## Aviation Noise

Thank you for the opportunity to respond to your Discussion Paper 05: Aviation Noise.

The first part of this paper is a general discussion of aviation noise.

The second part of this paper attempts to provide answers to the questions posed in your Discussion Paper No 5.

**<u>Part 1: Discussion of Aviation noise</u>**

### Noise Certification of Aircraft

The noise certification requirements for aircraft are governed by International Treaty via the Convention on International Civil Aviation (ICAO) Annex 16, which covers noise levels from individual aircraft. The UK discharges its responsibilities regarding ICAO requirements through the Aeroplane Noise Regulations 1999, the Aeroplane Noise (Amendment) Regulations 1999 and the Air Navigation (Environmental Standards) Order 2002.

The noise index used to assess aircraft noise in the ICAO certification scheme is the effective perceived noise level (EPNL) measured in EPN dB. The derivation of EPNL is complex and uses the 1/3-octave frequency spectrum of the sound and incorporates the time during which the aircraft noise remains within 10 dB of the peak noise at the measurement position. It is very approximately equal to the conventional dB(A) level + 13dB. In the certification process the EPNL is determined under fixed flight control parameters e.g. aircraft weight, engine thrust, flap settings etc, and is measured at specified fixed positions beneath the approach and take off flight paths, and on either side of the take off flight path. These flight parameters and measurement positions are selected to standardise the measurements and although the certified EPNL noise levels can be broadly used to compare how noisy different aircraft are; the index has restricted practical use in the assessment of the environmental effects of aircraft noise i.e. in general terms the EPNL is a reasonable way of comparing how noisy different aircraft are, but has limited direct value in environmental appraisal of noise from an airport; as aircraft will often fly in a manner different from specified in the noise certification process and unlike other noise indices little research exists correlating EPNL noise levels from aircraft to effects on humans etc.

Aircraft are classified according to the noise levels they produce as per the ICAO method described above. Certification is based upon an international scale of noise level bands called ‘Chapters’ in Europe or “Stages” in North America”. Each ICAO Chapter covers a relatively wide band of noise levels. This is mainly because the noise emission of an aircraft is dependent on weight and the aircraft can be certified at several noise levels and in more than one chapter depending on the certified loading of different aircraft variants, and aircraft can be re-classified to a more stringent chapter by retro-fitting of “hush kits”. In addition, noise at ground level for the same aircraft varies depending on altitude, loading, weather and how it is flown by the pilot. As Figure 5.1 in your report shows, throughout the past 30 years improvements in aircraft technology have resulted in substantial reductions in the noise of individual aircraft and a significant minority of the current fleet already achieves a noise target better than the Chapter 3 standards. However, the rate of reduction in aircraft noise has slowed dramatically since Chapter 2 aircraft were phased out and further improvements beyond the Chapter 4 standards will probably be increasingly difficult to achieve. Unfortunately your figure 5.1 shows the relative noisiness of aircraft referenced to chapter 3 standards, and although this shows that aircraft have become significantly quieter over the last 30 years, it doesn’t indicate the reality that they are still not “quiet” or that they are unlikely to become “quiet” in the near future. This means that even though individual aircraft noise foot prints and airport noise envelopes may shrink due to more marginally quieter aircraft entering the fleet mix; or airport noise envelopes stay broadly the same size if any reduction in the noise from individual aircraft is off - set by more flights; that each over flight is still perceived as noisy to some persons on the ground.

Some commentators[1] have expressed concern about how the proposed ‘Chapter 4’ will effectively control future noise from aircraft e.g. “*The 10 dB reduction represents the sum of the noise reduction at three measurement points and could be met by a combined margin including a reduction of 2 dB at two of the three measurement points. It has been suggested that almost all aircraft currently in production can already meet the new standard and therefore the increase in stringency is not enough to promote technological advances. Furthermore, regardless of how quiet a new aeroplane may be,*

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[1] N D Porter & D P Rhodes - Aircraft Noise in London: Past, Present and Future: see http://www.caa.co.uk/docs/68/Noise_London.pdf (last viewed 2nd September 2013).

*the existing noise may not be improved until the operations of the noisier aircraft are limited*". The last sentence is important when considering that aircraft are very expensive to design and build and to purchase/lease; this means aircraft manufacturers will want a particular aircraft type to have a long product life cycle in order to recoup initial costs and make profit; and airlines will wish to see planes in use for as long as airworthy in order to be commercially attractive. This will probably encourage the continued use of noisier "ageing" aircraft even though "quieter" (although not quiet) designs may be feasible or even on the market.

In summary, it is reasonably safe to say that individual aircraft may become marginally quieter in the short to medium term future; but it is unlikely that aircraft will become quiet, if at all, until much further into the future than can currently be reliably foreseen.

**Annoyance due to Aviation Noise**

As the spread of data in figure 4.1 in your report shows, extensive research into noise annoyance[2] and disturbance over many decades has revealed that although average long-term effects e.g. annoyance, can be determined by asking a representative sample of a population to rate their individual annoyance, these responses tend to be only weakly linked with the degree of sound exposure. This modest correlation reflects very large differences between individuals' reactions to the same noise due to modifying non-acoustic factors such as attitude to the noise maker, personality traits, whether the receptor directly benefits from the noise making activity, perception of control over the noise and noise sensitivity etc. rather than a failure of experimental design. The strong influence of non-acoustic factors on the subjective response to noise means that whilst some effects have been measured and correlated well with noise levels e.g. speech disturbance and noise induced levels of hearing loss. There are some behavioural indicators which can be quantified much more weakly with noise level e.g. annoyance; that are strongly influenced by non-acoustic socio-psychological factors such as location, activity, state of well-being, familiarity with the noise, personality, environmental expectations, and attitudes to noise makers etc. Such factors typically weaken or obfuscate correlations between response and noise level. Such relationships are further complicated by variations in the actual noise exposure over time and space, because the same aircraft type is not flown identically by different pilots or by the same pilots at different airports; and individual airports don't operate in the same way for every flight or on each day; and exposed individuals tend to move around and engage in varying activities with different sensitivities to noise on different days and times; and relevant socio-psychological factors that influence the subjective response to noise for a population and for individuals can be volatile with time and location.

Whilst non-acoustic factors undoubtedly make a significant contribution to the spread of the responses to aviation noise as shown in your figure 4.1; there is also considerable doubt[3] that the "equal energy" principle as embodied by the $L_{Aeq,t}$, or similar cumulative noise energy based indices e.g. $L_{den}$, $L_{dn}$, CNEL etc. reflects similar subjective response to identical values of such a noise index in different loations; and where the noisiness of each aircraft, the duration of each over flight, and probably most importantly, the number of flights varies between airports or modes of operation of the same airport i.e. the overall cumulative noise index values are the same but the number of aircraft, degree of noise from each aircraft movement and duration of each noise event, are different. This doubt arises because sounds like aircraft noise consists of discrete often individually loud noise events interspersed by periods of relative quiet repeated over a long period e.g. 16 hours for day or 8 hours for night. For example, all other factors remaining the same, the $L_{Aeq,t}$ noise index changes by only 3 dBA for any doubling or halving of the number of noise events during the period t. Consequently, subject to a lower limit, whilst a number of aircraft movements may produce a specific overall $L_{Aeq,t}$ value, it is conceptually difficult to expect that twice this number of aircraft movement each arguably only just perceptibly 3 dBA quieter, but still noisy; will engender the same subjective response, although the value of the overall $L_{Aeq,t}$ will be identical, to the fewer number of marginally noisier aircraft.

The Figure 4.1 in your report shows how an estimate of the underlying trend between annoyance and a noise index can be developed for a population as a whole, even though the scatter of data is extensive. Consequently, noise envelopes i.e. contours, only provide indications of the likely extent and severity of the general effects of aircraft noise on communities; but due to the averaging of fluctuating impacts inherent in their production and the significant variability and volatility of individual

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[2] The WHO guidelines for Community Noise (2000) provides a definition of noise annoyance as "*a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Lindvall & Radford 1973; Koelega 1987)"*.

[3] "*I do not, however, believe that it is right to rely entirely upon the single measure of LAeq,16hour. As I have already pointed out this suffers from a number of deficiencies which, in my judgement, limit its value as a true and complete reflection of the impact of aircraft noise on those living around Heathrow*". (Roy Vandermeer, QC, Terminal Five Inspector's Report).

subjective response to noise, and the significant influence of non-acoustic factors on these traits, noise envelopes or contours cannot indicate accurately how particular individuals will react under specific circumstances. Despite these limitations, the curve in your Figure 4.1 illustrates the probable form of the relationship between noise exposure and community annoyance. It aggregates results from many surveys in different countries and is likely to be typical, if not average. In practice, accounting for the effect of non-acoustic factors and every variation in noise propagation due to changes in airport operation is probably impracticable. Not least, because the prevalence and degree of effect on individual response varies substantially, and is location and scheme specific and volatile over time. Instead, as is common for many other noise sources, these factors are taken into account to some degree by the "averaging" inherent in the development of population dose responses and using them to derive control limits. However, this means that some individuals will respond negatively to aircraft noise at levels less than control limits derived in this way. Although these negative responses occur at levels below any identified threshold for community response, these individual responses are in fact normal i.e. they are within the range of expected reaction; it's just that they are not typical responses which attract some degree of protection. However, what tends to happen in reality is that those showing atypical, but normal responses, are regarded as "unreasonable" or in some other way motivated to react adversely. This can compound their reaction, as these people can feel that they are effectively being ignored, or worse. Using supplementary noise indices, some of which may be non-acoustic may help individuals whose subjective responses lie outside the "normal" range better understand what is happening and for decision makers and airport operators to have a clearer appreciation of the scope and range of effects of aviation noise (see later).

There is now reasonable evidence available on some of the critical effects of aviation noise e.g. annoyance, sleep disturbance, speech interference and impacts on the cognitive development of children; and emerging evidence on the direct health effects of aviation noise e.g. hypertension and ischaemic heart disease. Steady state dose response relationships are reasonably well defined in some areas e.g. cross sectional dose response relationships for annoyance – although as discussed later in this paper these responses nowadays appear to be more sensitive compared to when the ANIS study which currently drives UK aviation noise policy was carried out in the mid 1980's. However, even so the trend is for aviation noise to be assessed only in terms of annoyance and sleep disturbance. Given the current state of knowledge and modern noise modelling capability, it would seem more appropriate to broaden the assessment of aviation noise to the wider range of effects about which we now have reasonable knowledge.

However, one area of particular weakness in regard to effects of aviation noise is the near absence of longitudinal studies of effects resulting from changes in aircraft noise levels and patterns of exposure. In the absence of such studies data derived from cross sectional work is often used to assess the effects of changes in aviation noise. Based on what we know about other transport noise sources e.g. road traffic; this would appear to risk under estimating effects as such an approach doesn't take into account the influence the change itself has on the subjective response; when we know that often the adverse response of a population exposed to changes in noise levels is often stronger than would be expected from simply looking at the difference in response to separate groups exposed to different noise levels that vary by the same degree as the potential change under review. The influence of change on the subjective response to noise appears to be greatest when the change is due to introduction of a new dominant noise source into an existing soundscape; compared to intensification of an already dominant noise source. The effect of change on enhancing the dose response appears weaken over time i.e. several years after change has occurred the dose response appears to shift more towards the steady state situation. Whether this is due to those exposed habituating i.e. "getting used to", the noise" or those who are most sensitive moving away and those who move to replace them never experiencing the change is unclear. The lack of longitudinal dose response relationships or consensus of opinion in regard to the effects of changes in aviation noise levels does not mean that data from cross sectional studies should not be used. However, it does mean that such data should only be used with caution and be caveated by a qualitative assessment of the associated uncertainty.

Further problems arise when noise envelopes i.e. noise contours, are the only information provided in regard to noise impacts. From a practical perspective such an approach will inevitably involve making assumptions about factors influencing aircraft noise propagation e.g. aircraft numbers, aircraft types, aircraft weight, flight paths, flight profiles, flight control settings and weather etc. With typically an average of these factors over the summer period being used in the UK. This means that the presented information is an amalgam of possible noise propagation across a range of circumstances rather than an estimate of the actual noise conditions under specific circumstances. Consequently, it is not uncommon that the noise levels experienced by those on the ground on a day to day basis can be different from those presented in the contours. Additionally, non-specialists find noise contours difficult to understand and often misinterpret the information, e.g.

- They may not understand that the individual aircraft may be significantly noisier than the overall noise level off all the aircraft time averaged over the day or night period indicated by the contour.
- They may not understand that noise levels in any "peaks" in the numbers of aircraft movements e.g. during morning and early evening "rush hours" may be higher than the overall noise level over the day or night period indicated by the contour.
- It can be unclear that the boundaries between contours are not fixed and will move from day to day or even during a single day.
- Some people think that when the contour or envelope stops that the aircraft noise will stop as well.

**Recent Developments**

Relatively recently a report entitled Attitudes to Noise from Aviation Sources in England (ANASE) study has been published. The purpose of the ANASE study was to produce an up-to-date analysis of the impacts of aircraft noise, building on previous research.

The ANASE study found that average annoyance was greater than in the previous ANIS survey. Based on the ANASE study two hypotheses" can be inferred i.e. that:

(1) $L_{Aeq,t}$ is an appropriate measure, aviator noise generates more annoyance per decibel now than in the early 1980s;

and,

(2) $L_{Aeq,t}$ is not the appropriate measure, and annoyance would correlate better with another index of aviation sound levels.

The Government had commissioned the study as it intended to review national policy in regard to noise from aircraft and wished to base any changes it might make on a robust evidential basis. Consequently, the study incorporated a significant element of peer review, one purpose of which was to provide a means of assessing just how much weight could be given to the outcomes of the study. Unfortunately, the peer review of the ANASE includes the statements that:

> " *'the results of ANASE study are inconclusive and therefore should be treated with caution. Although the issue of the noise exposure characterisation of the [Common Noise Areas] could, in theory, be resolved by using the published values, the issues raised regarding the social survey cannot be addressed without repeating the survey using a modified approach that minimises the risk of bias.*'
>
> and
>
> *"…in the first version of this review it was stated that there were sufficient technical and methodological uncertainties still remaining with the study to mean that reliance on the detailed outcome of ANASE would be misplaced. In view of developments since the review of the July 2007 version of the ANASE main report, the reviewers are even more convinced that their concerns are fully justified…*"

Other commentators have reviewed the ANASE study and strongly question its findings, e.g. Peter Brooker, "ANASE: Lessons from 'Unreliable Findings' - Proceedings of the Institute of Acoustics, Vol. 30. Pt.2. 2008.

After publication of the ANASE study and its peer review, the Government decided that at that time there was insufficient evidence to warrant a change in policy on noise from aircraft, and the previous advice of the ANIS study remains current. Consequently, Government policy as recently restated in the APF therefore remains that 57 dB $L_{Aeq\ (16\ hour)}$ marks the approximate onset of significant community annoyance from aircraft noise.

**Increased Sensitivity to Aviation Noise**

However, in rejecting the ANASE study as a basis for changes in aviation noise policy the Chief Economist stated that:

> "*The evidence in ANASE indicates, in my view, that it is highly probable that concern or annoyance with a particular level of aircraft noise is higher than found in the ANIS study in the*

*early 1980s.This finding is in line with the emerging findings from the European Commission's HYENA Study.*[4]"

Scrutiny of the final HYENA study report shows no consideration of potential changes in sensitivity to aircraft noise over time, although the preliminary results report for the project[5] states:

> "*The data supports other findings suggesting that the people's attitude towards aircraft noise has changed over the years*."

This appears to be based on several studies[6] referenced in the HYENA preliminary results report, that have drawn conclusions indicating a shift in noise annoyance to greater sensitivity in comparison to dose-response curves generated from older studies. However, detailed consideration of this matter[7] applying simple linear regression modelling and textbook statistical analyses to the reported data leads to the following conclusions:

> "*There are some indications of an upward trend in annoyance versus noise exposure over the last 25 years, but basic tests show that the statistical evidence for an upward trend is weak, and may simply be due to sampling and/or methodological differences between the studies. The survey collection method may play a role. In some cases, study participation rate effects may exaggerate community responses*."

The research referenced in the HYENA study suggests that if there has been any increase in sensitivity to aviation noise over time then the effects are small and probably related to non-acoustic factors, as implied by the comments in the *Schreckenberg & Meis* study of noise annoyance associated with a major extension of Frankfurt airport in 2005 which found:

- "*A weak non-linear relation was found between age and aircraft noise annoyance in the sense that residents between 40 – 60 yrs were more annoyed than younger and older residents. Although statistically significant, the effect size is rather small."*
- *"Education, profession and household income was summarised to an index representing the socio-economic status. This index was associated with aircraft noise annoyance, indicating that interviewees with higher socio-economic status tended to be more annoyed by aircraft noise than interviewees with lower socio-economic status. Again, the effect size is rather small"*
- *"A Somewhat higher but still weak effect on aircraft noise annoyance was found for the variable 'house ownership' That is, house owners reported somewhat higher aircraft noise annoyance than tenants."*

Recently, it has been suggested that the annoyance of residents at a given aircraft noise exposure level has increased over the years. With a major study[8] reporting a significant increase in annoyance at any given level of aircraft noise exposure; with a sharp increase in response in the mid to late 1990s coinciding with the rapid growth in low-cost airlines – although there is no evidence to suggest a causal link.

The emerging evidence that sensitivity to aircraft noise may have increased since the research underpinning the policy that an $L_{Aeq,16\,hr}$ of 57 dBA represents the onset of significant community annoyance was carried out in the early 1980's sits well with psychological concepts such as Maslow's Hierarchy of need, as built on by Inglehart, Easton and Dennis et al[9] . These theories suggest that psychological needs are hierarchically ordered, such that lower-ordered material needs for physiological survival, such as food and shelter, must be fulfilled before higher ordered psychological

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4 See http://webarchive.nationalarchives.gov.uk/20091009144441/http://www.dft.gov.uk/pgr/aviation/environmentalissues/Anase/anasechiefeconomist (Last viewed 2nd September 2013)

5 Babisch, Wolfgang; Houthuijs, Danny; Pershagen, Goran; Cadum, Ennio; Velonakis, Manolis; Katsouyanni, Klea[6]; Jarup, Lars[7]; for the HYENA group Associations between road traffic noise, aircraft noise and noise annoyance. preliminary results of the hyena study, 19th international congress on acoustics Madrid, 2-7 september 2007

6 Van Kempen E.E. M.M & Van Kamp, I. Annoyance from air traffic noise. Possible trends in exposure-response relationships, Report Nr. 01/2005 MGO Evk, RIVM, Builthoven, 2005; and Schreckenberg D & Meis M. Noise Annoyance around an International Airport Planned to be Extended. Inter-Noise 2007, Istanbul, Turkey, 2007. http://www.verkehrslaermwirkung.de/DSint07a1.pdf (Last viewed 2nd September 2013).

7 Peter Brooker, Do people react more strongly to aircraft noise today than in the past, Applied Acoustics Volume 70, Issue 5, May 2009, Pages 747–752

8 Janssen SA, Vos H, van Kempen EE, Breugelmans OR, Miedema HM. Trends in aircraft noise annoyance: the role of study and sample characteristics. J Acoust Soc Am. 2011 Apr;129(4):1953-62. doi: 10.1121/1.3533739.

9 *The Oxford Handbook of Political Behaviour: Russell J. Dalton, Hans-Dieter Klingemann (pg 192 to 193).*

non-material needs emerge e.g. self-actualisation[10]. These ideas suggest that as socio-economic conditions improve and material needs are increasingly met, indeed to the point that a significant surplus over the minimum required for mere physiological survival often occurs, then the meeting of these needs becomes taken for granted; in which case higher ordered non-materialistic psychological needs can come to the fore, placing more emphasis on matters such as environmental protection, meaning of life and self-determination. This brings about the hypothetical paradox that as we become wealthier and more people are able and need to fly, we could at the same time be becoming less tolerant of aviation noise!

**Use of the $L_{Amax}$ Index to Assess Aviation Noise Impacts**
In the UK assessment of day time aircraft noise from airports conventionally uses contours i.e. envelopes, presenting the $L_{Aeq\ (16\ hrs)}$ noise levels. These provide an estimate of the total noise from aircraft using the airport, as recommended by the UK government. This method takes into account the number of aircraft, how noisy each aircraft is and for how long the noise of each aircraft movement occurs. However, the sole use of the $L_{Aeq\ (16\ hrs)}$ index for assessment of aviation noise has been criticised and use of supplementary indices has been discussed[11].

For example, the $L_{Amax}$ is a measure of the maximum (or peak) dB (A) value of the noise of a single aircraft over flight. On approaching an observer's position, aircraft noise increases to a maximum level, before fading gradually as the aircraft moves away from the observer's position to a point where it is no longer audible. Consequently, the $L_{Amax}$ can be used as part of the assessment of aviation noise impacts as it represents the highest levels of the aircraft noise experienced; and, therefore arguably the worst case in terms of noise impact; and is a noise descriptor more easily understood by the non-acoustician than the energy average based $L_{Aeq\ (16\ hrs)}$.

Dis-advantages of using the $L_{Amax}$ noise index to asses aviation noise include that most of the total noise associated with an aircraft noise event will fall below the maximum level; that the $L_{Amax}$ represents only the loudest single noise event during the assessment period and does not take account the number of aircraft noise events or the duration of each aircraft noise event, and there is little research in to the correlation of $L_{Amax}$ with the subjective impact of aviation noise.

With the foreseeable trend for increasing numbers of flights at airport, but with marginally quieter aircraft, it should be no surprise that the noise effects of aviation expansion on already noise stressed areas is likely to remain unchanged or only changed slightly. Because, even if the increased number of flights leads to modest decreases or increases in the $L_{Amax}$ of individual air movements, as supposedly quieter Chapter 4 aircraft come to dominate the fleet mix, this will not result in any individual air movement causing less or more impact e.g. speech interference, as any reduction is unlikely to be below the speech interference threshold and any increase will not lead to more speech interference as the threshold for this effect is already exceeded. As a result, the number of air movements becomes relevant, as increasing the frequency of occurrence of aircraft movements and the overall number and frequency of occurrence of potential speech interferences each day therefore increases the probability that such effects are likely to occur. This also goes some way to explaining why existing residents affected by aviation noise sometimes acknowledge that although individual aircraft have got quieter over time; they perceive that conditions have become noisier as the number of aircraft movements has increased over the same period i.e. the noise from individual aircraft has reduced, but still causes speech interference, and the number of occurrences of interference with speech has increased.

**Use of the $L_{Aeq,t}$ Index for Assessment of Aircraft Noise**
The AFP[12], and other sources advise that aircraft noise is assessed in terms of $L_{Aeq}$, furthermore the $L_{Aeq}$ forms the basis of methods of assessing noise recommended by the Government and the World Health Organisation (WHO) and the European Union (with supplementary indices when deemed appropriate). Additionally there is a substantial body of international research which uses and corroborates the use of the $L_{eq}$ to assess aviation noise. Fields[13], in a study which examined more than 70 aircraft and railway noise surveys, found that although estimates of the impact of the number

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[10] Abraham Maslow in his article, *A Theory of Human Motivation*, explicitly defines self-actualisation as "*the desire for self-fulfillment, namely the tendency for the individual to become actualised in what s/he is potentially. This tendency might be phrased as the desire to become more and more what one is, to become everything that one is capable of becoming.*"

[11] See Foot note 3; and The CAA document CAP 725 which discusses the N70, PEI and Average Individual Exposure indices, as well as $L_{Amax}$ footprints and spot levels; additionally operational diagrams and population counts are considered. Whilst the EU Directive 2002/49/EC, relating to the assessment and management of environmental noise stipulates use of $L_{day}$, $L_{night}$ and $L_{den}$, but Annex 1 (3) provides examples of where supplementary noise indicators can be used in "special cases".

[12] Aviation Policy Framework https://www.gov.uk/government/publications/aviation-policy-framework (viewed at 2nd September 2013)

[13] Fields, James M., The effect of numbers of noise events on people's reactions to noise: An analysis of existing survey data, J. Acoust. Soc. Am.75(2), February 1984

of events differ considerably, none is significantly greater than the impact implicit in the $L_{Aeq,t}$ index. Miedema, Vos and de Jong[14] found that the trade-off between the levels of events assumed by a metric based on $L_{Aeq,t}$ is approximately correct for the prediction of annoyance caused by aircraft noise in a large study conducted around Schiphol airport in Holland. Whilst Vogt[15] found that in a laboratory assessment the effect of number of events was less than in the $L_{Aeq}$ index.

Notwithstanding the reservations in regard to other conclusions of the ANASE study it did conclude that "***Overall**, we consider that while LAeq continues to be a good proxy for measuring community annoyance…..*"[16]

On the other hand, the sole reliance on $L_{Aeq,t}$ to asses aviation noise has been criticised on the grounds that the time averaging element of the index disguises or underestimates the true impact of aircraft noise. For example, at the Public Inquiries relating to Heathrow T5, the increase in capacity at Stansted Airport, and proposed developments at several regional airports e.g. Farnborough; typically it was pointed out that a significant increase in the number of Air Traffic Movements (ATMs) would have only a small effect on the value of the $L_{Aeq}$ level, and it was suggested that the peak noise levels ($L_{max}$) of individual events and the number of flights have a bearing on the degree of perceived noise impact from such a change.

A particular point of contention in the use of the $L_{eq,t}$ to asses aviation noise, is its use for the assessment of the significance of the impact of changes in aviation noise where the time averaging period, t, is relatively longer e.g. 16 hours, than each individual noise event e.g. 15 secs to 1 minute. Conventionally, from various sources[17], the guidance on the significance of the impact of changes in a noise level can be summarised as:

- A change in noise level of 1 dB is only perceptible under controlled conditions, and;
- A change in noise level of 3 dB(A) is the minimum perceptible under normal conditions.

It has been pointed out that crucial to the interpretation of the above "rules" is an understanding of the differences between the terms noise level and noise index. If the moment to moment noise level of steady sound or the peak noise level of a specific noise event only changes by 3 dBA, then such a change is likely to be only just perceptible. Whereas, if the value of a noise index, which is a single figure means of representing a complex fluctuating pattern of noise over a defined time period, changes by 3 dB or less, then these "rules" may not be applicable. For example, where the $L_{Aeq,t}$, changes by 3 dBA due to a doubling or halving of the number of noise events in the period t, then such a change in noise events is not likely to go un-noticed; although the significance of any noticeable change will be influenced by factors including the number of noise events to begin with and the noise level of each noise event.

Before the change to use of the $L_{Aeq,t}$ to assess aviation noise in the UK in the mid 1980's, the preferred index treated the number of events in a way that increased its value by more than 3 dB per doubling e.g. the Noise and Number Index (NNI). This index used a 15 x Log N term which gave a 4.5 dB increase per doubling of noise events. However, the term in the NNI formula that accounted for noise level was insensitive to the duration of each noise event and noise events that were just under the cut-off limit, or the degree to which the peak noise level exceeded the cut-off limit. Whereas all these factors are included in the $L_{Aeq,t}$ index.

At public inquiries for various UK airport developments the application of the "rules" described above to changes in noise indices such as the $L_{Aeq,t}$ has been challenged, and evidence presented that the subjective response to changes in $L_{Aeq,t}$ noise levels containing a series of discrete noise events with a large difference between the peak and minimum noise levels is more sensitive than suggested by the "rules", particularly when the time averaging period is significantly longer than the duration of each noise event. Typically, it has been argued that a supposedly barely perceptible 3 dB reduction in noise level of each individual aircraft would permit a doubling of the number of aircraft movements within the relevant time averaging period with no change in the overall $L_{Aeq,t,}$ or increase in noise impact. Many find this counter-intuitive as a doubling of aircraft movements would tend to be clearly noticeable in a wide range of circumstances. At the Heathrow Terminal 5 inquiry an expert witness for the DfT conceded that changes in $L_{Aeq,16\ hr}$ of less than 3 dBA could be significant. For example, if a

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[14] Miedema, Henk, M.E., Vos, Henk, de Jong, Ronald G. Community reaction to aircraft noise: Time-of-day penalty and tradeoff between levels of overflights, J. Acoust. Soc. Am. 107(6), June 2000

[15] Vogt, Joachim, Kalveram, Karl Th., *Trading Level for Number of Aircraft Immissions: A full-factorial Laboratory Design*, University of Dortmund

[16] ANASE main report conclusion, paragraph 11.3.9.

[17] Glossary of the now rescinded PPG 24 and the noise sections of WEBTAG and the DMRB.

less than 3 dB change in $L_{Aeq,16\ hr}$ was due to a large increase in aircraft movements during a much shorter and sensitive part of that longer period e.g. early in the morning or late evening, being averaged over the longer 16 hour period. In which case even though the apparent variation in the $L_{Aeq,16\ hr}$ could be less than 3 dB, the increased noise impact during the shorter sensitive period could be likely to be clearly noticed by some of the persons affected.

The T5 Inspector appeared to be concerned that $L_{Aeq,\ 16hr}$ does not directly indicate the maximum noise of individual events so that it cannot indicate how many times conversation is interrupted at a particular location. This is largely true, but this is really a criticism of the presentation of the information using $L_{Aeq,\ 16hr}$, as these factors are incorporated into the index, rather than explicitly articulated by it.

Planning Inspectors have also expressed concern and even rejected the 3 dB Rule of thumb in their decisions following Public Inquiries into increased numbers of flights flights at Stansted and Farnborough airports.

Since levels of aircraft noise vary according to type, size, height and location of aircraft, the maximum noise levels at a particular location vary. As a result what matters is the extent to which people are annoyed or disturbed e.g. by interruptions to conversation, and to assess that it is necessary to balance the loudness of the event against the number of times the events of different loudness occur. Unfortunately, there is no established guidance against which to weigh these factors in isolation. Whereas these factors are fundamental components of the $L_{Aeq,t}$ index which has been correlated with the subjective impact of aviation noise via extensive cross-sectional research. However, the absence of such technical guidance doesn't mean that the number of noise events and their temporal distribution are not important factors in the decision making process as reinforced by the recently released National Planning Policy Framework - Planning Practice Guidance on noise, which states that "*for non-continuous sources of noise, the number of noise events, and the frequency and pattern of occurrence of the noise*;"[18] are among the factors that need to be taken into account when considering noise and planning.

**Supplementary Indices**

As described in section 3.24 to 3.34 of your report, recently the use of supplementary indices has been discussed[19]. The primary purpose of supplementary indices is not to facilitate the assessment of aircraft noise, which is still best done by using the noise index best correlated to the effect under consideration; but to provide a better representation of how, and to what extent, aircraft noise may affect exposed persons; for example by providing information in response to the following hypothetical questions.

- *"Where will the flight paths be?"*
- *"How many aircraft will use the flight paths?"*
- *"At what time will I get the noise – during the day, early morning, evenings or weekends?"*
- *"What will it be like on the 'bad' days?*
- *"Will I get more noise in the summer?"*
- *"Will the largest and noisiest aircraft fly over my area?"*
- *"Will I get take-offs or landings over my houses?"*
- *"When will I get a break from the noise?"*

Whilst the questions may be simple, the conventional approach of providing noise contours on their own, based on cumulative noise energy based indices, does not give explicit answers to any of them. Consequently, it has been proposed that supplementing the primary metric/s used for the assessment of aviation noise effects with other metrics should improve understanding of the impacts. Five main methods of presenting the level of aircraft noise are considered appropriate as they are readily understood by non-specialists.

These are as follows:

- Flight Paths and Movement Numbers
- Respite
- The number above a specified noise level (NA)
- The total amount of time above a specified noise level

[18] See http://planningguidance.planningportal.gov.uk/blog/guidance/noise/when-is-noise-relevant-to-planning/

[19] ERCD REPORT 0904 Metrics for Aircraft Noise K Jones R Cadoux see http://www.caa.co.uk/docs/33/ercd0904.pdf (last viewed 15th July 2013).

*Flight Paths and Movement Numbers*
When considering noise effects at their homes near airports people may examine flight path data in order to assist them with their task. It is assumed that if a property is under a flight path it will be noisy, and if not it will be quiet. Whilst this is an oversimplification of the situation the basic principle is correct. The level of air traffic utilising the different flight paths is also a major factor that will affect the level of noise received on the ground. Therefore flight path movement charts can answer questions such as “where do the aircraft fly” and “how many over flights are there”.

Unlike traditional flight path plans which show individual thin lines for each path, more useful information is provided if the paths get wider as they get further away from the airport. This displays the natural dispersion of aircraft in flight and helps dispel the myth of aircraft flying along “railway tracks in the sky”. In addition, the charts can include:

- Data for each path on the average number of daily movements;
- The number of aircraft utilising the route as a percentage of the total number of aircraft movements associated with the airport;
- The daily range (i.e. min and max) of aircraft movements along the route; and,
- The percentage of days with no movements.

However, limitations of this method have been identified. These include that there is no distinction between small and large aircraft (all are taken to be similar) and that the wider paths, showing more dispersion, are often wrongly interpreted as noisier in comparison with narrower paths where flights are concentrated over a smaller area. Another issue is that flight paths often spread much further than noise contours and even cover areas untouched by the noise contours; creating an apparent mis-match.

*Respite*
A significant issue with the use of the $L_{Aeq}$ index or similar systems is that they are based on the “equal energy” assumption that annoyance will remain the same if the number of aircraft operations are doubled so long as the individual aircraft noise levels are reduced by a marginal 3 dB. Whilst a reduction of 3 dB for an individual aircraft event may only just be noticeable, a doubling of movements is likely to have a greater effect.

With this in mind, and as the number of aircraft movements increases, as they have in recent years and are predicted to in the future, the layperson is interested to know when they will have a break from the noise, hence the idea of specifying respite.

However, where respite charts have been provided they have not been as well received as the flight path and movement charts described earlier. One criticism of the technique has been that certain areas may be close to more than one flight path. This would mean that whilst no aircraft might be operating on the nearest route to a particular location, it might still be affected by noise from activity on other routes. This problem is likely to be particularly prevalent at locations close to an airport. No obvious solution has been found for this problem

*The Number Above a specified noise level*
Due to some of the apparent shortcomings of the noise contour system, supplementary ‘Number Above’ contours have been produced. For example The N70 contour indicates the number of aircraft movements that exceed 70 dB(A) $L_{Amax}$ at a given location. Locations with similar numbers of aircraft movements that exceed 70 dB(A) $L_{Amax}$, i.e. locations with similar N70 results, are joined together to provide the various N70 contours. The 70 dB $L_{Amax}$ value has been used in Australia, a different value may be appropriate in the UK where land use and building types may be sufficiently different to justify such a choice. In order to deal with ‘sensitive times’, it may be appropriate to produce Number Above contours for these specific time periods and to use different threshold values.

One criticism of the use of Number Above metric is that it does not differentiate between aircraft events imperceptibly under or over the chosen threshold values and those of much higher levels. This could be overcome by producing higher level ‘noise above’ contours e.g. but this may lead to more confusion rather than improving clarity.

*Time Above a specified Noise Level*

This is similar to the NA index except it represents the total duration that a specified noise level is exceeded by aviation noise during a defined day or night period.

**Conclusions**

Aviation noise can cause significant disruption to the quality of life and have health impacts for many who live near airports and under flight paths, to say nothing of its effect on the value of land and property beneath.

The effects of noise can be difficult to separate from other environmental stressors and the individual sensitivity to aviation noise is highly variable and significantly influenced by non-acoustic factors, and is probably volatile over time.

In the UK aviation impacts have conventionally been achieved by establishing noise contours i.e. noise envelopes around airports using an index called $L_{eq,t}$ i.e. the Equivalent Continuous Sound Level, which is essentially the total noise energy received on the ground averaged over time. It is measured in decibels, takes into account both the noise levels of aircraft, the duration of their noise and their number, and logarithmically averages the sound energy from all aircraft movements, based on average modes of use of the airport, in a certain area over a 16 hour period, between 0700 hrs and 2300 hrs each day.

Whilst the $L_{Aeq,t}$ has been reasonably well correlated to the subjective impact of aircraft noise in the UK and abroad, with its use for aviation noise being derived through study of the disturbance ratings of people and communities exposed to aircraft noise. There remain criticisms of its sole use for the assessment of aviation noise; with strong cases being made for the use of the peak noise levels of individual aircraft movements and the number of noise events as well, although there is no current UK guidance specifically on the noise implications of changes in numbers of air movements or the significance of peak aviation noise levels. However, this information appears to be useful in articulating potential noise impacts that can be obscured by $L_{Aeq,t}$ index.

Whilst it is suspected that sensitivity to aviation noise may have increased since the 1980's when the $L_{Aeq,t}$ index was adopted for aviation noise in the UK. The precise reasons for this change and the exact degree of change that may have occurred are not currently known.

Supplementary noise indicators, such as $L_{Amax}$, SEL etc. can assist in articulating the impact of aircraft noise; but are also subject to limitations and do not replace $L_{Aeq}$ type indicators that remain the basis of aircraft noise impact assessment in the UK and internationally. These noise indices are technical acoustic parameters, and although reasonably linked to specific impacts by extensive research, they can be difficult for the non-specialist to understand. Consequently, other indicators such as respite, Number Above and Time Above appear to have a role in communicating the impact of aircraft noise, but they are subject to limitations and do not replace the technical acoustic indices that will remain the basis of the aircraft noise impact assessment, but which the public find difficult to understand.

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**Part 2: Response to Questions**

*Q What metrics or assessment methods would an appropriate 'scorecard' be based on?*

Table 1: Suggested noise metrics for aviation noise appraisal and communication with the public

| Application/ Effect | Metric | Brief Description | Unit | Relevant Time Period |
|---|---|---|---|---|
| Policy: Land Use Restrictions/Zoning i.e. the ICAO "Balanced Approach"<br><br>Annoyance | $L_{Aeq,t}$ | Continuous Equivalent Sound Level - $L_{Aeq,t}$; a cumulative noise metric based on steady state noise level over a defined period. | dBA | 16 hr Day, 8 hr Night |
| Health Impacts | $L_{den}$ | Derived from the $L_{Aeq,24hr}$ with a 5 dBA penalty during the evening and a 10 dB penalty at night. | dBA | 24 hours |
| Cognitive Development of Children | $L_{Aeq,t}$ | Continuous Equivalent Sound Level - $L_{Aeq,t}$; a cumulative noise metric based on steady state noise level over a defined period. | dBA | 16 hr Day, 8 hr Night |
| Speech interference and<br>Sleep disturbance | $L_{MAX}$ | Maximum Sound Level: highest A-weighted sound level during a distinct event | dBA | Dependent on event duration |

| | | | | |
|---|---|---|---|---|
| Sleep disturbance | SEL | Sound Exposure Level: a composite metric that captures both the intensity and duration. SEL approximates the net impact of an entire acoustic event, since it estimates on a logarithmic scale the total sound energy transmitted to a recipient during a specified event. | dBA | Dependent on event duration |
| | $L_{Aeq,t}$ | Continuous Equivalent Sound Level - $L_{Aeq,t}$; a cumulative noise metric based on steady state noise level over a defined period. | dBA | 16 h Day, 8 h Night |
| Supplemental Metrics – Public Communication | TA | Time Above noise metric: The amount of time that noise levels are greater than a given threshold. | Minutes/day | Daily |
| | NA | Number of events Above noise metric: the number of noise events exceeding a given threshold | Events/day | Daily |
| | Flight Paths | Indication of flight "corridors" i.e. where to expect aircraft over flight | Day | Day and Night - Showing different airport modes of operation not just the average |
| | Respite | Opposite of TA – time when aircraft noise less than a specified level | Minutes/day | Daily |
| | No of Movements | Number of aircraft | Day | Day and Night - Showing different airport modes of operation not just the average |

*Q To what extent is it appropriate to use multiple metrics, and would there be any issues of contradiction if this were to occur?*

Multiple noise metrics would allow different effects of noise to be appraised.

Multiple non-acoustic metrics appear useful in communicating noise effects to the public.

Apparent contradiction might arise as the spatial dispersion of different noise metrics might be different e.g. the contours for LAeq,t related to annoyance may be a different size or shape to those for SEL or LAmax for sleep disturbance.

*Q Are there additional relevant metrics to those discussed in Chapter 3 which the Commission should be aware of?*

See above.

What baseline should any noise assessment be based on? Should an assessment be based on absolute noise levels, or on changes relative to the existing noise environment?

Why not both methods? e.g. set a lower absolute limit below which effects are not expected to be significant; above which use changes relative to the existing noise environment. Also it depends on the effect being considered e.g. Annoyance – changes relative to baseline; Sleep disturbance – Absolute noise levels.

*Q How should we characterise a noise environment currently unaffected by aircraft noise?*

Using a wide range of noise indices e.g. $L_{Amax,t}$., $L_{A10,t}$., $L_{Aeq,t}$, and $L_{A90,t}$ for day, evening and night as possible. As a minimum the existing ambient noise ($L_{Aeq,t}$) for day and night, and the diurnal hourly profile of noise variation, and the hourly peak noise levels e.g. $L_{Amax}$.

*Q How could the assessment methods described in Chapter 4 be improved to better reflect noise impacts and effects?*

Consider a wider range of effects than at present e.g. annoyance, speech interference (indoors and outdoors), sleep disturbance, impacts on children's cognitive development and direct health effects.

As well as modelling airport operations averaged over a range of modes, also show the predicted noise propagation under the main specific modes of operation.

Use supplementary indices such as

- Flight Paths
- Movement Numbers
- Respite
- The number above a specified noise level (NA)
- The total amount of time above a specified noise level

*Q Is monetising noise impacts and effects a sensible approach? If so, which monetisation methods described here hold the most credibility, or are most pertinent to noise and its various effects?*

Monetising noise impacts is useful for comparison of different options for managing the noise from an airport and for the evaluation of the cost benefit or cost effectiveness of the proposal. i.e. rating the noise impacts against socio-economic benefits and health impacts. As doing so allows the benefits and dis-benefits of decision making to have a value related to society's willingness to pay for these effects. This provides "standardisation" of different effects and brings more rigour to the balancing of adverse with beneficial effects in the decision making process which can be particularly helpful where resources are limited, and where choices must be made across different policy areas i.e. economic, transport, health and environmental policies. Stated preference approaches to valuing noise are preferred as the concept appears more credible and easier to articulate than hedonic pricing.

*Q Are there any specific thresholds that significantly alter the nature of any noise assessment, e.g. a level or intermittency of noise beyond which the impact or effect significantly changes in nature?*

There are noise levels at which adverse effects start to become detectable; However, that doesn't mean that the noise has a significant effect. For example, the WHO advises that in regard to sleep disturbance an external night noise level of 40 dB $L_{Aeq,\ 8\ hours}$ is the Lowest Observed Adverse Effect Level (LOAEL – see NPSE/NPPF) i.e. an effect on brain waves during sleep can be detected. But there doesn't seem to be a significant physiological effect on sleep patterns detected until the external noise level exceeds approximately 55 dB $L_{Aeq,\ 8\ hours}$ – Significant Observed Adverse Effect Level (SOAEL). Clearly below LOAEL noise is not a material consideration; levels between LOAEL and SOAEL should be minimised; and levels above SOAEL should only be allowed where substantial other benefits arise from the scheme and local mitigation to below SOAEL e.g. sound insulation and property value and amenity compensation; are available.

*Q To what extent does introducing noise at a previously unaffected area represent more or less of an impact than increasing noise in already affected areas?*

It depends, for example.

Introducing new noise so that levels are raised above established benchmarks of significant adverse effect or more noise to an area where such established benchmarks are already exceeded, is likely to have a more significant adverse physiological or health effect than introducing noise into an area where such benchmarks are not already exceeded; albeit the acoustic amenity may be eroded to a greater degree in such locations. This would normally militate against increasing noise in already significantly affected areas.

In broad terms policy in the NPPF and NPSE suggests that avoiding or minimising adverse health effects in already noisy locations would normally outweigh avoiding or minimising impacts on the amenity or ecological value of relatively quiet areas where the choice is between introducing noise to a previously unaffected area, or increasing noise in already affected areas.

Monetising effects can help the weighing of physiological or health effects of noise against the amenity and ecological effects. The Government already has a means to do this, see http://archive.defra.gov.uk/environment/quality/noise/igcb/documents/igcb-first-report.pdf (last viewed 2nd September 2013)

*Q To what extent is the use of a noise envelope approach appropriate, and which metrics could be used effectively in this regard?*

The discussion in pt 1 of this paper highlights the drawbacks to the use of noise envelopes based solely on an overall energy based noise index such as the $L_{Aeq,t}$ or $L_{den}$. However, The use of noise envelopes is appropriate within the context of a suite of controls that includes the maximum permitted number of persons in each noise contour between 50 and 75 dBA $L_{Aeq,t}$, and the overall maximum permitted number of aircraft movements per year and the diurnal pattern of movements.

Metrics – See table 1 above; also metrics that measure the noise efficiency of an airport (as discussed from section 3.35 to 3.39 of your report) have a role in comparing the impacts of different options for airport location and operation; although their value for predicting the type, degree and spatial scope of noise effects from a specific airport or on a particular community is limited.

*Q To what extent should noise concentration and noise dispersal be used in the UK? Where and how could these techniques be deployed most effectively?*

Where practicable, noise concentration over less sensitive localities should be promoted i.e. maximise use of noise preferential routes. Where this isn't practicable we should still aim for noise concentration affecting the least number of persons practicable; and put in place local mitigation schemes e.g. noise insulation, and compensate existing noise sensitive land occupiers for loss of amenity as well as depreciation of property values; and control land use to prevent creep of noise sensitive land use into areas affected by high levels of aviation noise e.g. > 69 dB $L_{Aeq,\ 0700\ to\ 2300\ hrs}$.

*Q What constitutes best practice for noise compensation schemes abroad? and how do these compare to current UK practice? What noise assessments could be effectively utilised when constructing compensation arrangements?*

There are airport noise insulation schemes in place at all of the principal airports in England, including Heathrow, Gatwick, Stansted, Birmingham and Manchester. Many regional airports also operate such schemes. The majority of the schemes are daytime only with the qualifying criteria ranging from 55 dB $L_{Aeq\ 16h}$ at East Midlands airport to 69 dB $L_{Aeq\ 16h}$ for Heathrow. At the three airports which operate night-time insulation schemes (all are SEL based), Heathrow and Gatwick have set a qualifying level of 90 dB(A) SEL, whereas Bristol is 82 dB(A) SEL. The table below provides a snapshot of International airport noise insulation schemes NB: this is a sample of schemes accessible via the internet in 2009.

**Table 2 International Airport Noise Insulation Schemes (2009)**

| **Airport** | **Qualifying Criteria** |
|---|---|
| ***North America*** | |
| JFK, La Guardia, Newark | Schools that are in or had previously been in the 65 dBA or higher $L_{DN}$ contour |
| Oakland International | 65 dB(A) CNEL for residential properties |
| New Orleans | 65 dB(A) $L_{DN}$ for residential properties |
| San Diego | 65 dB(A) $L_{DN}$ for residential properties |
| San Francisco | 65 dB(A) CNEL |
| Los Angeles | 65 db(A) CNEL |
| Seattle/Tacoma | Sound Insulation Program in operation, information on criteria not available |
| Anchorage International | 65-69 dB(A) $L_{DN}$ for residential properties |
| Vancouver | $L_{dn}$ dB(A) 60 for continuous noise and SEL 75 for sporadic noise |
| Calgary | None. Noise issues tackled through land use control |
| Montreal | None |
| Ottawa International | According to information provided by Transport Canada, building code requirements due to the cold climate have been in place since the early 1970s and include solid core doors, weather stripping, double glazed windows and a high rating of attic and wall insulation, so there is no need for airport to have sound insulation programs. |
| Toronto | No information available |
| ***Europe*** | |
| Schipol | 58 dB(A) ($L_{den}$), 49 dB(A) ($L_{night}$) |
| Amsterdam | 63.71 dB(A) $L_{den}$<br>54.44 dB(A) $L_{night}$ |
| Charles de Gaulle | $L_{den}$ 55 dB(A) |
| Frankfurt | Noise insulation contours of the insulation programme are defined by a combination of $L_{Aeq}$ 55 dB and a max noise level of 6 x 75 dB(A). The target is to avoid noise events that regularly exceed 6 x 52 dB(A) "at the ear of a sleeping person". |

| | |
|---|---|
| Dortmund | Eligibility based on a $L_{eq}$ > 62 dB(A) 24 hour noise contour |
| Hamburg | Exceedence of $L_{eq}$ 65 dB(A), 55 dB(A) for indoor areas |
| Madrid | 65 dB(A) $L_d$, ($L_{eq}$ 0700-2300), 55 dB(A) $L_N$ ($L_{eq}$ 2300-0700) |
| Prague | 65 dB(A) $L_d$, ($L_{eq}$ 0700-2300), 55 dB(A) $L_N$ ($L_{eq}$ 2300-0700) |
| Oslo | $L_{DEN}$ >60dB outdoor and $L_{Amax}$ > 60dB indoor |
| ***Australasia*** | |
| Auckland | Existing Buildings subject to noise from aircraft operations: AIAL is required to offer acoustic treatment based on Annual Aircraft Noise Contours once Existing Buildings are within the $L_{dn}$ 60 dBA contour and $L_{dn}$ 65 dBA contour. This includes educational facilities, registered preschools, household units, child centres, hospitals, and rest homes etc. Offers in the $L_{dn}$ 60 dBA contour are 75% funded by AIAL and offers in the $L_{dn}$ 65 dBA contour are 100% funded by AIAL. |
| Sydney | ANEF 30 dB(A) for residential properties (Australian Noise Exposure Forecast) |
| Cairns International | None |
| Thailand | Higher than NEF 40 dB(A) triggers offer of compensation |
| Macau International Airport | None |
| Changi International (Singapore) | None. Noise issues tackled through land use control |

The majority of airports listed above use derivatives of the $L_{eq}$, which makes direct comparison to the UK difficult. However, the three German airports all employ $L_{eq}$ based schemes, with the criteria ranging from 55 to 65 dB(A).

It should be noted that in the USA, FAA Sound Insulation Guidelines recommend a criterion of 65 dB(A) $L_{DN}$, which is regarded as being interchangeable with 65 dB(A) CNEL. An approximate $L_{eq}$ can be derived from $L_{DN}$ by the subtraction of 10 dB. Therefore, it can be seen that the qualification level for most U.S schemes is at the lower i.e. “more generous” end of the range found in the UK e.g. approximately $L_{eq,24\ hr}$ 55 dB(A).

Whilst direct comparison of the UK range of criteria with International standards is difficult because of the difference in noise indices and time periods use. However, in broad terms the UK can be regarded as about in the middle of range of the standards used internationally; with the bottom of the range found in the UK comparing favourably with the most generous schemes worldwide, and the top of the range found in the UK approximating to the least generous schemes found internationally.

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