-reported sleep disturbance, to more objective measures such as polysomnography (PSG) which records biophysiological changes that occur during sleep , including brain waves using electroencephalography (EEG), eye movements using electroculograph (EOG), muscle activity using electromyography (EMG), and heart rhythm using electrocardiography (ECG), and wrist-actimetry, which measures sleep disturbance based on body movements.

Michaud's recent review identified a range of sleep outcomes which have been examined for aircraft noise exposure including interference with ability to fall asleep, shortened sleep duration, awakenings, increased bodily movements and perceived quality of sleep (Michaud *et al.*, 2007). Self-reported sleep disturbance outcomes are potentially particularly vulnerable to bias, as such measures are likely to be influenced by noise annoyance, noise sensitivity, attitudes to the noise source, psychological health, psychosocial stress, age, and other individual factors. Effects of noise on self-reported sleep disturbance may indicate noise annoyance per se, rather than a direct effect of noise exposure on sleep outcomes. Many studies which use self-reported

sleep disturbance use fairly weak measures, often relying on single item questions. A meta-analysis of 24 field studies, including almost 23,000 individuals exposed to night-time noise levels ranging from 45-65dBA, found that aircraft noise was associated with greater self-reported sleep disturbance than road traffic, and road traffic noise with greater disturbance than railway noise (Miedema and Vos, 2007). This analysis also found inverted U-shaped association between rail, road traffic, and aircraft noise exposure and self-reported sleep disturbance, with the greatest disturbance being found for individuals aged 50-56 years. The study concluded that transportation noise was a widespread factor affecting sleep.

Objective assessments of sleep outcomes observed using EEG, assess noise effects on the different stages of the sleep cycle. The average sleep cycle last between 90 to 110 minutes, and an individual experiences between four to six sleep cycles per night (Michaud *et al.*, 2007). Non-rapid eye movement sleep has four stages; stage 1 is a light stage of sleep which lasts 5-10 minutes, acting as a bridge between wakefulness and sleep; stage 2 another light stage of sleep lasts around 20 minutes and is characterised by rapid brain waves, as well as a decrease in body temperature and heart rate; stage 3 sees the transition to deeper stages of sleep, and is characterised by delta waves indicating slow brain waves, interspersed with rapid brain waves; stage 4 is the deepest stage of sleep, characterised almost exclusively by delta waves. Stage 3 and stage 4 typically last approximately 30-40 minutes. Stage 4 can be followed by Rapid Eye Movement (REM) sleep, which is characterised by eye movements, as well as increases in brain activity and respiration rate, blood pressure and heart rate. REM sleep typically starts 70-90 minutes after falling asleep, although each sleep cycle does not have to include all the stages of sleep: often people will move between the non-rapid eye movement sleep cycles several times before undergoing REM sleep. Slow-wave sleep (stages 3 and 4) occurs more frequently in the first half of the night, and REM sleep occurs more frequently in the second half of the night (Michaud *et al.*, 2007).

A recent review concluded that there is evidence that aircraft noise can cause disrupted sleep as evidenced by increased number and length of awakenings, reduced short-wave sleep and REM sleep, increased heart rate and blood pressure, as well as effects on subjective sleep quality and increased noise annoyance but with only a

small effect on task performance the next day (Hales Swift, 2010). These conclusions mirror those of an earlier synthesis of field studies which concluded that there was sufficient evidence that nocturnal noise exposure (defined as rail, road, and aircraft noise) was causing direct biological responses, at approximately 40dB SEL, as well as affecting well-being and quality of sleep (HCN, 2004). This report also found that evidence was weaker for an effect of nocturnal noise on social interaction, task performance, and on specific disease symptoms. Recent evidence from the laboratory and field, confirms that nocturnal aircraft noise assessed as both average noise exposure during the night in the home (L_{Aeq}) and the number of noise events impairs cognitive performance the following morning, as evidenced by slower reaction times and lower accuracy on cognitive tasks (Elmenhorst *et al.*, 2010). These effects whilst small, were consistent and statistically significant, and could indicate an important public health implication of nocturnal aircraft noise exposure potentially influencing occupational performance.

In contrast to the reviews by Hales Swift (Hales Swift, 2010) and the Health Council for the Netherlands (HCN, 2004) a review focusing solely on aircraft noise exposure concluded that findings about noise-induced sleep disturbance differ considerably (Michaud *et al.*, 2007). The review, which was restricted to only five studies found little evidence for an effect of outdoor nocturnal aircraft noise on sleep disturbance, whilst indoor noise was associated more closely with sleep outcomes. There was evidence from these studies that a greater number of awakenings occur that are either spontaneous or attributable to other noise in the home, than are attributable to aircraft noise. The authors concluded that regulatory policy for night-time aircraft noise exposure should proceed cautiously, based on the findings of these five studies. However, sleep is a complex process and autonomic and minor sleep disruption does occur naturally during the sleep cycle in the absence of noise exposure (Hume, 2011a); conversely, autonomic responses to noise occurs at low levels that does not produce awakenings (Hume, 2011a, Muzet, 2007). Further, a large number of usually uncontrolled factors such as psychosocial stress, noise annoyance, age, physical and psychological health, and other individual differences affect both sleep and reaction to noise (Hume, 2011a). Michaud's conclusions are however supported by a laboratory study, which simulated the effect of aircraft noise exposure on sleep for 128 subjects over 13 nights (Basner and Samuel, 2005). Prior to the experiment, the subjects spent

a noise-free adaptation night in the laboratory, as sleep is initially affected by the laboratory setting. The experiment demonstrated a prominent first night exposure effect of noise on sleep disturbance, which wore off by the second night, which was interpreted as indicating habituation to noise exposure. On the subsequent nights no significant change in sleep structure was observed if the number of noise events and maximum sound pressure level did not exceed 4*80dB, 8*70dB, 16*60dB, 32*55dB, and 64*45dB. However, this study is still limited by having examined short-term exposure to aircraft noise, and conclusions cannot be drawn from these findings about the long-term effects of exposure to aircraft noise on sleep structure (Basner and Samuel, 2005).

Studies have also suggested that environmental noise may impact differentially on different sleep stages, for example, aircraft noise induced sleep disturbance may be more likely to occur during later parts of the night, because of the effect of aircraft noise on REM sleep (Michaud *et al.*, 2007). Conversely, it has been suggested that continuous noise exposure may be more likely to interrupt REM sleep, whilst intermittent noise may be more likely to interfere with slow wave sleep (Passchier-Vermeer *et al.*, 2002). Further studies are required before firm conclusions can be drawn about the influence of nocturnal aircraft noise exposure on specific sleep stages.

An interesting recent laboratory study examined the potential effects of a change in the night-time curfew at Frankfurt airport on sleep disruption (Basner and Siebert, 2010). Using polysomnography on 128 subjects over 13 nights, three different operational scenarios were compared: scenario 1 was based on 2005 air traffic at Frankfurt airport which included night flights; scenario 2 was as scenario 1 but cancelled flights between 2300-0500 hours; scenario 3 was as scenario 1 but with flights between 2300-0500 hours rescheduled to the day-time and evening periods. The study found that compared to the night without a curfew on night flights (scenario 1), small improvements were observed in sleep structure for the nights with curfew, even when the flights were rescheduled to periods before and after the curfew period. The authors however conclude that the benefits for sleep seen in the scenario involving rescheduling of flights rather than cancellation may be offset by the expected increase in air traffic during the late evening and early morning hours for

those who go to bed before 22.30 or after 01.00 hours. Whilst, this study has limited ecological validity, because of its laboratory setting it raises interesting possibilities regarding the setting of curfews for night-flights and the effects of different regulation regimes for night flights.

Evidence from field studies where change in nocturnal noise exposure has occurred also provides some evidence for an association between noise and sleep disturbance but the evidence is inconclusive. A Swedish study found that a reduction in road traffic noise exposure both during the day and during the night caused by a new road tunnel was associated with improvements in sleep quality and alertness, measured by actimetry and subjective reports (Öhrström, 2002). A large scale study of over 3500 subject-nights of observations, examining changes in night-time aircraft noise exposure at two airports in the United States found that noise change was not associated with changes in noise induced sleep disturbance (Fidell *et al.*, 2000). Overall, there are few studies examining changes in sleep disturbance, or other health outcomes, associated with either the reduction or increase in noise caused by a change in airport operations or through the installation of noise mitigation measures. Such studies remain a research priority.

One mechanism that has been suggested for the non-auditory effects of noise on human health, is that noise induced sleep disturbance could influence biological responses, which could have a long-term effect on health (HCN, 2004, Hume, 2011a). This potential mechanism for effects of nocturnal noise exposure on health has some support from studies linking sleep outcomes to later physical ill-health. A recent meta-analysis of longitudinal studies with at least a 3 year follow-up period, found that short duration of sleep, as assessed by questionnaire, predicted incident cases of coronary heart disease and stroke but not cardiovascular disease (Cappuccio *et al.*, 2011). Risk of developing or dying from coronary heart disease and stroke was increased by 48% and 15%, respectively for having ≤5-6 hours sleep per night compared with 7-8 hours sleep per night. However, sleep disturbance in these studies was not specifically related to noise and could have been a consequence of pre-existing ill-health.

Very few studies have included children and the specific effects of nocturnal aircraft noise on children's sleep are not known. One study used sleep logs and actigraphy to compare the effect of road traffic noise on child and parent sleep, finding an exposure-effect relationship between road traffic noise exposure and sleep quality and daytime sleepiness for children, and an exposure effect association between road traffic noise and sleep quality, awakenings, and perceived interference from noise for the parents (Öhrström *et al.*, 2006). Children are thought to have a higher awakening threshold than adults, so may be less vulnerable to noise effects on sleep (WHO, 2009); however, they are also likely to sleep earlier in the evening when aircraft noise exposure may be high. This field of research clearly warrants attention given the lack of knowledge available at present.

Taken as a whole, there are an ample number of laboratory and field studies which provide sufficient evidence that aircraft noise disturbs sleep and, depending on traffic volume and noise levels, may impair behaviour and well-being during the day (Basner *et al.*, 2010). However, the majority of evidence for the effect of aircraft noise on sleep disruption in community studies comes from cross-sectional studies (Basner *et al.*, 2010, Hume, 2011b), which do not enable the mechanisms for effects nor the role of long-term effects of aircraft noise disturbed sleep on health to be understood (Basner *et al.*, 2010). Further, little is known about the potential role of habituation to aircraft noise in relation to sleep disturbance. Evidence about these aspects could be obtained from large scale, longitudinal, epidemiological field studies, which include laboratory sub-studies (Basner *et al.*, 2010, Hume, 2011b, Jones, 2009). Such studies remain a research priority to further inform policy about the effects of nocturnal aircraft noise exposure on sleep disruption (Basner *et al.*, 2010, Hume, 2011b, Jones, 2009). Such studies should include repeated PSG assessment over a long-period of noise exposure, the assessment of health outcomes over a long-period, hormonal and cardiovascular measures to assess potential mechanisms for long-term effects of sleep disruption on health, and assessment of potential effect modifiers such as existing chronic ill-health (Basner *et al.*, 2010, Hume, 2011b, Jones, 2009). However, despite the existing gaps in knowledge on long-term health effects, experts believe that sufficient data are available for defining limit values, guidelines and protection, which should be updated with the availability of new data (Basner *et al.*, 2010).

One attempt to define such limits is the recent World Health Organisation Europe 'Night Noise Guidelines' (NNG) (WHO, 2009). These guidelines are the result of deliberations of international experts, which aim to provide clear guidance for planners and policy makers within Europe. The NNG use the noise metrics of $L_{night, outside}$, as used by the Environmental Noise Directive (END), the index of continuous sound levels outside during the night period (22.00-06.00 or 23.00-07.00), to define threshold levels for nocturnal noise exposure to protect health. The working group agreed that there was sufficient evidence that nocturnal noise exposure was related to self-reported sleep disturbance, medication use, and self-reported health problems and that there was some evidence along with biological plausibility for effects of nocturnal noise exposure on hypertension, myocardial infarction, and depression. This distinction reflects the relative newness of the L_{night} metric within the research field at the time the working group was convened. The NNG state that the target for nocturnal noise exposure should be 40 dB $L_{night, outside}$, which should protect the public as well as vulnerable groups such as the elderly, children, and the chronically ill from the effects of nocturnal noise exposure on health. The NNG also recommend the level of 55 dB $L_{night, outside}$, as an interim target for countries wishing to adopt a step-wise approach to the guidelines. An attempt to quantify the impact of nocturnal environmental noise exposure by the WHO Europe estimated that a total of 903 000 DALYs (Disability Adjusted Life Years) are lost per annum from noise-induced sleep disturbance for the EU population living in towns of >50 000 inhabitants (WHO, 2011).

3.3. Stress Hormones

Adrenaline, noradrenaline and cortisol, all of which are released by the adrenal glands in situations of stress have also been examined in relation to chronic aircraft noise exposure but these studies have demonstrated conflicting results (Babisch, 2003). These hormones can be extremely difficult to study as salivary and urinary measures of these hormones are easily biased by unmeasured factors. Cortisol has diurnal variation and is usually high in the morning and low in the evening making it difficult to measure effectively. Existing studies are further limited by small sample sizes.

A sub-study of the HYENA study, examined whether aircraft noise exposure was associated with salivary cortisol levels (Selander *et al.*, 2009). The sub-study found that aircraft noise exposure (L_{Aeq24}, L_{Aeq16}, L_{den}, $L_{evening}$, L_{night}) was associated with a significant increase in morning cortisol levels in women. Women exposed to >60dB L_{Aeq24} had a 34% higher morning saliva cortisol concentration compared with women exposed to <50dB L_{Aeq24} (Selander *et al.*, 2009). No effect was found for males, which may indicate that women are particularly susceptible to effects of aircraft noise on cortisol. Analyses by country, suggested that the association was stronger for the UK sample than for the samples from the other 5 countries. Interestingly, aircraft noise annoyance was not related to morning cortisol levels suggesting that the effect was not dependent on noise annoyance responses but was more directly associated with noise exposure.

Studies of aircraft noise exposure effects on endocrine markers in children have focused on day-time aircraft noise exposure at school. These studies, examining children living near London Heathrow airport found no association between aircraft noise exposure above 66 dB L_{Aeq16} and morning salivary cortisol measures (Haines *et al.*, 2001b), nor, in a similar study, between aircraft noise exposure above 62 dB L_{Aeq16} and twelve-hour urinary cortisol, adrenaline and noradrenaline measures (Haines *et al.*, 2001a). However, the lack of associations could be explained by misclassification bias, as morning salivary cortisol may be more strongly influenced by nocturnal aircraft noise exposure at home rather than day-time aircraft noise exposure at school. However, it is likely that home and school aircraft noise exposure are highly correlated (Clark *et al.*, 2006, Haines *et al.*, 2001a). Also, for adults, the HYENA study found an effect on morning cortisol using both day and night-time aircraft noise metrics.

The evidence from the methodologically robust HYENA study provides some of the most compelling evidence for aircraft noise effects on adult endocrine responses seen to date. Previous evidence, mostly from studies of road traffic noise exposure was inconclusive and contradictory (Babisch, 2003). Further studies on the effects of nocturnal aircraft noise exposure on endocrine responses in children and adults are required. Little is known about whether raised endocrine responses observed in some studies represent normal short-term responses to environmental stress or a longer-

term activation of the endocrine system. There is a lack of understanding about how long-term activation of the endocrine system links to health impairment and whether endocrine responses to noise exposure can habituate is not certain.

3.4. Annoyance

Annoyance is a multifaceted psychological concept including both evaluative and behavioural components (Guski, Schuemer, & Felscher-Shur, 1999), used to describe negative reactions to noise such as disturbance, dissatisfaction, displeasure, irritation, and nuisance (Guski *et al.*, 1999, Ouis, 2002). Annoyance is the most widespread, subjective response to noise (Cohen and Weinstein, 1981). The amount of the annoyance response explained by the sound level is generally thought to be small to moderate (Kroesen *et al.*, 2008, Le Masurier *et al.*, 2007, van Kempen and van Kamp, 2005). Acoustic factors such as noise source, exposure level and time of day of exposure only partly determine an individual's annoyance response: many non-acoustical factors such as the extent of interference experienced, ability to cope, expectations, fear associated with the noise source, noise sensitivity, anger, and beliefs about whether noise could be reduced by those responsible influence annoyance responses (WHO, 2000).

Noise annoyance is typically measured using the ISO question (ISO/TS 15666:2003) "Thinking about the last 12 months or so, when you were at home, how much does noise from aircraft bother disturb or annoy you?" answered either on a 5 point scale (Not at all, Slightly, Moderately, Very, Extremely) or on an 11 point numerical scale. Studies have derived exposure-effect associations for the effects of different noise sources on annoyance responses (Miedema and Oudshoorn, 2001, Schultz, 1978), finding that aircraft noise produces greater annoyance responses than road traffic noise at the same level of exposure (Miedema and Vos, 1998, Miedema and Oudshoorn, 2001). The 'Miedema curves' (Miedema and Oudshoorn, 2001) are used with the European Union to predict the number of highly annoyed subjects (European Commission Working Group on Dose-Effect Relations, 2002). Table 1 is taken from the European Commission Working Group on Dose-Effect Relations, 2002 report (page 4), showing the % of the population annoyed and highly annoyed (Figure 2) by aircraft noise, road traffic noise, and rail noise. Unfortunately, these data use L_{den}, so

look at noise exposure over the 24 hour period rather than for the night-time period per se. It is also important to realise that at any given sound level, a range of annoyance will be reported, as annoyance is not determined solely by sound level (Le Masurier *et al.*, 2007).

Recent studies suggest that the Miedema curves underestimate aircraft noise annoyance, suggesting that aircraft noise annoyance around major airports in Europe may have increased in recent years (Babisch *et al.*, 2009, Schreckenberg *et al.*, 2011). The HYENA study was able to compare annoyance responses separately for the day and the night period (Babisch *et al.*, 2009), finding that the London Heathrow sample reported significantly more annoyance to nocturnal aircraft noise than the samples from Schiphol Amsterdam, Tegel Berlin, Arlanda Stockholm, Bromma Stockholm, Malpensa Milan, and Elephterios Venizelos, Athens.

All the airports except Bromma Stockholm and Tegel Berlin allow night-flights, although some restrictions are in place (Jarup *et al.*, 2008). The authors argue that the difference between the airports in the presence of night-flights is unlikely to explain the higher annoyance observed around London Heathrow, however it remains possible that there may be differences between the airports in the number of night-flights or type of aircraft that may explain the higher annoyance observed. However, as previously noted, Schiphol Amsterdam and Elephterios Venizelos, Athens airports have a slightly higher number of night-flights compared with London Heathrow (EUROCONTROL, 2009). The London Heathrow sample also reported more day-time aircraft noise annoyance than the Schiphol Amsterdam, Tegel Berlin, Arlanda Stockholm, Bromma Stockholm, and Malpensa Milan samples. Whilst these data suggest that the population around Heathrow are highly annoyed by both day-time and nocturnal aircraft noise, it must be remembered that the HYENA study examined a limited age range of 45-70 year old residents, and may therefore not be wholly representative of the population living around these airports.

Table 1: % annoyed and % highly annoyed at various noise exposure levels (L_{den}) for aircraft, road traffic, and rail traffic (taken from the European Commission Working Group on Dose-Effect Relations, 2002, page 4).

Lden	Aircraft		Road traffic		Rail traffic	
	%A	%HA	%A	%HA	%A	%HA
45	11	1	6	1	3	0
50	19	5	11	4	5	1
55	28	10	18	6	10	2
60	38	17	26	10	15	5
65	48	26	35	16	23	9
70	60	37	47	25	34	14
75	73	49	61	37	47	23

The recent ANASE study (Attitudes to Noise from Aviation Sources in England) (Le Masurier *et al.*, 2007) carried out around 16 airports in England, found evidence that aircraft noise annoyance has increased over the past few decades in the UK, which could indicate that people have become less tolerant of environmental intrusion, and may have become less accepting of aircraft noise (Le Masurier *et al.*, 2007). Other studies have also indicated a trend for increased aircraft noise annoyance (Janssen *et al.*, 2011). The table below is taken from Le Masurier et al, 2007 (page 7.9) and indicates the range of annoyance scores in different L_{Aeq16} bands for residents around Heathrow airport, indicating fairly high levels of annoyance. In fact, mean annoyance levels around Heathrow airport were higher than the mean annoyance levels observed at other airports in England for a given L_{Aeq16}.

This survey used L_{Aeq16} noise metrics and it is therefore not possible to draw specific conclusions about the effects of nocturnal aircraft noise exposure on annoyance responses from this study. However, the ANASE study also examined willingness to pay to remove aircraft noise, with the findings suggesting that people are more sensitive to noise at night, particularly noise around midnight and the early hours.

Table 2: range of % annoyance scores by LAeq16 bands for Heathrow airport (taken from Le Masurier et al, 2007, page 7.9)

LAeq Band	No of Sites	Annoyance Range
37-41	1	19
41-45	2	17-25
45-49	6	22-42
49-53	7	29-50
53-57	4	42-64
57-61	5	59-74
61-65	2	64-76

It has also been suggested that noise annoyance responses might be an intermediate step between noise exposure and ill-health, although this hypothesis is not well supported by evidence. It has been suggested that noise annoyance may induce a stress reaction which could activate the sympathetic and endocrine systems leading to physiological changes such as changes in heart rate, blood pressure, and stress hormones (Babisch, 2011). Thus, noise annoyance could be an intervening step between noise and cardiovascular illnesses such as hypertension, as well as psychological symptoms such as depression. However, evidence for noise annoyance as a possible mediating factor between noise exposure and cardiovascular outcomes is mixed and largely comes from studies of road traffic annoyance (Babisch *et al.*, 2003, Belojevic and Saric-Tanaskovic, 2002). Evidence for annoyance as a mediating factor between noise exposure and psychiatric disorder is also weak, and it has been suggested that psychiatric disorder leads to annoyance rather than vice versa (Tarnopolsky *et al.*, 1978). It is likely that people with existing psychiatric morbidity or long term physical illness may be more disturbed and annoyed by noise and potentially more sensitive to any noise-related effects.

Recent studies have examined whether noise annoyance might moderate the effect of noise exposure on health outcomes. The HYENA study found that night-time aircraft noise annoyance was associated with use of anxiolytics and anti-hypertensive medication, but aircraft noise annoyance did not moderate the effect observed between nocturnal aircraft noise exposure and anxiolytic medication (Floud *et al.*, 2011). Similarly, the HYENA cortisol sub-study found that nocturnal aircraft noise annoyance did not relate to morning cortisol levels: women exposed to aircraft noise above >60 dB $L_{Aeq\ 24}$ hours had an increase in morning cortisol level regardless of whether or not they were annoyed by nocturnal aircraft noise (Selander *et al.*, 2009). Overall, further longitudinal studies of noise annoyance as a potential moderating or mediating factor of the effect of nocturnal aircraft noise exposure on health are required before more definite conclusions can be drawn.

Overall there is consistent evidence that aircraft noise annoyance has increased in recent years. In terms of London Heathrow airport specifically, there is evidence from methodologically strong studies that day-time aircraft noise annoyance is higher than

that observed around other English airports, as well as evidence that nocturnal aircraft noise annoyance is higher than that observed around other European airports. Taken as a whole, this suggest that the population around London Heathrow may be especially vulnerable to annoyance responses, which would have implications if aircraft noise exposure were to increase due to changes in airport operations.

3.5. Cognitive Development

It has been suggested that children may be especially vulnerable to effects of environmental noise as they may have less cognitive capacity to understand and anticipate environmental stressors, as well as a lack of developed coping repertoires (Stansfeld *et al.*, 2000). Exposure to stressors during critical periods of learning at school could potentially impair development and have a lifelong effect on educational attainment (Kuh and Ben-Shlomo, 2004).

Overall, evidence for the effects of noise on children's cognition has strengthened in recent years (Evans and Hygge, 2007). One of the most interesting and compelling studies in this field is the naturally occurring longitudinal quasi-experiment reported by Evans and colleagues, examining the effect of the relocation of Munich airport on children's health and cognition (Evans *et al.*, 1998, Evans *et al.*, 1995, Hygge *et al.*, 2002). In 1992 the old Munich airport closed and was relocated. Prior to relocation, high noise exposure was associated with deficits in long term memory and reading comprehension. Two years after the closure of the airport, these deficits disappeared, indicating that noise effects on cognition may be reversible if exposure to the noise ceases. Most convincing, was the finding that deficits in memory and reading comprehension developed over the two year follow-up for children who became newly noise exposed near the new airport.

The largest study of noise effects on children's cognition and health to date, the RANCH study (Road and Aircraft Noise exposure and children's Cognition and Health), compared the effect of road traffic and aircraft noise exposure for over 2000 children attending schools around Schiphol Amsterdam, Barajas Madrid, and London Heathrow airports. The study found an exposure-effect relationship between chronic

aircraft noise exposure (L_{Aeq16}) and impaired reading comprehension and recognition memory, after taking a range of socioeconomic and confounding factors into account (Stansfeld *et al.*, 2005). Aircraft noise was not associated with sustained attention or working memory. In terms of the magnitude of the effect of aircraft noise on reading comprehension, a 5dB L_{Aeq16} increase in aircraft noise exposure at school was associated with a 2 month delay in reading age in the UK and a 1 month delay in the Netherlands (Clark *et al.*, 2006): this association remained after adjustment for aircraft noise annoyance and cognitive abilities including episodic memory, working memory and attention.

The findings of the RANCH & Munich studies, along with previous findings (Haines *et al.*, 2001a, Hygge *et al.*, 2002) suggest that noise may directly affect reading comprehension and memory but they could be accounted for by other mechanisms including teacher and pupil frustration (Evans and Lepore, 1993), learned helplessness (Evans and Stecker, 2004) and impaired attention (Cohen *et al.*, 1973, Evans and Lepore, 1993). It has been suggested that children may adapt to chronic noise exposure by filtering or tuning out the unwanted noise stimuli: this filter may then be applied indiscriminately to situations where noise is not present, leading to learning deficits through lack of attention (Cohen *et al.*, 1986). The RANCH study concluded that whilst aircraft noise has only a small effect on reading comprehension, it is possible that children may be exposed to aircraft noise for many of their childhood years and the consequences of long-term noise exposure on cognitive development remain unknown (Clark *et al.*, 2006).

Studies of aircraft noise effects on children's cognition have predominantly focused on day-time noise exposure, estimated for either the child's school or home address. Few studies have focused specifically on nocturnal aircraft noise exposure in children. However, aircraft noise exposure outside school hours in the night, as well as in the evening may also impact on children's cognition: evening noise exposure could impact on children's learning activities carried out within the home, and evening and nocturnal exposure may also disturb sleep causing after effects on children's school performance during the day (Stansfeld *et al.*, 2010). Recent secondary analyses of the Munich and RANCH study datasets have examined the effects of nocturnal aircraft noise exposure at the child's home on cognition (Stansfeld *et al.*, 2010). Analyses of

the Munich data revealed that self-reported sleep quality did not influence the associations observed between aircraft noise exposure and children's reading and memory, suggesting that sleep loss did not explain the effect of aircraft noise on cognition. Analyses of the RANCH data revealed that nocturnal aircraft noise exposure at the child's home was associated with impaired reading comprehension and recognition memory. However, nocturnal aircraft noise exposure had no additional effect on these cognitive outcomes, once day-time aircraft noise exposure at school had been taken into account. Whilst studies in West London have consistently found very high correlations between children's day-time aircraft noise exposure at school and nocturnal aircraft noise exposure at home (Clark *et al.*, 2006, Haines *et al.*, 2001a), these findings suggest that the school should be the main focus for the protection of children against the effects of aircraft noise on school performance (Stansfeld *et al.*, 2010).

3.6. Psychological Morbidity & Well-Being

Given the effect of chronic noise exposure on annoyance responses, it has been hypothesised that chronic noise exposure could have a serious effect on psychological health, as noise can cause annoyance and prolonged annoyance could lead to poor psychological health (McLean and Tarnopolsky, 1977). The effect of noise on psychological health is complicated as studies have found that poorer psychological health is also associated with greater annoyance responses (Tarnopolsky *et al.*, 1978, van Kamp *et al.*, 2007) and greater noise sensitivity (Stansfeld *et al.*, 1985).

Studies of aircraft noise exposure and psychological health in adults and children have predominantly used day-time or 24 hour noise exposure metrics, making it hard to establish the effects of nocturnal aircraft noise exposure, per se. Psychological morbidity as an outcome has been measured in several ways. Historically, research in this field started out examining associations of aircraft noise exposure on psychiatric diagnoses that could be diagnosed by an interview with a psychiatrist or by screening questionnaires. Later studies have tended to move away from this approach, due to the lack of evidence that noise exposure may relate to clinically diagnosable psychiatric disorders, to focus instead on increases in the number of psychological symptoms

reported, such as symptoms of anxiety and depression. Recent studies have broadened this approach to include the assessment of well-being and quality of life.

In the West London Survey (Tarnopolsky *et al.*, 1980) aircraft noise exposure measured by the noise and number index was examined in relation to psychiatric disorder in the community measured by the General Health Questionnaire (Goldberg *et al.*, 1970). Both the pilot study and the main study of over 5000 adults living in areas of West London exposed to aircraft noise found no association between noise exposure and the prevalence of psychiatric morbidity either for GHQ scores or for estimated numbers of psychiatric cases, using various indices of noise exposure (Tarnopolsky *et al.*, 1978, Tarnopolsky and Morton-Williams, 1980, Tarnopolsky *et al.*, 1980). There was however some evidence of an association between aircraft noise exposure and psychiatric morbidity for participants with 'higher education' and 'professional/managerial occupations' (Tarnopolsky *et al.*, 1978, Tarnopolsky and Morton-Williams, 1980, Tarnopolsky *et al.*, 1980). The authors concluded that "noise per se in the community at large, does not seem to be a frequent, severe, pathogenic factor in causing mental illness but it is associated with symptomatic response in selected subgroups of the population" (Tarnopolsky and Morton-Williams, 1980). It should be considered that this study, along with many others in the field, may have predominantly sampled 'noise survivors' as members of the population who are most susceptible to noise effects may have moved away or avoided living in the area. The study also examines total noise exposure and does not distinguish day-time exposure from night-time exposure.

A recent study in Sardinia compared psychiatric diagnoses measured using the Composite International Diagnostic Interview for 71 residents living close to Elmas airport with control subjects matched by gender, age and employment status from another area (Hardoy *et al.*, 2005). Those living near the airport had a higher frequency of diagnosis for 'generalised anxiety disorder' and 'anxiety disorder not otherwise specified', compared with the controls; no differences were observed in frequency of diagnosis for 'major depressive disorder' or 'depressive disorder not otherwise specified'. However, the findings of this study should be treated with caution. The study is underpowered to detect psychiatric diagnoses with only a few participants with noise exposure having any of the psychiatric diagnoses. More

seriously, there is potential for exposure misclassification in this study, as aircraft noise exposure was assumed based on residence in a district around Elmas airport; similarly, the control group were assumed not to have exposure to any type of noise exposure. The findings of this study are interesting but need replication in a much larger, better controlled study.

Several studies from Japan have indicated effects of military aircraft noise on psychological symptoms.
Exposure to higher daily levels of military aircraft noise around the Kadena military airport in Japan was related in an exposure-effect association to 'depressiveness' and 'nervousness' measured by questionnaire, using the Todai Health Index, based on the Cornell Medical Index (Hiramatsu *et al.*, 1997). A further Japanese study of 5,963 inhabitants around two air bases in Okinawa, also found that those exposed to noise levels of L_{dn} 70 or above had higher rates of 'mental instability' and 'depressiveness' (Hiramatsu *et al.*, 2000). However, these studies are also seriously compromised by having estimated aircraft noise exposure using exposure data in the late 1970s and assessing health in the mid- 1990s, nearly 20 years after the noise surveys, making exposure-misclassification an important potential bias as noise exposure is known to have reduced in some of these areas in the intervening time-period with the end of the Vietnam war. A smaller-scale study after the opening of Narita International airport in Japan, found that scores on the GHQ-28 were significantly associated with average aircraft noise exposure during the period from evening to night (1800-2300 hours): the study did not examine the night period (Miyakawa *et al.*, 2007).

Most studies of aircraft noise effects on psychological health are cross-sectional, assessing exposure and health outcomes concurrently making it difficult to distinguish cause from effect. One of the few longitudinal studies of aircraft noise exposure and psychological health was carried out recently around Schiphol airport in Amsterdam, finding no association between L_{den} and L_{night} aircraft noise exposure levels and mental health assessed using the GHQ12 either at baseline, or after the opening of a fifth runway (van Kamp *et al.*, 2007).

Evidence for an effect of aircraft noise on well-being is inconclusive. A study of residents living around Frankfurt airport which has night-flights, found that whilst

day-time aircraft noise exposure ($L_{Aeq\ 16\ hours\ 6am\text{-}10pm}$) was associated with the SF-36 vitality and mental health scales, and the SF-12 mental health scale, nocturnal aircraft noise exposure ($L_{night\ 10\text{-}6pm}$) showed no associations with these outcomes (Schreckenberg *et al.*, 2011). Similarly, lower scores on the general mental health scale of the SF-36 were associated with DNL (day-night average sound level) aircraft noise exposure in a study of residents around Sydney airport (Black *et al.*, 2007). Whilst these results suggest that there may be an association between daytime aircraft noise exposure and well-being, it is possible that several potential confounding factors have not been taken into account in these studies. Further studies are needed on associations between nocturnal aircraft noise exposure and well-being before firmer conclusions can be drawn.

Several studies have examined associations between aircraft noise exposure and children's psychological health, although most of these studies do not specifically examine nocturnal aircraft noise exposure. (Poustka *et al.*, 1992) studied the psychiatric health of 1636 4-16 year-old children in two geographical regions that differed according to the noise made by jet fighters frequently exercising at low altitude. Associations with noise exposure were demonstrated for subclinical depression and anxiety although there was no adjustment for the differing socioeconomic status of the areas. In a study that did adjust for socio-economic factors, the Schools Health & Environment Study around Heathrow airport (Haines *et al.*, 2001b), chronic aircraft noise exposure was not associated with anxiety and depression (measured with the Child Depression Inventory and the Taylor Manifest Anxiety Scale), after adjustment for socio-economic factors. The larger West London School study of children attending school near London Heathrow airport found that aircraft noise exposed children had higher levels of psychological distress (Haines *et al.*, 2001a), as well as a higher prevalence of hyperactivity. The RANCH study failed to replicate an effect of aircraft noise exposure at school on psychological distress in samples from the Netherlands, Spain or the UK (Stansfeld *et al.*, 2005): however, the effect of aircraft noise on hyperactivity was replicated (Stansfeld *et al.*, 2009). Recent analyses of specific effects of nocturnal aircraft noise exposure showed no effects of nocturnal aircraft noise exposure on children's psychological distress (Stansfeld *et al.*, 2010).

Studies have also shown effects of noise exposure on milder indicators of children's psychological health. For example, in the Munich Study, children living in areas exposed to high aircraft noise had lower levels of psychological well-being than children living in quieter environments (Evans and Maxwell, 1997). In subsequent longitudinal analyses from around Munich, after the opening of the new airport, the newly noise-exposed communities demonstrated a significant decline in self-reported quality of life, measured on the Kindl scale, after being exposed to the increased aircraft noise for 18 months, compared with a control sample (Evans *et al.*, 1998). This longitudinal evidence is compelling.

Overall, the evidence suggests that for both adults and children aircraft noise exposure is probably not associated with serious psychiatric disorder, but that there may be effects on psychological symptoms, well-being, and quality of life. However, this conclusion is largely drawn from studies of day-time aircraft noise exposure and evidence in relation to nocturnal aircraft noise exposure is lacking. There may be a stronger link to psychiatric disorder for nocturnal noise exposure and further studies need to explore this issue in large scale longitudinal studies using standardised interview measures of psychiatric disorder.

4 CONCLUSION

In conclusion, this review indicates that nocturnal aircraft noise exposure is potentially associated with considerable public health impact and impact on quality of life for residents living near major airports. Whilst gaps in knowledge remain regarding effects of nocturnal aircraft noise exposure on psychological health and well-being, and for longer-term health outcomes, evidence for an effect of nocturnal aircraft noise exposure on human health has strengthened over the past decade. There is good and robust evidence for an effect of nocturnal aircraft noise exposure on hypertension, sleep disturbance, and noise annoyance. This evidence is sufficient to support preventive measures such as policy, guidelines, and limit values for nocturnal aircraft noise exposure in communities near airports. The need for a preventive approach is further strengthened by the evidence from several recent studies which indicate that the population around Heathrow airport may be particularly vulnerable to effects of nocturnal aircraft noise on health. There is a need to consider the protection of public health and quality of life in the surrounding area when considering night flying regimes around London Heathrow airport.

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Appendix 5 - Evidence on Climate Change

A note on the Government Response to the Committee on Climate Change Report on Reducing CO2 Emissions from UK Aviation to 2050

Prepared for Local Authorities' Aircraft Noise Council

Ubina Environmental Consulting

OCTOBER 2011

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Summary

The Coalition Government inherited a self-contradictory aviation policy: on the one hand, a programme of airport expansion set out in the *Future of Air Transport* White Paper that would lead to emissions of around 60 $MtCO_2$ in 2050; on the other hand, a target for the sector to emit no more than 37.5 $MtCO_2$ in 2050. It also inherited a report from the Committee on Climate Change (CCC) that laid bare the disparity and made clear that given the likely pace of improvements to fleet efficiency, passenger growth would need to be restrained in order to meet the target.

By cancelling new runways and committing to develop a new Sustainable Framework for UK aviation, the Coalition indicated its willingness to tackle these contradictions. But its *Response* to the CCC report shifts the emphasis away from hard questions about how to allocate limited capacity, and onto ways – sometimes quite speculative ways – that policy might be used to increase efficiency gains beyond those already factored in to forecasts.

This note argues that in order to deliver a genuinely sustainable policy, the Government should:

- Confirm the 2050 Target for aviation, which is implied (as a minimum) by the provisions of the Climate Change Act;
- Clarify that, in order to meet the Target with a reasonable degree of certainty, airport capacity will be *planned* on the basis that fleet efficiency will improve at the rate forecast either in the CCC Likely scenario or its own central forecasts. Further capacity would only be released when there is evidence that additional gains have materialized in practice;
- Assess the effects of fiscal measures, working with HM Treasury, and incorporate this into its draft framework as one possible 'lever' to manage emissions;
- Commit to tackling aviation non-CO_2 impacts and be clear about the implications these might have for carbon budgets;
- Rule out policies that set mandatory levels of biofuel uptake, as these have been shown to drive unsustainable practices in the road sector.

A few comments are also offered on specific aspects of the underlying analysis, for instance forecasting beyond 2030, or the treatment of videoconferencing.

Background

In January 2009, the Department for Transport (DfT) made a series of major policy announcements, among them approval in principle for the building of a third runway at Heathrow airport and a new target for UK aviation emissions to be no higher in 2050 than they were in 2005 (37.5 $MtCO_2$). This target was to be in terms of absolute emissions, ie actual emissions on flights from aircraft departing from UK airports, with no account taken of carbon offsets or credits purchased via the EU Emissions Trading System (ETS). The DfT asked the Committee on Climate Change (CCC) to report on how this target could be met.

In December 2009, the Committee produced its report *Meeting the UK aviation target – options for reducing emissions to 2050* (the *CCC Report*)[6]. The report analysed Likely, Optimistic and Speculative scenarios for improvement in fleet fuel efficiency through airframe and engine technology, ground and air operations, and biofuels, as well as looking at possibilities for modal shift and travel substitution. The report also discussed the latest evidence on aviation's non-CO_2 climate impacts.

The report's central finding was that Likely annual efficiency improvements would average 0.9%, implying that the maximum number of UK airport passengers compatible with achieving the 2050 Target was 370 mppa (million passengers per annum), and that Government should plan its airports policy on this basis. This contrasted with the airport developments set out in the 2003 *Future of Air Transport* White Paper, which would lead (on DfT forecasts) to around 570 mppa in 2050. The Committee noted that deeper efficiency improvements might be achieved, thereby allowing additional passenger growth, but that the Government should not plan on the basis that these would materialize.

Immediately after its election, the Coalition Government ruled out new runways at Heathrow, Gatwick and Stansted[7]. By October of 2010 it had committed to developing a new Sustainable Framework for UK aviation to replace the 2003 White Paper[8], and in March 2011 it published a Scoping Document for consultation. The intention was for a six-month consultation period on this document; a draft policy to be published in March 2012 for a further 6-month consultation; and a final policy to be published in March 2013.

The DfT also committed itself to respond to the CCC report by July 2011. In the event, the *Response*[9], with accompanying updated *Forecasts*[10] and Marginal Abatement Cost Curve (MACC) report[11] was published in August 2011. The DfT has extended the deadline for replying to the Scoping Document consultation to October 20th 2011 in recognition of this slight delay.

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[6] www.theccc.org.uk/reports/aviation-report

[7] *The Coalition: Our Programme for Government,* May 2010. www.cabinetoffice.gov.uk/sites/default/files/resources/coalition_programme_for_government.pdf

[8] *Department for Transport Business Plan 2011-2015,* October 2010 www.number10.gov.uk/wp-content/uploads/DFT-Business-Plan1.pdf

[9] *Government Response to the Committee on Climate Change Report on Reducing CO_2 Emissions from UK Aviation to 2050,* August 2011 http://assets.dft.gov.uk/publications/response-ccc-report/ccc-response.pdf

[10] *UK Aviation Forecasts,* August 2011 http://assets.dft.gov.uk/publications/uk-aviation-forecasts-2011/uk-aviation-forecasts.pdf

[11] *Marginal Abatement Cost Curve (MACC) Model for the UK Aviation Sector,* August 2011 http://assets.dft.gov.uk/publications/response-ccc-report/mac-report.pdf

This note comments on strategic-level climate change policy issues arising from the *Response*, and is intended to assist LAANC in framing its overall response to the consultation. It follows the evidential trail into the *Forecasts* and *MACC Report* only where this is necessary to give informed comment, but is not intended to provide a detailed critique of, for instance, the DfT passenger forecasting methodology (which in any case has been extensively peer-reviewed).

Comments

The 2050 Target and inclusion of aviation in national carbon budgets

Paragraph 1.8 of the *Response* notes that

the Climate Change Act 2008 requires the Government, by the end of 2012, either to include international aviation and shipping emissions in the UK's wider 2050 climate change target and associated carbon budgets or to submit a report to Parliament explaining why it will not do so

and goes on to state that its decision will be informed by CCC advice due in March 2012. There is no reason in principle not to include such emissions, and if the CCC finds that there is an acceptable accounting method for doing so, its advice should be followed. The Response continues:

We also need to decide whether to adopt the 2050 aviation CO_2 target, announced by the previous administration in the context of its decision to support a third runway at Heathrow, now that decision has been reversed.

The equation of the 2050 Target with the decision to expand Heathrow is somewhat misleading, since it is not rendered unnecessary by the reversal of that decision. The 2050 Target is fact a statement, in unambiguous terms, of the implications of including aviation within the UK's overall climate framework.

In its first report in 2008[12], the CCC argued that in order to achieve the UK's overall target of an 80% cut on 1990 levels of greenhouse gases (GHG) by 2050, emissions from international aviation and shipping would have to be no higher than then current levels. (Emissions in 2008 were around 120% higher than in 1990, so this allocation is therefore already extremely generous relative to other sectors, which are required to make deep cuts on 1990 levels.) This treatment, together with a maximum feasible reduction of 70% for non-CO_2 gases, would require other sectors to cut their emissions by 90% if the economy as a whole was to meet the 80% reduction target.

Although the move to 90% for land-based sectors was reckoned to be feasible, it was not explicitly costed. Allowing more emissions from the aviation sector would require yet steeper cuts from other sectors, potentially reaching unfeasible levels and certainly increasing costs.

Furthermore, if the world is to stay on track to keep global surface temperature rise below 2°C, the CCC foresaw that 'in the long term, low cost opportunities to cut emissions in developing

[12] *Building a low-carbon economy - the UK's contribution to tackling climate change,* December 2008 www.theccc.org.uk/reports/building-a-low-carbon-economy

countries will diminish and radical reductions in emissions of developed countries will be unavoidable', and therefore that 'the majority of the 80% cut will in the long term need to be achieved via domestic action'.[13]

The 2050 Target for aviation should therefore be seen as flowing from the requirements of the Climate Change Act 2008, not as a gesture linked to the announcement to expand Heathrow. It represents a sector-specific statement, in unambiguous terms, of the maximum emissions from aviation that can be compatible with achieving the UK's legally binding climate change targets.

Why should such a sector-specific statement be required? It focuses minds on the task at hand and provides a yardstick for assessing progress in a way that simply including aviation within the overall mix of UK GHG emissions does not. Without a sector-specific target, the question remains (ostensibly) open of what a 'fair' proportion of aviation emissions in the overall mix might be; the answer to this question is then open to manipulation by special interests and vulnerable to short-term political decision-making. In fact, the question has been settled by the arithmetic presented in the 2008 CCC Report. It is far clearer policy to state as much, and also to remove the option to rely on offsets, which at best is only an interim solution, and at worst counter-productive as it distracts the industry from the urgent need to reduce its absolute emissions.

The rest of this note therefore assumes that the 2050 Target is retained.

The overall narrative and approach to efficiency improvements

The *Response* seeks to change the narrative of the *CCC Report* in a way that plays down awkward questions about managing the growth in demand. The CCC presented a stark disparity between a target-compatible level of passenger growth and the level endorsed by the Government through the White Paper. The 'gap' was 21.5 $MtCO_2$, which translated to about 200mppa in 2050 (the difference between the White Paper's 570mppa and the target-compatible 370 mppa). 18 months later, a combination of the recession, and the Coalition's 'no new runways' policy has reduced the size of the disparity, but a gap still remains. The gap is now 11.5 $MtCO_2$, but the *Response* declines to translate this into a gap expressed in terms of passenger numbers, instead presenting an analysis of 'levers' that might reduce emissions faster than the baseline forecast.

It should be emphasised that the baseline forecasts already factor in significant efficiency improvements and biofuel uptake, at a level that reflects expert judgment of likely developments. There is already considerable commercial pressure to improve fuel efficiency given the high cost of kerosene (as well as the incentive for biofuel use offered by its zero emissions factor in the EU ETS), meaning that much of the feasible reduction potential is already projected to be captured. The CCC's approach was to take this likely level of improvement into its central (Likely) scenario, and recommend that passenger/airport growth be planned on this basis, with further capacity being released where faster reductions were proven in practice.

While it is of course possible, in theory, to drive efficiency improvement at a faster rate through policy, it would be preferable for the DfT to acknowledge clearly that this is an uncertain proposition, and that it does not intend to plan allowable capacity/passenger numbers on the basis that faster reductions will be achieved.

[13] ibid, Executive Summary page 3.

A precautionary approach to achieving the target is all the more important because:

- Historic trends are for emissions growth to track passenger growth very closely, with fuel efficiency improvements lost in practice;
- Aviation's non-CO_2 impacts may require its target to be strengthened once they are accounted for in policy-frameworks – ie the target is a minimum.

These points are discussed in more detail on pages 8 and 9 below.

Fiscal Measures

In fact, the Response and MACC Report do discuss demand levers: Capacity Constraint (where no further incremental expansion of airports is allowed) and two behavior-change incentives that have a very small effect. The analysis is, glaringly, missing any discussion of fiscal measures. The reason for this omission is that fiscal measures are 'a matter for HM Treasury' (*Response* 1.13).

This is inadequate. Is it impossible to work cross-departmentally to develop policy? It did not seem to be at the time of the White Paper, which promised (3.42) that (as well as developing EU ETS):

the Government will continue to explore and discuss options for the use of other economic instruments for tackling aviation's greenhouse gas emissions.

Aviation fuel has long been free from fuel duty and many areas of the industry's operations are zero-rated for VAT. The combined exemptions are acknowledged to cost the Treasury around £10 billion a year.[14] Fuel tax on domestic flights could be introduced tomorrow, and between pairs of European countries by mutual agreement. A change to VAT rules or a Europe-wide fuel tax would require EU agreement, but the relevant Directives are currently up for review. Failing any more radical change, APD can be increased at will, and as European neighbours (Germany, Austria) have recently introduced similar taxes, the scope for doing so without generating leakage to other hubs is expanding.

Since increased Government revenue is counted as a benefit in the cost-benefit analysis of measures, fiscal measures that recoup some of the lost £10 billion are likely to rate as cost-effective. HM Treasury has in the past been willing to estimate the emissions savings from changes to APD.[15] (see eg Pre-Budget Report 2007).

DfT should avoid a Departmental silo approach to policy-making as it draws up the draft Sustainable Aviation framework and work with the Treasury to analyse the effectiveness of further fiscal measures to manage demand and ensure aviation makes a fair contribution to the public purse.

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[14] Treasury Minister Angela Eagle MP stated in a Commons debate on June 10, 2008 that if aviation fuel were taxed at the same rate as cars, coaches and diesel trains then it would pay an additional £6.5 billion in tax. The Transport Select Committee in 2010 calculated that removing the VAT exemption would raise another £2.3 billion. Duty free is a further effective subsidy amounting to around £1 billion. See *A new basis for aviation taxation*, Policy Studies Institute, June 2010 for details. www.psi.org.uk/pdf/ANewBasis**Aviation**Taxation-Final.pdf

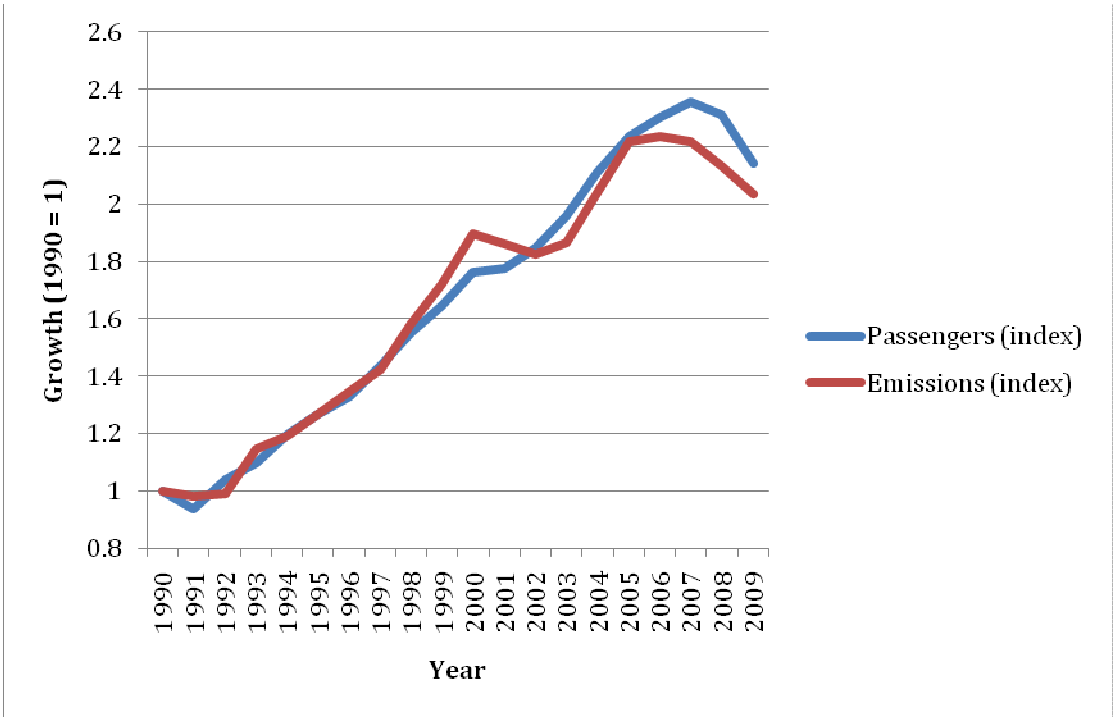
[15] eg *Pre-Budget Report 2007*, HMT October 2007, www.hm-treasury.gov.uk/pbr_csr07_repindex.htm

Projected efficiency improvements vs historic trends

The *Response* notes (para 1.4) that 'in order to grow the industry needs to create headroom by reducing its environmental impact.' Where the industry target is for no increase in emissions, this statement is literally true, and should be fundamental to the policy approach. Furthermore, an environmentally robust approach requires that this headroom should be demonstrated in practice *before* growth is allowed, as future efficiency gains are highly uncertain.

This argument has even greater force when the growth rate of passenger numbers and the growth in emissions since 1990 are compared. Despite claimed efficiency improvements over the period, it is clear that little or no 'de-coupling' has taken place.

Figure 1: Trends in UK terminal passengers and emissions from UK aviation



Source: CAA airport Statistics and UK National GHG Inventory data (DECC)

The reasons for this failure to de-couple are not clear. With the rise of (almost exclusively short-haul) low-cost carriers in the 1990s, one would expect both the average distance flown per passenger to have decreased, and the average load factor per plane to have increased – both factors that would tend to *improve* emissions per passenger.

Whatever the reasons, the historical trends clearly illustrate the danger of relying on theoretical projections of fleet efficiency improvements.

Non-CO_2 climate impacts

The *CCC Report* devoted a whole chapter to aviation's non-CO_2 effects. By contrast, they are barely mentioned in the *Response*.

Para 1.15 states that the 'analysis concentrates on reducing emissions of CO_2 as these represent the bulk of aviation's contribution to climate change.' On its own, this statement is misleading: CO_2 is responsible for around half of aviation's warming impact (see below) – hardly 'the bulk'. The picture is further confused by a footnote stating that 'CO_2 makes up 99% of the Kyoto basket of 6 greenhouse gas emissions from aviation' (note 12). While technically true, this gives the highly misleading impression that CO_2 is responsible for 99% of aviation's warming, when in fact it has very significant *non-Kyoto* warming impacts.

The Response continues:

Research to reduce uncertainties about the non-CO_2 impacts of aviation such as NO_x and water vapour is ongoing. As our understanding of the non-CO_2 effects of aviation increases we will be in a position to address their impact.

The non-CO_2 impacts, in fact, are well enough understood to factor them into policy decisions about the overall level of aviation growth. And it is only by indicating a willingness to account for these impacts that policy-makers will give the aviation industry an incentive to reduce them. The cursory treatment in the *Response* gives the impression that the issue is will continue to be studied indefinitely. Despite advances in scientific understanding, the language in 2011 is weaker than in 2003, when the White Paper was able to comment: 'While further research is needed on these issues, the broad conclusion that *emissions are significantly more damaging at altitude is clear.'* (box on p.40, emphasis added).

The *CCC Report* presented the latest scientific work, which is solidifying understanding and quantification of these impacts and also moving towards developing a policy-relevant metric to compare them to CO_2 emissions. In brief, using the Radiative Forcing Index as an emissions multiplier (as a number of environmental groups have done in the past) is incorrect, and this has allowed the industry to characterize the whole concept of 'multipliers' as unscientific. However, estimates are now available of an entirely appropriate metric, the 100-year Global Warming Potential (GWP(100)) – the metric used to weight Kyoto gases. Estimates of a GWP(100) for aviation indicate that its overall climate impact of aviation is around twice that of CO_2 alone.

In the CCC's view, these effects will in due course be sufficiently well understood to be included in policy frameworks; this implies either a reduction (potentially of a half) in the available aviation CO_2 budget, a further emissions reduction demand placed on land-based sectors, or some combination of both. The *CCC Report* concluded (page 132) that

It is reasonable to assume […] that some additional emissions reduction effort would be required in aviation.

This, then, is a further reason to take a precautionary approach to achieving the 2050 Target: there is a strong chance that it may have to be revised downward in a decade or so.

In terms of reducing the non-CO_2 impacts themselves, there are technological options to reduce NOx emissions, and operational possibilities for avoiding contrails. Despite potential trade-offs against CO_2 emissions, both are worth exploring, and the beginnings of a strategic prioritization are emerging: it is understood, for instance, that it is most worth avoiding contrails at night, when they cause the greatest warming.[16] But the *Response* gives no sense that such approaches are being evaluated, or even that they would be worthwhile. And one would hardly expect the industry to pursue them, when their current liability for contrails is nil, and that situation looks set to continue.

Treatment of EU ETS

As noted above, a UK-specific target should be in terms of absolute, not net emissions. To its credit, the bulk of the *Response* proceeds on this basis. Where it discusses the ETS, however, it takes a very 'perfect-world' view of its effects, assuming uncritically that all emissions reductions are of precisely equal robustness.

Paragraphs 2.11 and 3.13 are two sides of this coin: at 2.11 it is argued that aviation's net contribution cannot exceed the cap; at 3.13 that reductions in actual aviation CO_2 emissions have no net effect:

because an ETS cap on aviation emissions is set at the EU level [so that]reductions from within the aviation sector would reduce their [sic] demand for ETS allowances from other sectors, therefore displacing emission reductions from elsewhere within the system (rather than being additional).

This implies that the EU ETS is a sealed system, and aviation will need to purchase emissions from eg EU steel plants if its emissions grow. In practice, all sectors have access to carbon reduction credits imported into the system from Kyoto Clean Development Mechanism and Joint Implementation projects; many of these represent future emissions 'avoided' rather than directly reduced and are themselves of questionable additionality[17].
As well as questions over additionality, there are other reasons why reducing direct aviation emissions is preferable to the purchase of low-quality offsets:

- As discussed on page X above, offsets may not be readily available in the longer term, and all sectors must therefore maintain a focus on reducing direct emissions;
- most methods of reducing aviation will also reduce the associated non-CO_2 impacts.

[16] See for instance *elib.dlr.de/44088/1/Poster_avoid_TAC2006_HM.pdf*

[17] There is a sizeable literature on this point, from all points on the spectrum from anti-market climate justice campaigners to carbon investors. To select just one example, the United States Government Accountability Office reported in 2008 that 'available evidence suggests that some offset credits were awarded for projects that would have occurred even in the absence of the CDM, despite a rigorous screening process. Such projects do not represent net emission reductions and can compromise the integrity of programs--including the ETS--that allow the use of CDM credits for compliance'. See http://www.gao.gov/products/GAO-09-151

Biofuels

The measure that delivers the largest emissions reduction according to the MAC curve analysis is the mandatory uptake of biofuels (reaching 3% penetration in 2030 and 20% by 2050 in the mid policy case, as against 2.5% in the baseline forecast).[18] This policy is problematic for the following reasons:

- Biofuels are assumed to have an emissions factor of zero. Although this is in line with international carbon reporting practice (and reflected in the Climate Change Act) it is admitted to be a fiction.
- Mandatory targets risk driving the production of unsustainable biofuels, as has already happened in practice with the Renewable Transport Fuel Obligation (RTFO).

Emissions factors: it is true that the zero emissions factor is in line with IPCC, EU ETS and Climate Change Act accounting, but the justification for this choice is weak. The *Response* argues (3.22) that 'Any emissions from biofuel production and transportation would count against the emissions of the relevant sectors'. If this is the case, the capture of atmospheric carbon as the feedstock is grown should be counted as a reduction in the land-use sector of the growing country, since that is where the draw-down takes place – and it must be balanced against any increased emissions from land-use change. Other than a small adjustment to take account of the increased calorific content of synthetic fuel, the emissions of CO_2 from aircraft using biofuel are the same at the exhaust as for fossil fuel.

It would be more logical to account for emissions from the aviation sector as 1 (or 0.99), and capture benefits and disbenefits of agricultural effects in the growing country. In the absence of emissions caps in many of the developing countries where biofuels are grown, this may not be possible; an alternative would be to certify the lifecycle savings from each type of biofuel and use this factor to count emissions savings in the UK ETS and for the purposes of UK carbon accounting (with periodic checks to ensure that the rated saving is being delivered in practice).

Recognising the possibility for land-use changes to reduce life-cycle GHG savings, the *CCC Report* assumed an average 50% lifecycle GHG reduction in its analysis.

Mandatory biofuel targets: The RTFO sets mandatory targets for the biofuel percentage of road fuel at given dates. In response to criticism that this artificial stimulus was triggering a rush for unsustainable biofuels, the Government commissioned the *Gallagher Review of the indirect effects of biofuel production*[19], which reported in 2008. The Review recommended that the drive to increase biofuel blends should be slowed, until greater sustainability safeguards were in place and genuine lifecycle emissions savings were demonstrably being achieved.

At a time when many of Gallagher's recommendations have been accepted by Government, it is disconcerting to find the DfT analysing a policy that not only mandates a level of biofuel far above the business as usual level (20% in 2050 with the policy, 2.5% without) but is, by its accounting

[18] MACC Report, page 67

[19] http://webarchive.nationalarchives.gov.uk/20110407094507/http://renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf

procedure, blind to the lifecycle GHG savings (or increases) achieved by the fuel. The *Response* goes some way to acknowledging this (3.27):

Further, it is assumed that the amount of biofuel required to be available to the aviation sector in order to achieve the assumed mandated levels of take-up could be supplied sustainably. Limits to the amount of sustainable biofuel that could be supplied would result in either higher biofuel prices (thus reducing the cost-effectiveness of the policy) or would render the policy unachievable.

This fails to grasp, however, the risk that a weak definition of 'sustainable' is agreed, or that even a reasonably robust definition cannot be enforced effectively, and that the policy simply drives the use of unsustainable biofuel under a figleaf of sustainability, with consequent negative impacts on land-use change, food production and GHG emissions.

Tourism effects

The *Response* at 3.31 states that 'there could be a loss to the UK economy if tourists and business people are discouraged from travelling to the UK, but goes on to state that 'On the other hand the UK economy may benefit from UK residents spending more of their incomes in the UK rather than overseas.'

We are left with the impression that these two effects are likely to be of equal magnitude. Although they are not quantified in the underlying *MACC Report*, it should be possible to give some comment on the likely relative magnitude: in both numbers of passengers, and aggregate spending, UK travellers abroad outstrip foreign visitors, by a factor of very roughly two to one[20]. The benefits of a measure that reduced the attractiveness of flying (eg fiscal measures or capacity constraint), are therefore likely to outweigh the disbenefits to the UK economy, since reduction in outbound travel and spending is likely to outweigh reduction in inbound travel and spending.

Post-2030 – passengers and CO_2

It is stated in several places in the *Response* and *Forecasts* that 'the effects of market maturity and airport capacity constraints cause the growth of activity at UK airports to slow' in the period 2030-2050. (eg Response 2.7). Since around 10 years of growth have been lost due to the recession, it is not clear why 'market maturity' should still occur around 2030, as it did in pre-recession forecasts. In fact, the description rather overstates the slowdown that is forecast to take place – while annual percentage increases might be lower after 2030, roughly the same number of passengers is added to the airport system in the 2030's and 2040's as in previous decades.

Table 1: increase in absolute passenger numbers by decade

Year	Forecast pax (mppa)	Change over 10 years (mppa)
2010	211	n/a
2020	270	+59
2030	335	+65

[20] *International Passenger Survey*, Office of National Statistics (ongoing)

2040	405	+70
2050	470	+65

Source data: *Forecasts* table 2.11

So there is no slowdown of growth in absolute passenger numbers, and the 'slowdown' cannot be the reason why (absolute) emissions are beginning to fall by 2050. Table 3.4 (page 79) of the *Forecasts* show that the annual fleet efficiency improvement for 2040-2050 is assumed to be 2.0%, compared to 1.0% for 2020-2040. Table 3.6 shows that by 2050, over 80% of aircraft-kms will be flown by 'Future Generation' (post-2020) aircraft. While this estimate is not objectionable in itself given typical fleet roll-over times, it does illustrate the degree to which the emissions trajectory in the final years of the *Forecasts* is dependent on assumptions about the fuel efficiency of such unknown aircraft types.

An airports policy geared to achieving an emissions target with a high degree of uncertainty should recognize such uncertainties explicitly and ensure that capacity increases are conditional on delivery of the technological assumptions that underpin emissions forecasts.

Videoconferencing lever

The assessment of the potential for videoconferencing to reduce emissions is somewhat superficial and dismissive. Paragraph 3.40 reports that the

modelling suggests that this policy would not reduce emissions. The reason for this is that as airports fill up, reductions in (generally shorter) business trips frees up capacity for (generally longer) leisure trips.

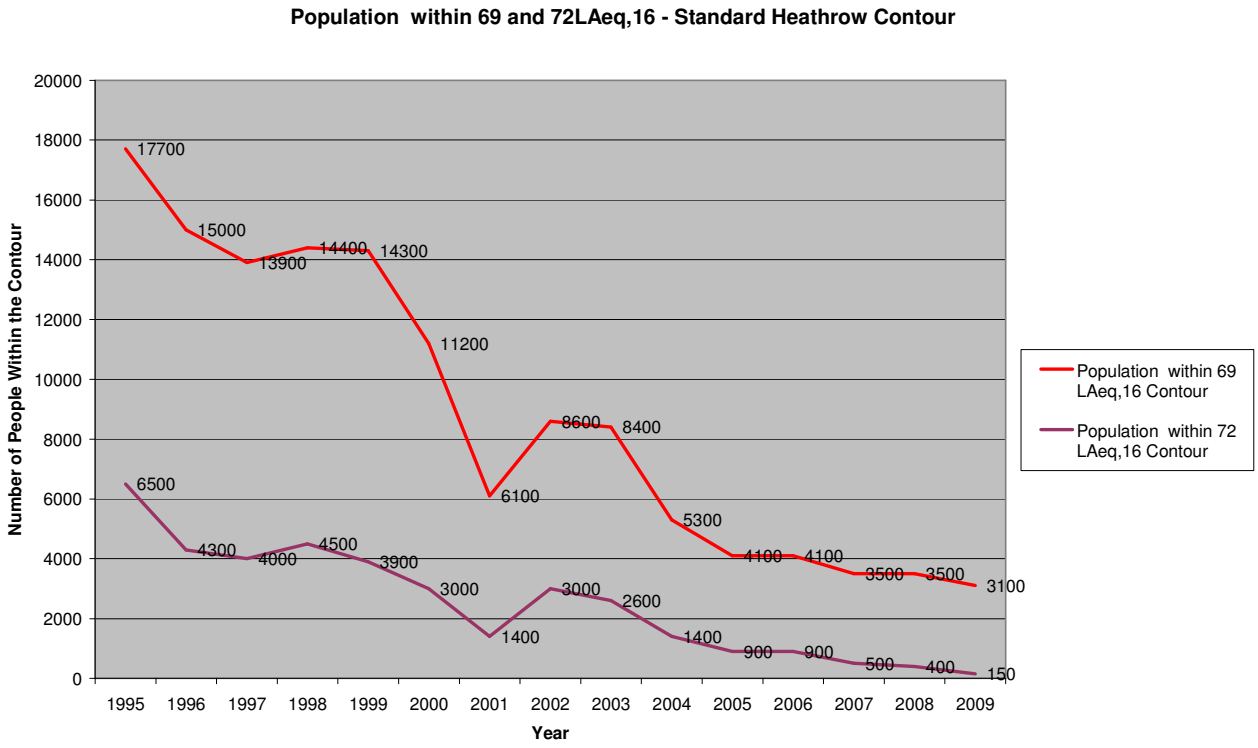
It would be helpful to have a reference to data supporting the statement about the average flight lengths of business trips and leisure trips. Even if this is the case, the financial and emissions saving from substituting a longer flight with videoconferencing is greater than that for substituting a shorter flight, so to the extent that this trend is cost- or environment-driven, the picture may not be so simple. Nor is it clear whether the higher emissions factor for business-class travel has been accounted for.

The assessment also ignores any secondary effects on airline revenues from a reduction in business travel; although the proportion will vary with the airline's business model, premium travellers make up a far greater proportion of revenues than they do passengers. A weakening of this demand may drive up leisure fares, which are subsidized by premium travellers in many airlines business models. This would tend to dampen leisure demand and offset the supposed 're-bound' effect.

Finally, no account has been taken on the significant cost-savings to companies, or the resilience benefits to the UK economy of a well-developed virtual meeting architecture as was demonstrated during the airspace shut-down from the volcanic ash cloud in 2010 – or might arise from a sustained future oil price shock.

A Review of Current Arrangements and REcommendatuions for Change

Graph 2



The Councils suggest that given this historical trend it is possible to reduce the numbers of people exposed to high levels of noise to zero.

The final timings of this objective would have to be developed in consultation with the airport operator and airlines as together they have responsibility for the aircraft fleet. However the Councils would expect:

- the direction of travel of high noise exposure to be downwards,
- no one to be exposed to noise levels greater than 72 dB,$L_{Aeq,16}$. by 2018,
- no one to be exposed to noise levels greater than 69 dB,$L_{Aeq,16}$. 2030.

In addition to improvements in the environmental performance of the fleet, other measures such as those outlined below and those within the Heathrow Noise Action Plan would drive this improvement.

Appendix 6 Slot Provision and Allocation

Question 5.26

Could existing airport capacity be more efficiently used by changing the slot allocation process, for example, if the European Commission were to alter grandfather rights? If so, what process of slot allocation should replace it?

The difficulties that have arisen over slot allocation reflect the wider problem of demand exceeding capacity at major airports. In a world of perfect competition every major airport would have sufficient slots to enable every airline to offer competing services to every destination. But that world would require a vast expansion of capacity at most major airports (i.e. well in excess of predicted demand, in order to permit competition in meeting the demand - see the seventh paragraph below in response to this question on the scope and need to carry passengers to the most popular destinations in fewer movements per day) which would be unacceptable politically even if it were viable economically and environmentally. Therefore existing capacity must be used as efficiently as possible, while reserving some capacity for resilience and minimising adverse local environmental impacts.

It is not clear whether a viable alternative to grandfather rights for the allocation of slots has been identified at national or European Union level. Slot auctioning has been mentioned, but the Department for Transport, the Civil Aviation Authority and BAA all said in their evidence to the Heathrow Terminal Five Public Inquiry that an auction would be difficult to organise and would require agreement at a higher international level than the European Union. It would therefore seem that slot allocation will continue to be based on grandfather rights for the foreseeable future and that any alternative allocation process will take many years to negotiate. The European Union should therefore consider what measures could be adopted in the short term to promote the most efficient use of slots allocated by grandfather rights, particularly the application of the "use it or lose it" rule and rules on the reallocation of surrendered slots under the EU regulation on slot allocations [21].

Competition between airlines in theory should result in the most efficient use of slots because each airline should have an interest in maximising its income from each of its slots, particularly in comparison with its competitors. But in practice competitive considerations may operate in the opposite direction. Airlines may be reluctant to make the most efficient use of their slots - e.g. by increasing the number of passengers per existing aircraft movement and/or by introducing aircraft with larger passenger capacity - if as a result they would need fewer slots than at present, because under the "use it or lose it" rule unused slots would have to be surrendered for re-distribution among competing airlines, including airlines that currently do not hold slots at the airport. We have already commented in our response to Question 5.22 above that Heathrow is operating at a much lower ratio of passengers per aircraft movement than was envisaged when planning permission was granted to develop Terminal Five. We are not aware of any explanation for this outcome, which has not been commented on even in recent debates about capacity and congestion at Heathrow. But it would seem likely that the desire of the airlines to retain most if not all of their existing slots is at least a contributing factor if not the only factor.

Taxing slots should be considered. It would add to airline costs which would be an incentive to use every slot to the maximum or to surrender slots that could not be put to maximum use. We assume that Member States have the freedom to adopt a slot tax without the need for EU co-ordination. The UK slot tax could be set at a level that would raise the shortfall between the revenue collected in air passenger duty and the value of the exemption from fuel duty and VAT that aviation enjoys (see our response to Question 5.1 above). This equation would guarantee that the total tax burden on aviation was fair. The additional revenue so raised could be used to reduce other taxes (e.g. the threshold at which income tax becomes payable, a priority for

[21] Council Regulation (EEC) No 95/93 of 18 January 1993 on common rules for the allocation of slots at Community airports

the Coalition Government that is intended to be funded in part by an increase in the taxation of aviation [22]) and need not be seen simply as a net increase in total tax revenues.

A slot tax may not be sufficient by itself to deliver the most efficient use of slots in the shortest possible time, particularly if the tax is set at a low level. It may therefore be necessary supplement a slot tax by reforming the European Union's "use it or lose it" rule. Under the present rule allocated slots must be used at least 80 per cent of the time. That may now be too lax, given the growth in air traffic since the rule was introduced in the early 1990s. A higher threshold of use should apply - at 90 per cent or even 95 per cent - for airports that are not subject to seasonal fluctuations in their volume of air traffic. This reform would promote the more frequent use of allocated slots.

At the most congested airports (including Heathrow) it is likely that slots are already in use at least 95 per cent of the time (taking into account the presumed temporary downturn in air traffic during the current economic recession). Under-utilised capacity at these airports is likely to be found only in the ratio of passengers to aircraft movement. The "use it or lose it" rule focuses entirely on whether an aircraft movement takes place at the allotted slot time, regardless of the number of passengers. As a result, the best use is not being made of Heathrow's capacity because the airlines are not carrying the number of passengers per movement that was envisaged at the time of the Terminal Five Public Inquiry (see our response to Question 5.22 above).

The "use it or lose it" rule should therefore be amended to promote the largest number of passengers in the smallest number of movements. The scope for this efficiency would be greatest on routes to the most popular destinations that have several arrivals and departures per day (including in the night period). There could be a requirement for those services to use aircraft with the largest passenger capacity and to fill the capacity in each movement to not less than a specified percentage. By increasing the number of passengers in each movement to the most popular destinations, this reform should reduce the number of daily movements to the most popular destinations and free up slots for less popular destinations that otherwise would be squeezed out [23].

Measures would have to be taken to prevent any reform of the "use it or lose it" rule from distorting the market by stimulating even more transfer passengers. The disproportionate growth in the number of transfer passengers at Heathrow since the early 1990s coincided with the introduction of the original "use it or lose it rule". The rule as drafted may inadvertently have stimulated transfers as a way that the airlines can retain all their slots without operating at a loss. The removal of the exemption of transfers from air passenger duty and the introduction of a slot tax might provide sufficient disincentive.

Reform of the EU regulation should also extend to the reallocation of surrendered slots. At Heathrow more than 95 per cent of slots are allocated from season to season on the basis of grandfather rights, with less than 5 per cent of slots reallocated from one airline to another. The EU regulation provides that surrendered slots should be reallocated to airlines that have applied for spare slots, with 50 per cent of the available slots reserved for first refusal by airlines that currently do not have any allocated slots at the airport. The process of reallocation is intended to be fair among the competing airlines and does not envisage payment in exchange for slots. But at Heathrow there is a tradition of airlines selling their slots to other airlines on a bilateral basis (i.e. not by open auction among all the airlines with an interest in acquiring the slots).

The bilateral sale of slots undermines the fair reallocation of slots provided for in the EU regulation. They may also have an anti-competitive element (e.g. the airline selling the slots may only offer them to airlines that will not offer competing services). The slots at Heathrow have become tradable assets of significant

[22] *The parties agree that the personal allowance for income tax should be increased in order to help lower and middle-income earners. … The parties agree that a switch should be made to a per-plane rather than per passenger duty; a proportion of any increased revenues over time will be used to help fund increases in personal allowance* (Coalition Agreement, 11 May 2010). The proposed switch to a per-plane tax has since been adjudged to be incompatible with international agreements. But the policy objective of increasing revenue from aviation presumably continues and could be delivered by introducing a slot tax.

[23] The number of destinations served by Heathrow has fallen by 20 per cent since 1990 despite the growth in the number of aircraft movements and passengers. The increase in the number of aircraft movements and passengers and the fall in the number of destinations can be explained only by an increase in the number of movements and passengers to the most popular destinations, with less popular destinations squeezed out.

value [24]. But their high value is in part a consequence of the relative infrequency with which they are sold, which in turn can give airlines an incentive to hang on to slots until they can get the best price. The "use it or lose" it rule can be readily circumscribed by running services in the allocated slots that under-use the capacity and would not be economically viable other than as a means of retaining the slot [25]. The EU regulation should therefore prohibit sale of slots between airlines, with all unwanted slots to be surrendered for reallocation through the process currently provided for in the regulation.

The slot reallocation rules should also be amended to include the setting of capacity and environmental conditions for reallocated slots. For example, if the slot is intended to serve the most popular destinations it could be a condition that the airline acquiring the slot will operate a higher number of passengers per movement (in absolute and relative terms) than the previous slot holder; and that the aircraft operating in the slot will operate to the lowest gaseous and noise emission standards that are commercially available when the slot is reallocated.

[24] Deloitte has valued peak-time return slots at Heathrow at £25-30 million per pair. See reference in footnote 3 below.

[25] See the article "Planes fly empty to keep slots at Heathrow" in *The Times* of 16 July 2008.

Appendix 7 Evidence on Transfer Passengers - Heathrow

Heathrow has significantly more transfer passengers than all the other main UK passenger airports combined

The proportion of transfer to terminating passengers at Heathrow is significantly higher than at any of the other airports. (source: CAA)

The question is therefore particularly relevant in considering the role of Heathrow in the Government's new aviation strategy.

The table below shows the numbers of transfer passengers at the UKs principal airports.

Transfer Passengers at UK Main Passenger Airports

Airports	***All passengers***	***Transfer passengers***	
	000's	*000's*	*%*
Heathrow (2009)	65 786	24 930	*37.9*
Gatwick (2009)	31 989	3 017	*9.4*
Stansted (2009)	19 894	1 475	*7.4*
Manchester (2009)	18 308	352	*1.9*
Birmingham (2006)	8 975	219	*2.4*
Aberdeen (2009)	2 497	211	*8.4*
Luton (2009)	9 003	208	*2.3*
Edinburgh (2009)	8 986	156	*1.7*
Glasgow (2009)	7 171	157	*2.2*
Liverpool (2007/8)	5 426	78	*1.4*
Bristol (2008)	6 170	69	*1.1*
London City (2008)	3 256	64	*2.0*
East Midlands (2006)	4 672	28	*0.6*
Belfast International (2006)	4 998	11	*0.2*
Leeds Bradford (2005)	2 514	10	*0.4*
Newcastle (2009)	4 526	7	*0.2*
Belfast City (2006)	2 095	5	*0.2*

Source: Civil Aviation Authority, *Passenger Survey Reports*

The table shows that by very large margins Heathrow has the largest number of transferring passengers (24.9 million) and the highest proportion of transferring passengers (38 per cent). Transfer passengers accounted for between 7 and 10 per cent of passengers at Aberdeen, Gatwick and Stansted. The share of transfer passengers at all other UK main passenger airports was less than 3 per cent.

Terminating and Transfer Passengers at Heathrow Airport 1972 - 2009

Year	Terminating passengers		Transfer passengers		Total passengers	
	millions	%	Millions	%	millions	%
1972	14.3	*76.4*	4.4	*23.6*	18.7	*100.0*
1978	20.8	*77.2*	6.1	*22.9*	26.9	
1984	22.6	*76.6*	6.9	*23.4*	29.5	
1987	27.0	*76.9*	8.1	*23.1*	35.1	
1991	29.8	*73.8*	10.6	*26.2*	40.4	
1996	37.3	*66.8*	18.5	*33.2*	55.8	
1997	38.6	*66.6*	19.1	*33.0*	57.9	
1998	40.6	*67.4*	19.6	*32.5*	60.3	
1999	?	?	?	?	?	
2000	44.7	*70.2*	19.0	*29.8*	63.7	
2001	41.1	*68.6*	18.8	*31.4*	59.9	
2002	39.6	*64.0*	22.3	*36.0*	61.9	
2003	40.1	*63.7*	22.8	*36.3*	62.9	
2004	43.6	*65.2*	23.3	*34.8*	66.9	
2005	43.6	*65.3*	23.2	*34.7*	66.8	
2006	44.2	*65.9*	22.9	*34.1*	67.1	
2007	44.0	*65.8*	22.9	*34.2*	66.9	
2008	43.2	*64.6*	23.6	*35.3*	66.8	
2009	40.9	*62.1*	24.9	*37.9*	65.8	*100.0*

source: Civil Aviation Authority *Passenger Surveys Reports* [26]. T

N.B The Reports for the years 1972 to 1998 give the number of terminating and transfer passengers only as percentages of the annual total number of passengers. The numbers in the table for the years to 1998 have been calculated from the percentages and the total

[26] The surveys have been undertaken annually at Heathrow since 1996, and at less frequent intervals prior to 1996. At the time this table was prepared the report for 2010 had not been published, and the report for 1999 had not been consulted, hence the data gap in the table for 1999.

number. At the time of preparing the table the Report for 1999 had not been consulted. Where the totals do not sum this is due to rounding.

The above table shows that numbers of terminating and transfer passengers have increased significantly between 1972 and 2009 (the earliest and most recent year for which data is available), with terminating passengers growing from 14.3 million to 40.9 million (growth of approximately 300 per cent) and transfer passengers growing from 4.4 million to 24.9 million (growth of approximately 450 per cent). The faster rate of growth for transfer passengers means that more than one in three passengers were transfers in 2009 compared with less than one in four in 1972, with a corresponding decline in the proportion of terminating passengers.

The table also shows that the proportion of transfer passengers at Heathrow remained constant between 1972 and 1991 at about 25 per cent, but grew steadily in the subsequent years to reach nearly 40 per cent in 2009. The disproportionate growth in transfer passengers in the mid-1990s was commented on at the Terminal Five public inquiry, but neither the Department for Transport, the Civil Aviation Authority, BAA or BA forecast that the rate of growth would continue for the following fifteen years [27]. Such growth can hardly be dismissed as "natural". The general growth in passenger numbers should have seen a gradual reduction in the number of transfers, as more airports offer more direct services, especially to the most popular destinations.

The disproportionate growth in transfer passengers in the mid-1990s was commented on at the Terminal Five public inquiry, but neither the Department for Transport, the Civil Aviation Authority, BAA or BA forecast that the rate of growth would continue for the following fifteen years [28]. Such growth can hardly be dismissed as "natural". The general growth in passenger numbers should have seen a gradual reduction in the number of transfers, as more airports offer more direct services, especially to the most popular destinations. But as indicated in the table in Annex 4 the opposite trend has applied at Heathrow, possibly stimulated by the inter-play of four related developments in the early 1990s:

- The introduction by the European Community of the "use it or lose it" rules for reallocating under-used slots between competing airlines and the impetus this gave to the airlines at Heathrow to find more passengers to fill under-utilised slots [29].

- The strategy adopted by the airlines holding slots at Heathrow to route more transfer passengers through Heathrow [30].

- The exemption for transfer passengers from air passenger duty in order to attract more transfers to Heathrow [31].

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[27] See Report to Secretary of State by Roy Vandermeer QC on the Heathrow Terminal Five Public Inquiry, *Topic Report 1: The Need for Terminal 5,* paragraphs 2.2.10 - 2.2.13 (Transfer or Interlining Traffic in Demand Forecasting).

[28] See Report to Secretary of State by Roy Vandermeer QC on the Heathrow Terminal Five Public Inquiry, *Topic Report 1: The Need for Terminal 5,* paragraphs 2.2.10 - 2.2.13 (Transfer or Interlining Traffic in Demand Forecasting).

[29] Council Regulation (EEC) No 95/93 of 18 January 1993 on common rules for the allocation of slots at Community airports.

[30] Evidence by the Department for Transport and BAA to the Heathrow Terminal Five Public Inquiry, as summarised in the Vandermeer Report, ibid., paragraph 2.2.12.

[31] *We are concerned to maintain the international position of the British air transport industry particularly that of Britain's hub airports, such as Heathrow, and to help the airlines serving them, by preventing the tax from acting as a disincentive to passengers changing planes in Britain*, Sir John Cope MP (Paymaster General), *Hansard*, 31 Jan 1994, Col. 643.

- The rapid growth in the number of movements in the period 0600-0700 hours in response at least in part to the growth in transfers [32].

As regards the benefits and disbenefits of transfer passengers to the UK, the table in Annex 1 to this response shows that in 2009 there were 24.9 million transfers at Heathrow, of whom 5.2 million (20.1 per cent) were on flights between a UK airport outside the South East and either an overseas airport or an airport in another UK region; and 19.7 million (79.1 per cent) were on flights between two overseas airports [33].

Transfer passengers at Heathrow are by definition passing through South East England en route to their ultimate destination, so they contribute little to the South East economy beyond expenditure on consumables and entertainment at the airport itself while waiting for their connecting flight. Transfer passengers flying between at least one other UK region may benefit that region, although it is arguable that the withdrawal of transfer services could stimulate more direct flights in other UK regions (see response to Question 5.20 below). Transfer passengers flying between two international airports benefit no UK region; and are a disbenefit to the extent that they cause congestion at Heathrow and are exempt from paying air passenger duty.

In the consultation document *Reform of Air Passenger Duty* (March 2011), HM Treasury argued that transfer passengers provide two related benefits for terminating passengers at Heathrow and for the UK economy:

- They enable services to be provided to destinations that would not otherwise be served and support higher frequencies to many popular destinations

- The enhanced connectivity from transfers provides an important benefit for UK passengers and the economy as a whole.

But the Treasury analysis appears to have been based on out-of-date data. The Department of Transport reported in 2009 that the number of destinations served by Heathrow had fallen by 20 per cent [34] since 1990. This decline coincided with the disproportionate increase in the number of transfers by more than 130 per cent [35]. The growth in transfers has therefore reduced rather than increased the number of destinations served by Heathrow, although it has probably increased the frequency of services to the most profitable destinations [36]. But it has not been established that the benefits of increased frequency are greater than the disbenefits of increased congestion at Heathrow from 14 million additional transfers and the loss of capacity to meet local passenger demand.

As regards transfer passengers providing enhanced connectivity, the current websites for Heathrow and Gatwick claim respectively to provide flights to "*over 180 destinations*" and "*more than 200 destinations*". Gatwick has therefore been able to surpass Heathrow's connectivity despite having

[32] The number of movements in the period 0600-0700 increased by 63 per cent between 1991 and 1996 (Vandermeer, *Topic Report 5: Noise*, paragraph 1.3.18).

[33] The numbers are derived from the table in Annex 1 to this response by assuming that all non-UK resident transfers on international flights are flying between two overseas airports and that all other transfer passengers are flying between at least one other UK airport. This may understate the number of transfers between two international flights and overstate the number of transfers between international and domestic flights.

[34] Department for Transport, *Adding Capacity at Heathrow Airport: Consultation Document*, January 2009, page 9.

[35] From 10.6 million in 1991 (figures have not been published for 1990) to 24.9 million in 2009 - see Annex 4 to this response.

[36] The number of air transport movements at Heathrow increased from 368 000 in 1990 to 460 000 in 2009, an increase of 25 per cent. It has not been established by what percentage the frequency of flights has increased to destinations served by Heathrow in 1990 and 2009.

fewer passengers overall than Heathrow; and despite having a lower ratio of transfers to terminating passengers than Heathrow [37].

The disproportionate growth in transfers since 1991 has increased congestion at Heathrow and was one of the principle arguments used by the previous Government for developing a third runway [38]. But the aviation sector will have to review its strategy of attracting an ever-increasing proportion of transfer passengers to Heathrow in the light of the present Government's decision to not support a third runway. A study for the sector forecast that if capacity constraints occurred at UK airports the airlines would aim to concentrate any loss of passengers on those who yield least revenue, identified as transfer passengers and some leisure passengers [39].

In the changed circumstances of no further expansion at Heathrow, the original reason given for exempting transfer passengers from air passenger duty - to encourage their growth at UK hub airports - is similarly no longer justified. The exemption should be withdrawn in order to give airlines an incentive to offer more direct services and to attract fewer transfer passengers.

In summary, transfer passengers in the UK are concentrated at Heathrow as a result of disproportionate growth of transfers at the airport. This growth is probably due to slot allocation distortion, exemption of transfer passengers from air passenger duty and growth in movements. Around 80% of transfers are between two overseas airports and do not benefit the UK economy. The growth has been accompanied by a decline in connectivity and the marginal benefit of higher frequency to popular destinations is unproven and seems likely to be low. The growth has been accompanied instead by congestion. APD exemption should be withdrawn so as to attract more direct flights instead of transfers.

[37] There were 32 million passengers at Gatwick in 2009, of whom 3 million (9.4 per cent) were transfers.

[38] Heathrow's passenger capacity is 90 million with two runways and would be 116 million with three runways, of whom 60 million were forecast to be transfers (i.e. more than 50 per cent).

[39] Oxford Economic Forecasting, *The Contribution of the Aviation Industry to the UK Economy*, 1999, page 45.