

Environmental Research and Consultancy Department



ERCD REPORT 0904

Metrics for Aircraft Noise

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Summary

The aim of this paper, originally produced for the Aircraft Noise Monitoring Advisory Committee (ANMAC), is to provide an overview of the current metrics used to measure aircraft noise. The review is a factual account of the methods used to measure noise internationally and outlines the main strengths and weaknesses of each metric.

The authors of this report are employed by the Civil Aviation Authority. The work reported herein was carried out for the Department for Transport. Any views expressed are not necessarily those of the Secretary of State for Transport.

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Glossary of Terms and Abbreviations

A-weighting	A frequency weighting that is applied to the electrical signal within a noise-measuring instrument as a way of simulating the way the human ear responds to a range of acoustic frequencies.
AIE	Average Individual Exposure
ANEF	Australian Noise Exposure Forecast
ANIS	Aircraft Noise Index Study
ANMAC	Aircraft Noise Monitoring Advisory Committee. The committee is chaired by the Department for Transport and comprises, among others, representatives of the airlines, Heathrow, Gatwick and Stansted airports and airport consultative committees.
(CNEL)	Californian Community Noise Exposure Level
dB	Decibel units describing sound level or changes of sound level.
dBA	Units of sound level on the A-weighted scale.
DNL	See L_{dn} .
DfT	Department for Transport (UK Government).
ERCD	Environmental Research and Consultancy Department of the Civil Aviation Authority.
ICAO	International Civil Aviation Organization.
L_A	The A-weighted sound level (in dBA).
$L_{Aeq, 16-hour}$	Equivalent sound level of aircraft noise in dBA for the 16 hour annual day. For conventional historical contours for a particular year this is based on the daily average movements that take place between 0700 and 2300 local time during the 92-day period 16 June to 15 September inclusive.
L_{Amax}	The maximum A-weighted sound level (in dBA) measured during an aircraft fly-by.
L_{day}	Equivalent sound level of aircraft noise in dBA for the 12-hour annual day (0700-1900).
L_{den}	Equivalent sound level of aircraft noise in dBA for the 24-hour annual day, evening, and night where the evening movements are weighted by 5 dB and night movements are weighted by 10 dB.
L_{dn}	24-hour L_{eq} measure with an un-weighted 11-hour daytime period (0700-2200) and a 10 dB weighting for any noise events occurring during a 9-hour night-time period (2200-0700). This metric is commonly referred to as the Day-Night Level (DNL).

L_{eq}	Equivalent sound level of aircraft noise, often called equivalent continuous sound level. L _{eq} is most often measured on the A-weighted scale, giving the abbreviation L _{Aeq} .
L_{evening}	Equivalent sound level of aircraft noise in dBA for the 4-hour annual evening (1900-2300).
L_{night}	Equivalent sound level of aircraft noise in dBA for the 8-hour annual night (2300-0700).
NEF	Noise Exposure Forecast
NNI	Noise and Number Index: the noise exposure measure that preceded L _{eq} for airport noise exposure contours in the UK.
NTK	Noise and Track Keeping monitoring system. The NTK system associates radar data from air traffic control radar with related data from both fixed (permanent) and mobile noise monitors.
PEI	Person Event Index
PNL/PNdB	Perceived Noise Level, measured in PNdB. Its measurement involves analyses of the frequency spectra of noise events as well as the maximum level.
PNLT	Tone-corrected Perceived Noise Level. PNLT is a refinement of PNL that accounts for any strong tonal content in an individual spectrum.
SEL	The Sound Exposure Level generated by a single aircraft at the measurement point, measured in dBA. This accounts for the duration of the sound as well as its intensity. (SEL is referred to as L _{AE} or L _E in some texts.)
WECPNL	Weighted Equivalent Continuous Perceived Noise Level

1 Introduction

Aircraft noise can be calculated in a number of ways that can loosely be classified into three groups of measurement types:

- i. Single event metrics: *Measurements taken to describe the noise occurring during one noise event, such as an aircraft over-flight.*
- ii. Exposure metrics: *Used to provide a description of the type of noise exposure experienced over a given period of time.*
- iii. Supplementary metrics: *Measurements often used in conjunction with the above, to provide a more meaningful depiction of the potential impact of noise exposure.*

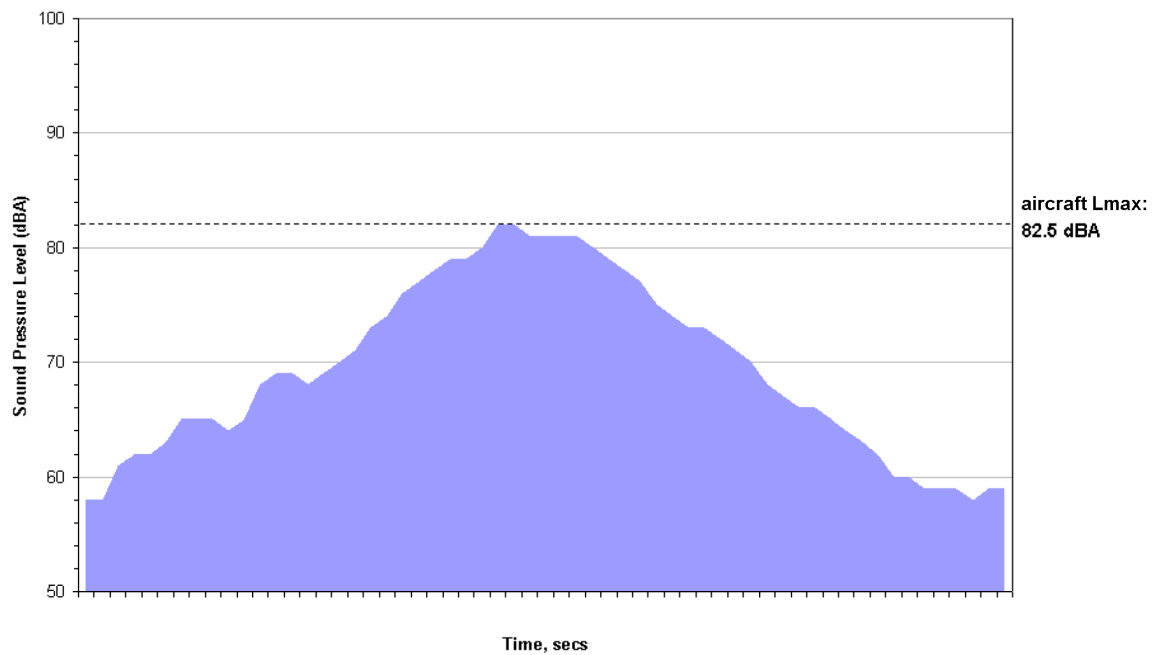
The aim of this paper is to provide a descriptive account of the metrics used to measure aircraft noise that are currently in use globally. Metrics will be grouped into the above categories for ease of classification. The list is not exhaustive, the intention being to cover the main metrics currently in use.

2 Single Event Metrics

2.1 Maximum sound level - L_{\max}

The simplest measure of a noise event such as the over-flight of an aircraft is the maximum sound level recorded. In many applications a frequency weighting is applied to approximate the measurement to the response of the human ear. Most commonly, the A-weighting is used, as in Figure 1, with the level termed L_A and measured in dBA. For aircraft noise it is usual to measure $L_{A\max}$ (which is sometimes simply referred to as L_{\max}) using the sound level meter's 'slow' response, which damps down the very rapid, largely random fluctuations of level (as opposed to the 'fast' response which causes the meter to track them). Metrics that are based on L_{\max} do not take into account the duration of the noise, and hence are possibly less representative of the disturbance due to the noise event. However, they are easier to measure and often much simpler for the public to understand.

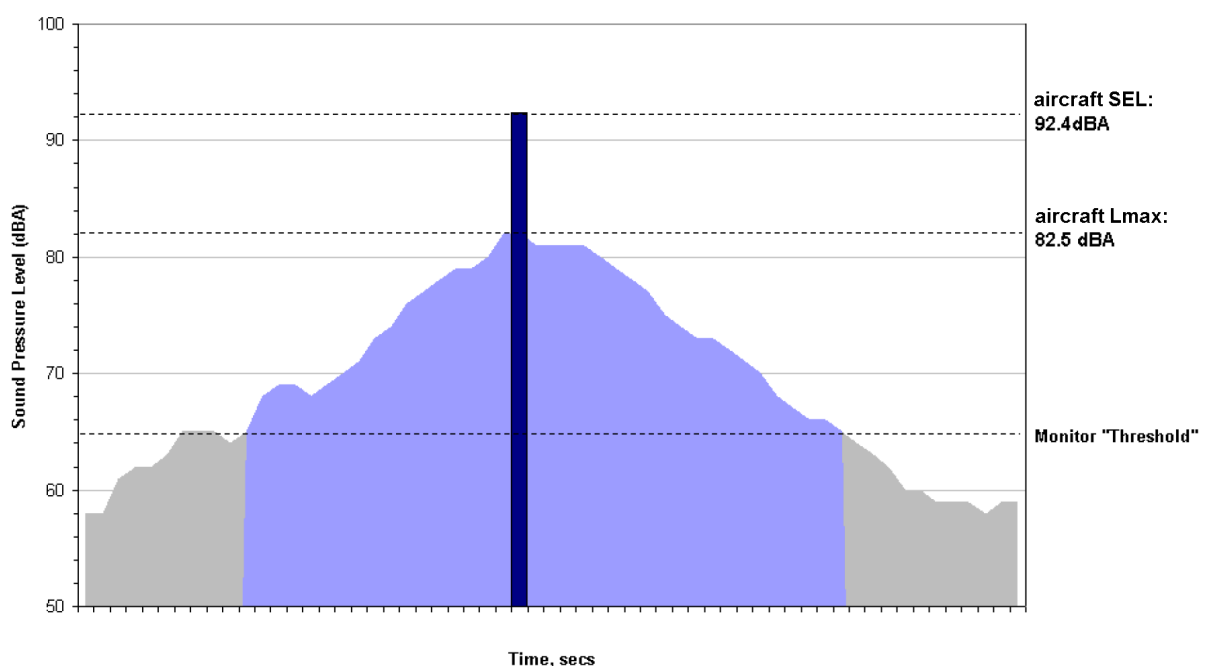
Figure 1: Graphical representation of L_{max}



2.2 Sound Exposure Level - SEL

The sound exposure level (SEL) of an aircraft noise event is the sound level, in dBA, of a one second burst of steady noise that contains the same total A-weighted sound energy as the whole event (Figure 2). In other words, it is the dBA value that would be measured if the entire event energy were uniformly compressed into a reference time of one second. Aircraft noise event SELs are usually measured using integrating sound level meters, which measure the total sound energy and normalise it to a reference duration of one second.

Figure 2: Graphical representation of SEL



Mathematically, SEL is defined as:
$$\text{SEL} = 10 \log_{10} \left\{ \frac{1}{T_{\text{ref}}} \int_0^T 10^{L(t)/10} dt \right\}$$

where $L(t)$ is the A-weighted instantaneous sound level at time t and T_{ref} is the reference duration of one second.

Most of the sound energy recorded from an aircraft is concentrated in the highest sound levels. This means that SEL values can usually be accurately estimated (to better than 0.25 dB) by including only those sounds that lie within 10 dB of $L_{A\text{max}}$. This may be impractical when measuring the noise of quieter aircraft at locations where the background noise level from other sources is relatively high. To reduce this kind of background interference, it is standard practice for airport noise monitoring systems to incorporate fixed threshold levels at which measuring instruments are triggered (as illustrated on Figure 2). For a constant level sound event, the SEL increases by 3 dB if the duration is doubled, because the energy is doubled. As most aircraft noise events have durations significantly greater than the reference time of one second, their SEL values are invariably numerically greater than $L_{A\text{max}}$ - typically by around 10 dB.

2.3 Perceived Noise Level - PNL

Different types of aircraft such as jets, propeller driven aircraft and helicopters all have distinctive noise characteristics due to particular combinations of sound from different sources having different frequency ranges, intensities and time histories. The 'annoying' characteristics of the noise event perceived by an observer as an individual aircraft passes nearby are described by its noisiness rather than its loudness and researchers in the 1950s/1960s concluded that simple weighted sound level measures did not adequately reflect these characteristics. Thus, to capture more completely the complex signature of aircraft noise, a special scale was developed: Perceived Noise Level, PNL, expressed in PNdB units.

Perceived noisiness is defined as a measure of how unwanted, objectionable, disturbing or unpleasant the sound is. Like L_A , the PNL scale allows for different human sensitivity to different frequencies but it is more complicated. PNL is determined by a combination of measurement and mathematical calculation, involving spectral analysis. The spectrum of a sound illustrates how its energy is distributed across the audible range of frequencies (approximately 20 to 20,000 Hz); to determine PNL it is measured with a sound level meter equipped with electronic 1/3-octave filters. Each frequency band level in the spectrum is converted to a noisiness value and these are summed in a special way to obtain the total noisiness of the sound. As originally used, a single value of PNL for the event was recorded - an instantaneous maximum value, PNL_{max} .

Because of the different ways of processing the frequency distribution of energy, there is no simple relationship between L_A and PNL; it varies from event to event. Nevertheless, in practice there is a fairly high correlation between the two measures and, approximately,

$$\text{PNL}_{\text{max}} \approx L_{A\text{max}} + 13$$

The rationale for using the value of 13 dB was taken from studies referenced in the ICAO Circular 205 "Recommended method for computing noise contours around airports" (**Ref 1**), which provided the constant values to be added to obtain PNL from dBA. The exact correction figure depends on factors such as aircraft type, operational characteristics, meteorological conditions and the distance from the aircraft flight path.

It should be noted, however, that although this figure was reached following a number of observations, it is an approximate correction and in one of the studies, the constant was observed to range between 8 dB and 13 dB. A considerable range of possible constants was also observed in a study carried out by NASA in 1968 (**Ref 2**), which averaged more than 4,000 flyovers measured in an area within a 19.3 km radius of an aerodrome. The standard deviation observed here for the constant value to obtain PNL from dBA was given as 2.2, and 3.0 for obtaining PNLT from dBA.

2.4 Effective Perceived Noise Level - EPNL

The noise made by a passing aircraft is complicated by its motion, which causes its intensity and frequency composition to change with time. Much research into human perception of aircraft noise led to the conclusion that PNL did not adequately reflect the true noisiness of a complete aircraft event unless account was also taken of the effects of both tones and duration. Sounds that exhibit distinct whistles and whines and/or have longer durations proved to be more annoying than simple PNL measures indicate. The modified scale developed to accommodate these parameters is EPNL, which continues to be used for setting the international noise standards by which the noise performance of jet (and most other large) aircraft is assessed in the process of noise certification (**Ref 3**).

The calculation of EPNL involves the measurement of a sequence of 1/3-octave band spectra at 1/2-second intervals during the noise event, that event being tightly controlled (for certification testing) through defined operating procedures and test conditions. Each individual spectrum is examined using a specified process for the presence of tones, identified by 'spikes', for which a tone-correction is computed. This is a penalty added to the PNL calculated for that individual spectrum to give the so-called tone-corrected perceived noise level or PNLT. To determine EPNL, the complete set of 1/2-second PNLT values is then aggregated (mathematically integrated) in order to determine the level of the 10-second long steady sound which would have the same perceived noisiness (a similar process to the integration of L_A to obtain SEL). For EPNL, the reference duration T_{ref} is 10 seconds rather than one second; this means that EPNL is numerically quite close to the maximum value of PNLT during the event.

2.5 Relationship between EPNL and SEL

EPNL and SEL both involve the integration of noise energy over a time period, which is then normalised with respect to a reference duration. For EPNL, the reference duration is 10 seconds, whereas SELs are normalised to one second. The rationale for normalising EPNLs to 10 seconds is to penalise those aircraft that make a lot of noise for a relatively long time (i.e. 10 seconds is considered to be the baseline duration for a typical aircraft fly-past at the certification measurement points). Either metric can be used to compare the energy of noise events that have different time durations, although it should of course be remembered that without additional information the actual duration is unknown.

However, the key differences between the EPNL and SEL metrics lie in two areas: (i) EPNL imparts greater subjective emphasis to energy at frequencies above 1 kHz, and (ii) it applies a tone correction, or 'penalty', in proportion to the protrusion of any discrete frequencies above the adjacent 1/3-octave band levels.

The tone correction in EPNL was originally introduced because early jet aircraft engines generated extremely high (and therefore annoying) fan and turbine tone levels. 'Simpler' metrics such as SEL were not thought to fully reflect these annoying tone levels. However, for modern engines, the corrections tend to be zero or small so that, although EPNL values remain numerically larger than SELs, the differences are fairly consistent across a wide range of current aircraft types.

Analysis of NTK noise data collected as part of the Quota Count Validation Study (Ref 4) indicates that EPNL is typically around 3 to 5 dB higher than SEL, on average, for the same aircraft noise event, although it should be noted that there is no direct mathematical relationship between the two metrics.

3 Exposure Metrics

3.1 Noise and Number Index (NNI)

NNI was used for nearly 30 years in the UK from 1963 before being replaced by L_{Aeq} in 1990. It is based on the average aircraft noise levels in PNdB and the number of aircraft movements. NNI represents a composite level measure of exposure to aircraft noise taking into account the average event noise level and the number of aircraft in a specific period (0700-1900 local time). NNI was established by means of social surveys and noise measurements. Social surveys measured, amongst other things, the annoyance from aircraft noise expressed by a sample of individuals living at different places around Heathrow. Noise data were then matched to this reported disturbance, measured by scales constructed from the social survey data. Therefore, physical noise variables could be combined in an empirical form, the NNI. NNI provides a way of estimating the total disturbance at the time of the surveys, and a way of estimating the disturbance resulting from a change in the scale or pattern of airport operations.

The NNI formula is:

$$NNI = L + 15\log_{10}N - 80$$

where L is the logarithmic average aircraft noise level (PNdB) heard and N is the number of aircraft heard during the day. For both terms "heard" is defined as events of 80 PNdB or above. The logarithm (base 10) means that an equal proportional change in the number of aircraft produces an equal step in NNI. The factor '15' indicates the relative importance i.e. the 'trade-off' between the effects of noise level and number. Due to both of these terms being included, the highest disturbance through high NNI generally corresponds to large numbers of high noise level aircraft; high noise levels for a few aircraft therefore produce 'moderate' rather than high NNI. An NNI of 55 was used to indicate a high annoyance area and NNI = 35 was used to indicate the threshold of community annoyance.

The main criticisms of NNI were that it was out of date; that people's reactions and the change in attitudes to aircraft traffic and noise invalidated its use. It was also considered to be out of line with the metrics used by other countries, and therefore was not standardised. The weighting was not thought to be sufficient for the number of aircraft, and because the noise level and number are not averages from all aircraft (only those above the 80 PNdB cut-off) including all aircraft in this count would constitute a better match with annoyance. A final main criticism of the NNI index was that not including movements during the night led to an underestimate of disturbance.

3.2 From NNI to L_{eq}

The Department of Transport commissioned the CAA to carry out the Aircraft Noise Index Study (ANIS) in 1982, to address some of the concerns about the NNI and to assess whether it was still a valid indicator of annoyance from aircraft noise. The results of ANIS suggested that the trade-off factor of 15 in the NNI was not substantiated, as it placed too much emphasis on the number of aircraft (Ref 5). It was suggested that a value of 9 or 10 would be more appropriate, and that the noise events below 80 PNdB (the noise level cut-off), should be included in the calculation for an index. Furthermore, aircraft movements outside daytime hours should be included in the index, but not weighted to be more severe in their relative effect than the daytime movements. A major concern was that continued use of the NNI would tend to lead to overestimation of the extent of environmental improvements through the introduction of more, but less noisy aircraft, which would not contribute to the NNI because of the 80 PNdB cut-off.

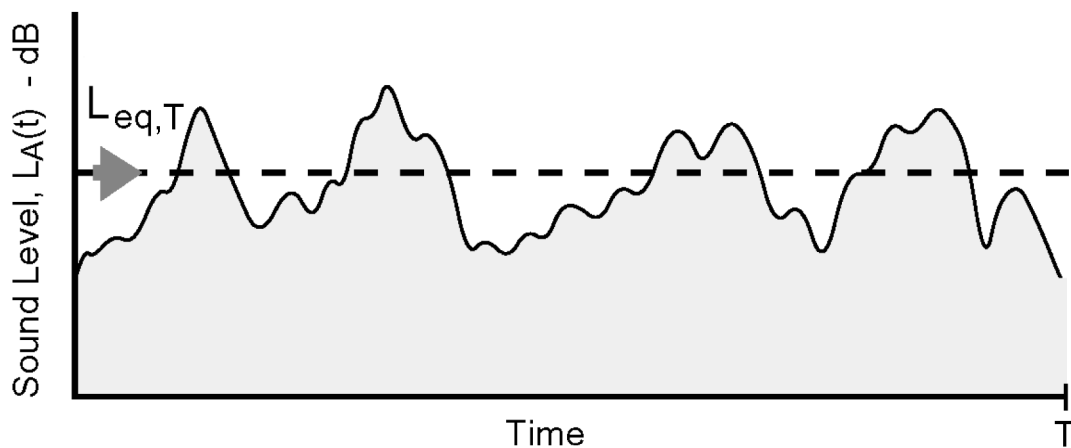
It was concluded that a more suitable fit to disturbance responses was given by the 24 hour L_{eq} i.e. the average noise over the whole 24 hours, with a L_{eq} of 55 dB representing the onset of community disturbance and 70 dB L_{eq} signifying a point of high disturbance levels. The averaging of L_{eq} was found to be statistically preferable to L_{eq} calculated on a worst mode basis (which assumes that the runway is operated solely in the worst direction in noise terms for each respondent).

Following the publication of the ANIS report, the Department of Transport undertook a substantial formal consultation on a proposal to change from NNI to L_{eq} as the index for monitoring aircraft noise exposure for the designated airports. The results of the consultation showed substantial support for the adoption of L_{eq} with many advantages being recognised. However, many consultees expressed reservations about the details - in particular, the time-of-day factor. ANIS revealed no better predictor of annoyance than $L_{eq, 24 \text{ hours}}$. However the consultation indicated that the adoption of a 24-hour index was seen to be too radical a change from the 12-hour period specified for NNI and, without special weightings for evening and night-time periods, would not recognise the somewhat different considerations applying to evaluation of noise outside the 'working day' period. Consultees were, in general, against moving to a 24-hour L_{eq} index. ANIS had shown that, as a predictor of annoyance, $L_{eq, 16 \text{ hour}}$ was statistically indistinguishable from $L_{eq, 24 \text{ hour}}$, while most aircraft movements occur between the hours of 0700 and 2300. The conclusion was to adopt $L_{eq, 16 \text{ hour}}$ for the period 0700 to 2300 as the aircraft noise index. Furthermore, the Government decided that 57 dBA $L_{eq, 16 \text{ hour}}$ should mark the approximate onset of significant community annoyance.

3.3 Equivalent continuous sound level - L_{eq}

L_{eq} can be defined as the hypothetical steady sound, which contains the same sound energy as the actual variable sound, over a defined measurement period, T (Figure 3). L_{eq} is the most commonly used noise descriptor for all types of noise source, and for aircraft noise its use is widespread across the world. L_{eq} is most often measured on the A-weighted scale, and usually with the averaging time indicated in the format, giving for example the abbreviation $L_{Aeq, 16 \text{ hour}}$. For a constant level sound event, the L_{eq} remains unchanged if the duration is doubled, because the average energy is the same.

Figure 3: Graphical representation of L_{eq}



Aircraft noise is composed of individual noise events, therefore L_{eq} can be expressed in terms of the number of events N that occur during the measurement period T , and their logarithmic average Sound Exposure Level (SEL):

$$L_{eq} = \text{Average SEL} + 10\log_{10}N - 10\log_{10}T$$

$$\text{where the average SEL is: } \overline{\text{SEL}} = 10\log_{10} \left[\frac{1}{N} \sum 10^{\text{SEL}_i/10} \right]$$

In the term $10\log_{10}N$, the use of 10 as the coefficient gives an energetic summation of noise events, i.e. doubling the number of events increases the overall L_{eq} by 3 dB, since $10\log_{10}2 = 3$. This number coefficient is often referred to as the ‘trade-off’ factor, as it determines how many less noisy events can be ‘traded’ for one event at a higher noise level.

L_{eq} is a measure of average (A-weighted) sound energy, which involves no empirical adjustments other than the A frequency weighting. L_{eq} can be measured or calculated in a variety of ways. The total noise exposure is measured if the meter runs continuously during the measurement period. If it is desired to monitor only the contribution of aircraft noise to the total, as aircraft events are discontinuous, the meter (or rather the integration process) can be programmed to attempt to operate only when aircraft noise is controlling the overall sound level. When individual aircraft noise levels are higher than those due to other sources this is often readily accomplished with automatic noise monitoring systems by choosing a suitable threshold level to trigger the integration.

The above equation for L_{eq} requires that the SEL is a logarithmic average rather than an arithmetic one, since decibels are measured on a logarithmic scale. This is particularly important with respect to aircraft noise because of the wide variation in noise levels between noisier and quieter aircraft noise events. By means of an example, consider three noise events of 70, 80 and 90 dB SEL. The arithmetic average is simply the sum divided by the number of events or:

$$\overline{SEL} = (1/N) \sum SEL_i = 80\text{dB}$$

For the logarithmic average SEL, the anti-log is taken of each of the level of each event (in bels); these are then summed and divided by the number of events and then the logarithm taken, i.e.:

$$\overline{SEL} = 10 \log_{10} \left[(1/N) \sum 10^{SEL_i/10} \right] = 85.7\text{dB}$$

Thus, arithmetic and logarithmic average SEL levels are typically quite different. Additionally, the difference between the two is not necessarily constant. The range of SEL values measured from aircraft will tend to increase with distance from an airport, one factor being the increasing difference in height between the fastest and slowest climbing aircraft, which increases with distance from an airport.

The UK uses the noise exposure index $L_{Aeq, 16 \text{ hour}}$, covering the day period 0700-2300 (local time). $L_{Aeq, 24 \text{ hour}}$ represents the noise exposure index over the entire 24-hour period. $L_{Aeq, 1 \text{ hour}}$ has been used to describe noise levels around Lisbon Airport, and L_{Aeq} is used in the Ukraine for day and night periods. The Netherlands also uses a L_{Aeq} approach to model night-time noise.

4 Variations of L_{eq}

4.1 L_{night}

L_{night} represents the noise exposure index over the night-time period, typically 2300-0700. Measures of L_{night} have been used to assess night flying restrictions, but this metric is not widely used.

4.2 Day-Night Level - L_{dn} (also referred to as DNL)

L_{dn} is a 24-hour L_{eq} measure with a 10 dB weighting for any noise events occurring during night-time (2200-0700), when it is considered that people's sensitivity to noise is heightened. There is a split of 15 hours for the daytime and 9 hours for night-time. No weightings are applied to the day and evening periods. This metric is currently used in the United States, Belgium and New Zealand.

4.3 **Day-Evening-Night Level - L_{den}**

L_{den} is similar to L_{dn} , except that it essentially adds an extra weighting, of 5 dB, to aircraft noise levels occurring in the evening. It has three component parts: L_{day} measured over a 12 hour day period from 0700 to 1900 (the same as L_{eq} for that period), $L_{evening}$ measured over a 4 hour evening period from 1900 to 2300, and L_{night} measured over an 8 hour night period from 2300 to 0700 (all times local). Countries currently using this metric include Denmark and Finland, and it is the metric specified for the environmental noise maps produced under the European Noise Directive (Directive 2002/49/EC). The default day/evening/night time periods in the EU Directive are 0700 to 1900, 1900 to 2300 and 2300 to 0700, but Member States are allowed to shorten the evening period by one or two hours if they wish to and lengthen the day and/or the night period accordingly.

4.4 **Störindex, Q**

The German Störindex 'Q' is similar to L_{dn} but gives a greater emphasis to the number factor (trade-off factor ≈ 13.3) and less to the night-time weighting (5 dB penalty only). Luxembourg has also adopted this noise metric.

4.5 **L_{VA}**

This metric is used in Italy, as an Equivalent Continuous Sound Level. A 10 dB-weighting factor is applied to night movements.

4.6 **FBN**

The Swedish equivalent of L_{eq} , this metric includes a nine-hour night period (2200-0700), with a weighting of 10 dB and a three-hour evening period (1900-2200) with a weighting of 4.78 dB. Using 4.78 dB gives a numerical weighting on the number of flights of exactly 3, whereas the 5 dB weighting in L_{den} effectively makes one evening flight count as 3.162 day flights.

4.7 **Californian Community Noise Exposure Level (CNEL)**

This metric uses the same parameters as FBN, with a twelve-hour day, nine-hour night period, and three-hour evening period. The evening period also has a weighting of 4.78 dB.

4.8 **EFN**

Equivalent Aircraft Noise (EFN) is Norway's L_{eq} based metric. It is a composite index based on the equivalent continuous A-weighted sound level comparable to L_{den} but including a continuous time weighting factor. This applies the commonly used night weighting factor of 10 but avoids discontinuities at the beginning and end of the night period. In addition, a Sunday daytime penalty is introduced. These functions are based on considerations of both sleep disturbance and annoyance.

4.9 **Hourly L_{eq} around the shoulder hours**

In civil airports in Switzerland, the 16-hour L_{eq} is used (0600-2200) for the daytime, whereas for the night-time three one-hour L_{eq} values apply, for 2200-2300, 2300-2400 and 0500-0600. The one-hour L_{eqs} at night have a twofold function: they impose a limitation of the maximum allowable noise from a single event to minimise sleep disturbance, whilst on the other hand they are also sensitive to the number of movements.

5 Other Noise Exposure Metrics

5.1 Noise Exposure Forecast - NEF

The NEF descriptor was originally derived by the USA in the 1960s to make Noise Exposure Forecasts for commercial airports. It combines the sound level expressed in EPNL with the number of events. A trade-off factor of 16.7 is applied to night-time operations only (10 for daytime movements). Similar to NNI, only events above a certain EPNL level are taken into account. NEF is used in Canada, Hong Kong, Spain and Greece. A practical disadvantage of NEF is the difficulty of routine noise monitoring in EPNL. Australia uses a modified version of NEF, the Australian Noise Exposure Forecast (ANEF), which incorporates a weighting for the period 1900-0700. The line for acceptability of residential building construction was drawn at a level that corresponded to the 10% 'seriously affected' level in the dose/response relationship established in a socio-acoustic survey study conducted in 1980.

5.2 Weighted Equivalent Continuous Perceived Noise Level - WECPNL

WECPNL may be considered as a hybrid of EPNL, since it incorporates EPNL, which is tone and duration corrected, but also includes a time-of-day energy average, and a seasonal correction based on temperature. Japan was one of the few countries that adopted WECPNL, but is now moving towards an L_{eq} based metric.

5.3 Kosten Index - Ke

Until 2003, the Netherlands employed the Kosten Index, Ke; a noise metric founded on L_{Amax} . In February 2003, a new Aviation Act came into effect for Schiphol Airport and L_{den} replaced the Kosten Index. L_{night} (2300-0700) also replaced L_{eq} (2300-0600) as the night-time index.

5.4 Psophic Index - IP

The Psophic Index (IP) was used in France until April 2002, and was based on the PNL scale, with night-time movements weighted by a 10 dB factor, and with a trade-off factor of 10. The IP method was also used in French-speaking areas of Belgium. Since 2002, L_{den} has replaced the Psophic Index. In France, the day-time period is 0600-1800, evening is 1800-2200 and the night-time period is 2200-0600.

6 Supplementary Metrics

6.1 L_{90} and L_{10}

The levels of individual noise events are required for many purposes, including aircraft noise certification. However, in order to assess environmental noise exposure, it is necessary to consider and take account of many events over a longer term, events that may differ in magnitude and be either repetitive or isolated. Long-term noise exposure levels have been quantified in a variety of ways. These ways have been dictated partly by available instrumentation and partly by the nature of the events and their relationship to background levels, which are in turn controlled by other sources. One such measure is L_n , the A-weighted sound level exceeded for n% of the measurement period. For example, in situations where the instantaneous sound level is continuously fluctuating, L_{90} and L_{10} can be used to characterise background and typical high levels respectively. In the UK, a particular version of

L_{10} is used to specify levels of exposure to road traffic noise. Nowadays however, the most commonly used noise exposure measure for all sources is L_{eq} and, for aircraft noise, this is in widespread use around the world.

6.2 N_{70}

In order to provide more meaningful information on the levels of aircraft noise exposure to the Australian public, the N_{70} metric was devised to represent 'Number Above' contours, combining information on single event noise levels with aircraft movement numbers (**Ref 6**). The N_{70} contour maps showing the number of aircraft events louder than 70 dBA were produced using the United States Federal Aviation Administration's (FAA) Integrated Noise Model (INM). The N_{70} is useful to the layperson, as it is an arithmetic indicator. All other things being equal, if the number of aircraft movements over an area doubles, the N_{70} doubles, which is a different outcome to logarithmic indicators such as the ANEF, which are relatively insensitive to change. However, if the extra movements were of a quieter type, not exceeding 70 dBA at the location, then the N_{70} would remain unchanged. The N_{70} is also a useful metric as it permits measured noise levels to be very neatly summarised for any given period. This type of presentation can be very useful as a supplement to a L_{eq} type metric and as a communication tool.

Another weakness with this metric is that it treats a noise event at 70 dBA the same as one at 90 dBA. There are arguments that this is not important since the N_{70} is based on the concept that once a certain threshold is reached the event becomes intrusive and the actual level of the noise is not necessarily important. For example, a person may have the same reaction whether they are exposed to a noise event at 70 dBA or 80 dBA. This issue can be addressed by the production of Number Above contours for other noise levels, however producing such additional contours for regular public reporting would not necessarily assist in understanding of the noise exposure patterns, due to the multiplicity of charts that would be produced.

6.3 The Person Events Index - PEI

The PEI allows the total noise load generated by an airport to be computed by summing, over the exposed population, the total number of instances where an individual is exposed to an aircraft noise event above a specified noise level over a given period. For example, if a departure off a specific runway at an airport by a particular aircraft type leads to 20,000 people being exposed to a single event noise level greater than 70 dBA then the PEI(70) for that event would be 20,000. If there were a further similar event the PEI(70) would double to 40,000 since there would have been that number of instances where a person was exposed to a noise level louder than 70 dBA. The PEI is expressed by the formula:

$$PEI(x) = \sum P_N N$$

Where: x = the single event threshold noise level expressed in dBA

P_N = the number of persons exposed to N events $> x$ dBA

6.4 The Average Individual Exposure - AIE

The PEI does not indicate the extent to which the noise has been distributed over the exposed population. For example, an annual PEI(70) of 2 million for an airport could mean that one person has been exposed to two million events in excess of 70 dBA (assuming this were possible), or that two million people have each received

one event or it could be arrived at by any other combination of the two factors. The AIE is given by the formula:

$$\text{AIE} = \text{PEI}/\text{total exposed population}$$

7 Conclusion

L_{eq} type indicators are widely used and take into account the number of noise events, the noise energy and duration of those events. More recently introduced indicators, such as N_{70} and PEI/AEI are useful in communicating the impact of aircraft noise but are subject to limitations and do not replace L_{eq} type indicators that remain the basis of aircraft noise impact assessment in the UK and internationally.

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