Noise Metrics Guidance

CAP 2598

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Contents

List of Figures

Abstract

Noise is an inherent part of daily life in a developed society, and, for many, the noise produced by aircraft is as well. Aviation noise has a significant impact upon the living-standard of people under flight-paths world-wide. As the UK's aviation regulator, the Civil Aviation Authority (CAA) has a remit to provide transparent and reliable information and research on noise in the UK. It is therefore essential that we communicate *how* we measure noise impact to important parties, including airports and community groups near airports. In doing so, we ensure that the information and research produced by the CAA remains accessible to everyone.

This document explores 'noise metrics', which are commonly used in the UK to understand and assess aviation noise impacts. The document also provides definitions for common terms and indices within the aviation industry and explores the visual representations of aviation noise, such as graphics and charts. This document ultimately serves as a resource to improve engagement with stakeholders and the wider community by enhancing noise metrics comprehension.

The document was produced as part of a request made by the Department for Transport (DfT) after the CAA assumed the technical, research and policy functions of the Independent Commission on Civil Aviation Noise (ICCAN) following its dissolution in September 2021.

Introduction

1.1 Noise is defined as unwanted and/or harmful sound.[1]

1.2 Aviation noise is a key environmental concern for communities in the vicinity of airports and other aviation-related activities, as well as for wider public health, as it can negatively affect human health and wellbeing.

1.3 According to the World Health Organisation (WHO), 25% of the burden of diseases are linked to environmental risks. 'Widespread exposure to environmental noise from road, rail, airports and industrial sites contributes to this burden'.[2] This suggests that reducing exposure to aviation noise will help improve human health and wellbeing.

1.4 The most common adverse health effects associated with aviation noise are annoyance, sleep disturbance, cardiovascular disease and cognitive impairment.

About

1.5 In 2020, ICCAN conducted a review on the monitoring and publishing aviation-related noise data. They concluded that there was a lack of transparency surrounding data collection and publishing practices. The review further recognised a need for the de-mystification of noise metrics amongst both industry leaders and people affected by noise.[3]

1.6 In response to these issues, the DfT requested that the CAA draft this noise metrics guidance document.

1.7 As the UK's aviation regulator, the CAA has a responsibility to provide guidance on best practice to those responsible for and those affected by aviation noise. This includes individuals who are unlikely to be familiar with the technical language that is common in discussions surrounding noise.

Scope & Limitations

1.8 This document is intended to improve noise metric accessibility amongst non-academic audiences. It is not intended as an evaluation of the aviation

[1] Fink, Daniel MD. A New Definition of Noise. The Hearing Journal 76(11):p 6,7, November 2023. | DOI: 10.1097/01.HJ.0000995260.15519.9e

[2] World Health Organisation, Environment and health EURO (who.int)

[3] A review of aviation noise metrics and measurement, Independent Commission on Civil Aviation Noise (ICCAN), July 2020

industry's impact or as an assessment of the CAA's approach to noise measurement.

1.9 Subsequently, although this document explains *what* metrics are used to assess noise exposure, it does not explain *why* certain metrics are calculated in the manner that they are. More information on the reasoning behind the use of these metrics can be found in ERCD REPORT 0904: Metrics for Aircraft Noise.[4]

[4] K Jones, R Cadoux (2009) ERCD REPORT 0904: Metrics for Aircraft Noise. CAA

The Fundamentals

2.1 To a layperson, ‘noise’ might seem subjective. One person might care most about the frequency of flights over their house. Another might care about the intensity of the noise. The impact of noise on humans is known as ‘noise impact’.

2.2 ‘Noise exposure’ is a physical measure of sound or noise. In contrast to ‘noise impact’, ‘noise exposure’ does not focus on human perception. This document is solely concerned with ‘noise exposure’.

2.3 Sound measurement takes many elements into consideration, such as ‘amplitude’ and ‘frequency’. Concepts such as these have a defined meaning that is important for understanding sound.

2.4 It is normal to find the concepts surrounding noise measurement confusing. Before we explain how we calculate noise metrics, it might first be beneficial to explain what these concepts mean, and what sound is.

A. What is Sound, and How Does it ‘Happen’?

2.5 The sensation of sound is triggered by pressure fluctuations in the air. These fluctuations usually originate from a vibration at the source, which in turn causes a wave of vibrations travelling through the air to the hearer’s ear drum.

2.6 Aircraft noise is one of the rare cases where the source of the noise is not vibrations, but by pressure fluctuations originating from engine blade rotation.

2.7 Although the terms ‘sound’ and ‘noise’ are often used interchangeably, ‘noise’ has a scientific definition that differs from sound. Whilst sound can typically denote any form of pressure fluctuation that reaches a person’s ear, noise denotes a sound that is considered unwanted or unpleasant by the hearer. For example, a piece of music the hearer enjoys would only be considered a sound. The sound of drilling, on the other hand, can also be considered a noise. Hence the expressions ‘sound of music’ and ‘drilling noise’.

2.8 Sound properties can be both subjective and objective. ‘Loudness’ and ‘pitch’ are subjective, as they are at least partially determined by an individual’s subjective experience. For example, as people get older, they tend to lose their ability to hear higher pitched noises. Loudness and pitch are, however, each influenced by an objective property of sound: frequency and amplitude. Frequency refers to the number of pressure fluctuations, or ‘vibration’ waves, per second, and is measured in hertz (Hz). Amplitude refers to the height of those waves and is measured in distance. A higher frequency usually results in a listener hearing a 'higher' pitch, whereas a higher amplitude tends to result in the subjective experience of a 'louder' sound for the listener. Whilst two people might disagree on the 'loudness' and 'pitch' of a sound, frequency and amplitude are always the same.[5]

2.9 Another property of sound is 'wavelength'. Whereas amplitude refers to the height of each wave, wavelength refers to the distance over which the wave's shape repeats. This is the same as the distance between each peak of the wave. If we know the frequency (the number of waves per second) and the speed that a wave is travelling at, then wavelength can be calculated using the equation wavelength = speed/frequency.

2.10 As sound always travels through ground-level air at the same speed, wavelength and frequency are directly correlated. This, of course, differs if a sound is travelling between mediums, such as through water, or between parts of the atmosphere where air density is reduced.

2.11 Figure 1 shows the difference between a low and a high pitch sound with the same volume. Whereas the wavelength (and, subsequently, frequency) of the wave has changed, the amplitude has stayed the same.

[5] F Alton Everest and Pohlmann, K.C. (2015). Master handbook of acoustics. 5th ed. New York Etc.: Mcgraw-Hill, Cop.

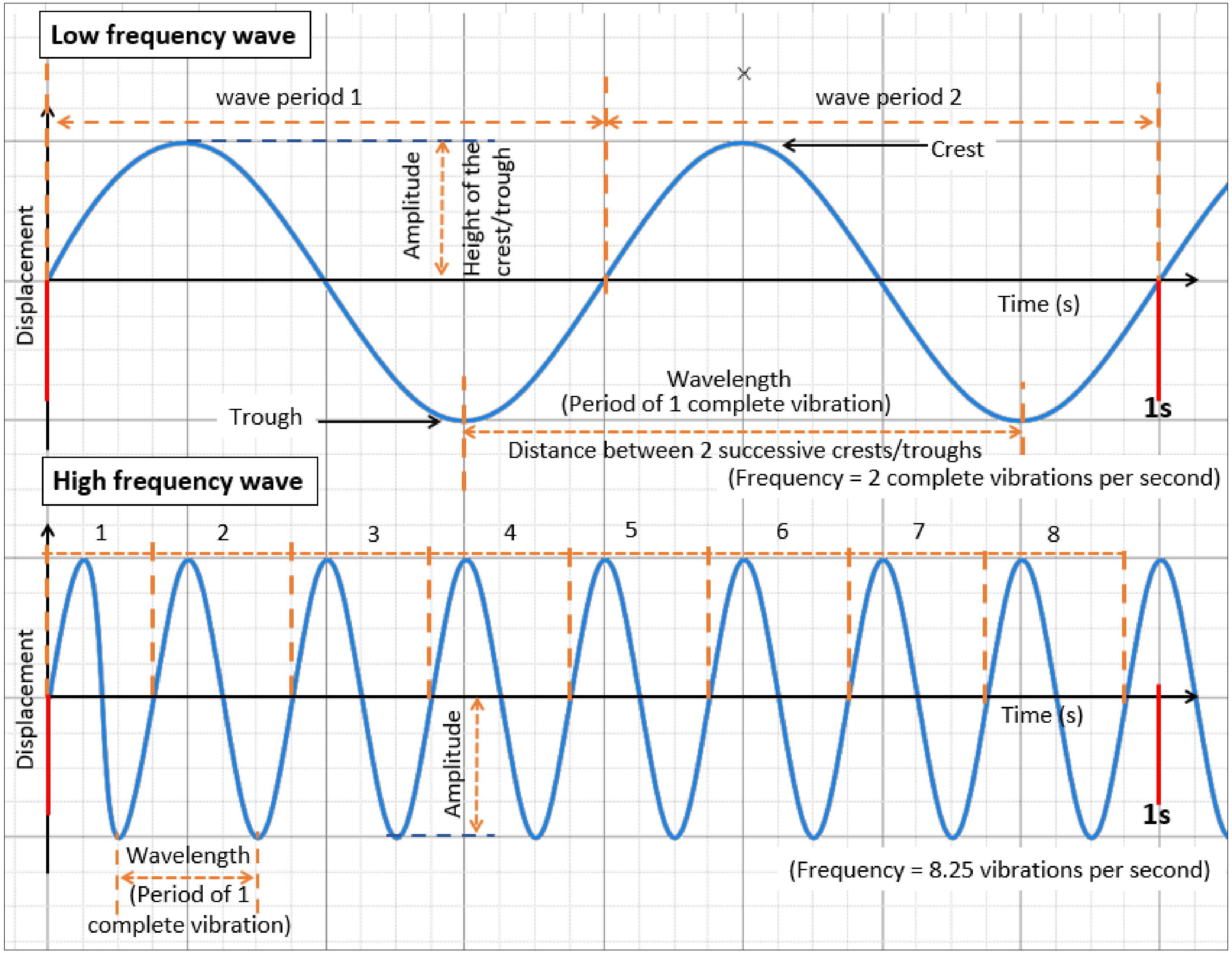

Figure 1: Two waves of different frequencies. The amplitude refers to the height or peak in displacement of the particle from its original position. Amplitude, wavelength and frequency are discussed in section A above.

B. How Do We Measure Sound?

3.1 The frequency and amplitude of a sound wave impact local air pressure. Our ears 'hear' by using this change in pressure to produce and send an electrical signal to our brain. A sound level meter (SLM), consisting of a microphone, and amplifier and a meter, reproduces this effect. It converts fluctuations in local air pressure to voltage, which is then used to provide a measurement in decibels (dB).

3.2 Weighting filters and time weighting are built into a SLM. They help produce noise measurement outputs that suit various measurement needs.

Weighting Filters

3.3 The human ear is most sensitive to mid-frequency sounds between 400 Hz and 4000 Hz. A sound level meter is able to pick up a much wider range of frequencies. 'Weighting filters' are attached to sound level meters to attenuate[6] or amplify certain frequency bands during measurement to better reflect noise levels as perceived by humans.

3.4 The most commonly used noise weighting filter is the A-weighting filter, denoted as dB(A). Noise measurements used for assessing impact on humans have A-weighting applied to them, as it is considered to best represent human sensitivities. Note that unweighted sound pressure levels are also referred to as Z-weighted.

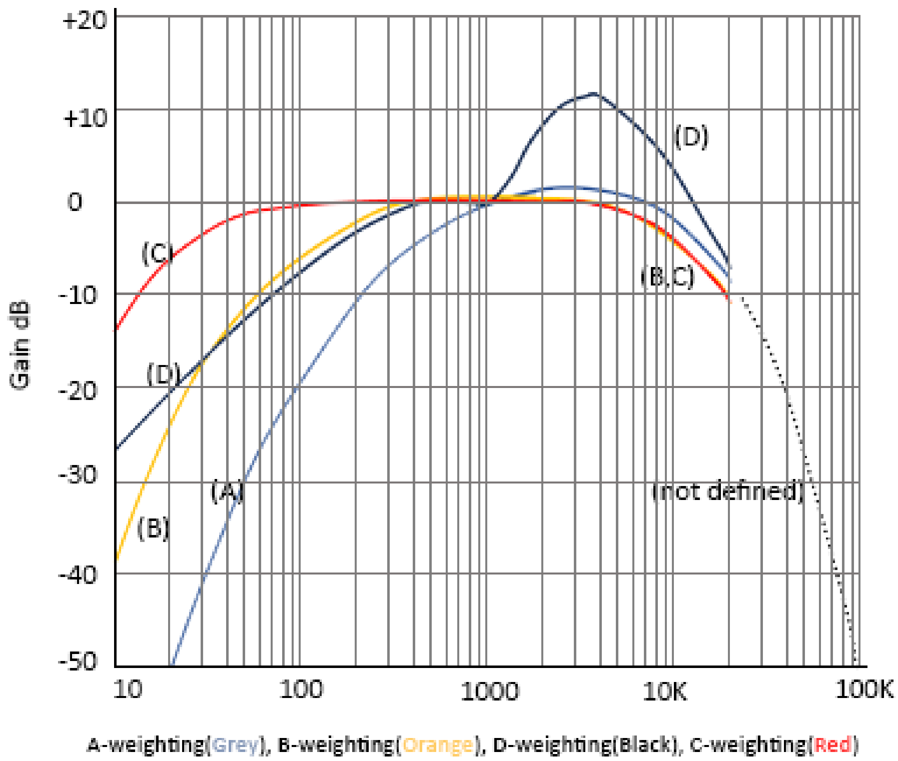

Figure 2: Relative response of A, B, C and D weighting scales. See paragraph 3.7.

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[6] Sound attenuation refers to the reduction in sound energy as it moves through a medium.

3.5 Figure 3 below shows the noise levels downloaded from an airport Noise and Track Keeping system for a Boeing 787-9 departure. The blue line shows the unweighted noise levels measured at the microphone. The orange line shows the A-weighted noise levels which are perceived by humans. Notably, there is considerable convergence in the noise levels within the mid-frequencies, specifically from 500 Hz onwards. This phenomenon arises due to the inherent insensitivity of the human ear to lower frequencies, with greater sensitivity observed in the mid-frequency range.

3.6 In the context of measuring noise to assess its impact on humans, the application of A-weighting to these measurements becomes crucial. A-weighting is employed to ensure that impact assessments are conducted based on what the human ear perceives, acknowledging its heightened sensitivity in the mid-frequency range. This practice aligns the measurements with the auditory characteristics of the human hearing system, providing a more accurate representation of the noise impact on individuals. It also enhances the reliability and relevance of the noise measurements in gauging their potential impact on human perception.

3.7 Other weightings include B-weighting (dB(B)), C-weighting (dB(C)) and D--weighting (dB(D)). Further information on frequency weighting can be found in IEC 61672 standard[7].

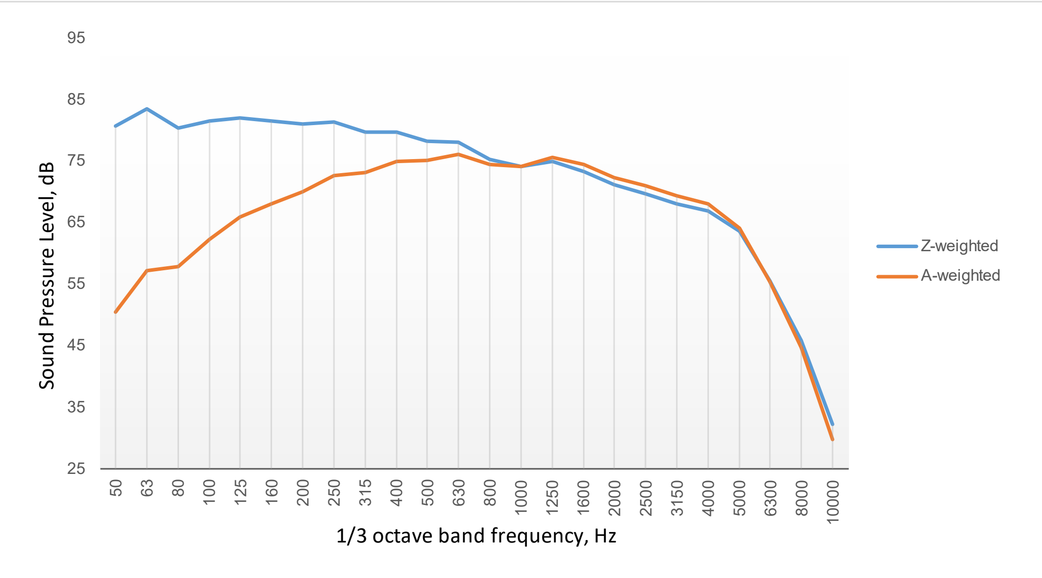

Figure 3: Boeing 787-9 departure noise level (6 km from take-off). For more information see paragraph 3.5.

[7] IEC 61672-1:2013. Electroacoustics - Sound level meters - Part 1: Specifications. Available at https://webstore.iec.ch/publication/5708

Time Weighting

3.8 The pressure fluctuations generated by sound waves occur in such rapid succession that using accurate local air pressure readings in real-time would produce incoherent results. Time weighting helps offset this problem by reducing the impact of sudden changes on the output of a sound level meter.

3.9 There are two commonly used time-weightings – Fast (F) and Slow (S). Fast weighting is used to measure sounds that produce fewer rapid fluctuations in pressure. Slow weighting is used when local air pressure fluctuates significantly. In aviation, slow weighting is almost always used. This is especially true for noise certification, as standards are set using slow weighting to conform with measurements taken using older analogue instruments.

For more information, see the IEC 61672-1, which provides information on the electro-acoustic performance of sound measuring instruments.

C. Noise Metrics

3.10 Noise metrics are mathematical units of measurement, or indices, used to quantify noise. They provide standardised ways to assess and compare noise levels, characteristics and their potential effects on human health and wellbeing. They are valuable for several reasons:

- *Noise Impact Assessment:* Experts can use standardised noise metrics to assess the impact of noise on health and wellbeing across different communities. This is especially true when noise metrics are analysed in conjunction with exposure-response relationships (ERR), in which increasing levels of exposure are associated with certain responses from participants to determine “safe” and “hazardous” ‘doses’ of noise.
- *Establishing Regulations and Standards:* Noise metrics allow regulators to set and communicate expected standards at the local, regional and national level.
- *Design and Implementation:* By providing a means to assess noise impact, noise metrics allow regulators to develop appropriate strategies that reduce and mitigate noise in areas where improvement is needed.
- *Resource Allocation:* The standardisation of noise measurement enables more efficient comparison between noise sources. These comparisons encourage effective prioritisation and resource allocation amongst decision-makers.
- *Monitoring and Compliance:* By standardising noise measurement, noise metrics give regulators the tools necessary to monitor and enforce specific regulations. For example, authorities can identify areas where noise restrictions are not being met and take action.

Noise Metric Definitions

3.11 Before this document was created, we engaged with individuals from non-technical backgrounds and highlighted the elements of noise reporting they found challenging. Below is a series of detailed definitions for the indices used to quantify noise produced by the aviation industry. These definitions should serve as a starting point for readers who wish to better understand the purpose of different metrics used in noise reporting.

3.12 Noise metrics largely fall into two categories – Short term metrics and long-term metrics.

3.13 Short term noise metrics are used to describe single noise events. Long term metrics are averaged over multiple noise events. These could be half an hour to an average day over several months. Metrics like LAeq, Nx etc falls into this category.

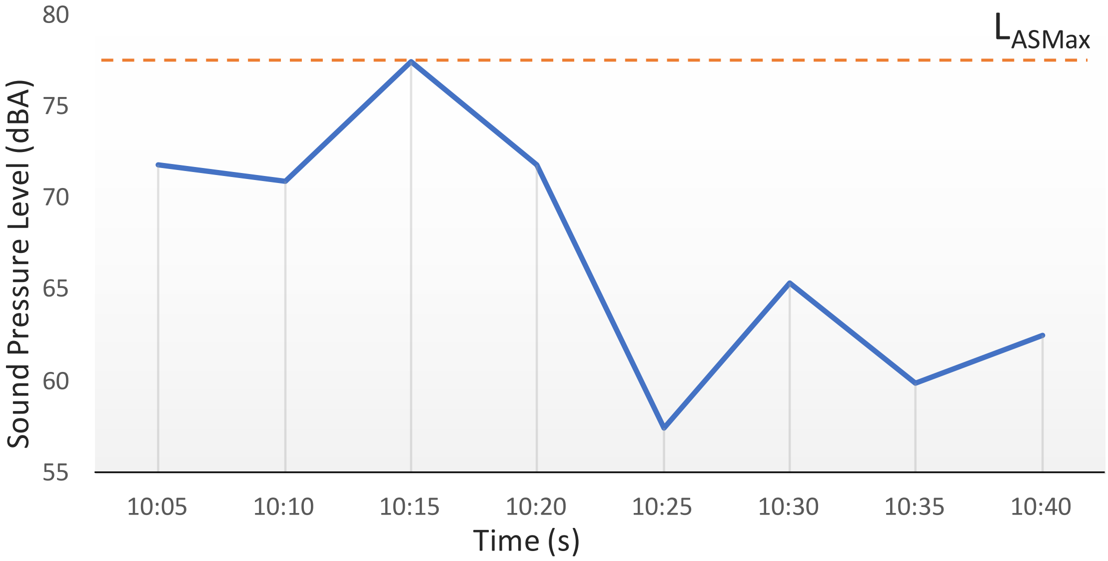

Figure 4: Maximum A-weighted Sound Pressure Level for a time-varying sound, recorded using slow time weighting. See paragraph 3.16.

Maximum A-weighted Sound Pressure Level, L_{Amax}

3.14 L_{Amax} refers to the maximum sound level. It represents the highest or peak sound level recorded during a specific time period. To determine L_{Amax} for a specific duration, sound levels are measured at regular intervals and the highest recorded value is identified. It provides information about the loudest noise peaks. The A in L_{Amax} represents A-weighting.

3.15 In the label L_{Amax}, the first capital letter 'L' stands for 'level' (as in the sound pressure level measured through the microphone). The second letter 'A' stands for frequency weighting. The word 'max' refers to the maximum value measured over a certain period of time.

3.16 Figure 4 shows the L_{Amax} for a noise measured over a period. Where the level is recorded using slow-time weighting, it is good practice to report the maximum as L_{ASmax}. Because it is standard practice to use slow-time weighting for aircraft noise, it is often common practice to omit the 's'.

Sound Exposure Level, SEL

3.17 SEL is the total A-weighted sound energy of the event compressed into a 1-second period. The total sound is defined as the top 10 dB, which accounts for approximately 90% of the sound energy of an aircraft noise event. Figure 5 shows a time-varying noise event and its SEL. Because of the typical duration of aircraft noise events, the SEL is typically 10dB higher than the numerical value of the L_{ASMax}.

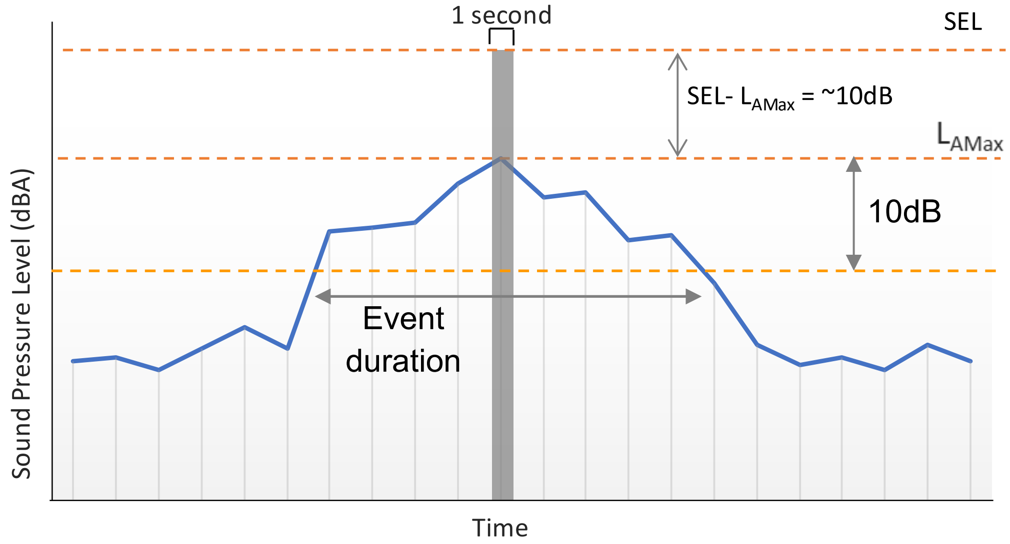

Figure 5: Maximum Sound Level(L_{Amax}), Sound Exposure level (SEL), A-weighted Equivalent continuous noise level (L_{Aeq}). See paragraph 3.17 above.

Effective Perceived Noise Level

3.18 Effective Perceived Noise Level (EPNL) is a specialised metric used in aircraft noise certification. It is a single-number evaluator for an aircraft pass-by, accounting for the subjective effects of aircraft noise on human beings, consisting of an integration over the noise duration of the Perceived Noise Level (PNL) adjusted for spectral irregularities[8] giving a tone-corrected Perceived Noise Level (PNLT). The time varying PNLT is then integrated over time and normalised to a reference duration of 10 seconds to give the EPNL. It accounts for human response to the intensity, spectral shape, tonal content and duration of noise from an aircraft. The certification quality EPNL cannot be directly measured and has to be calculated. The standard calculation methodology can be found in ICAO Annex 16.[9] Numerically, an EPNL is around 2-6 dB higher than the associated SEL, the variation being due to the extent of the spectral irregularities present in the noise event.

Equivalent Continuous Sound Level, L_{eq}

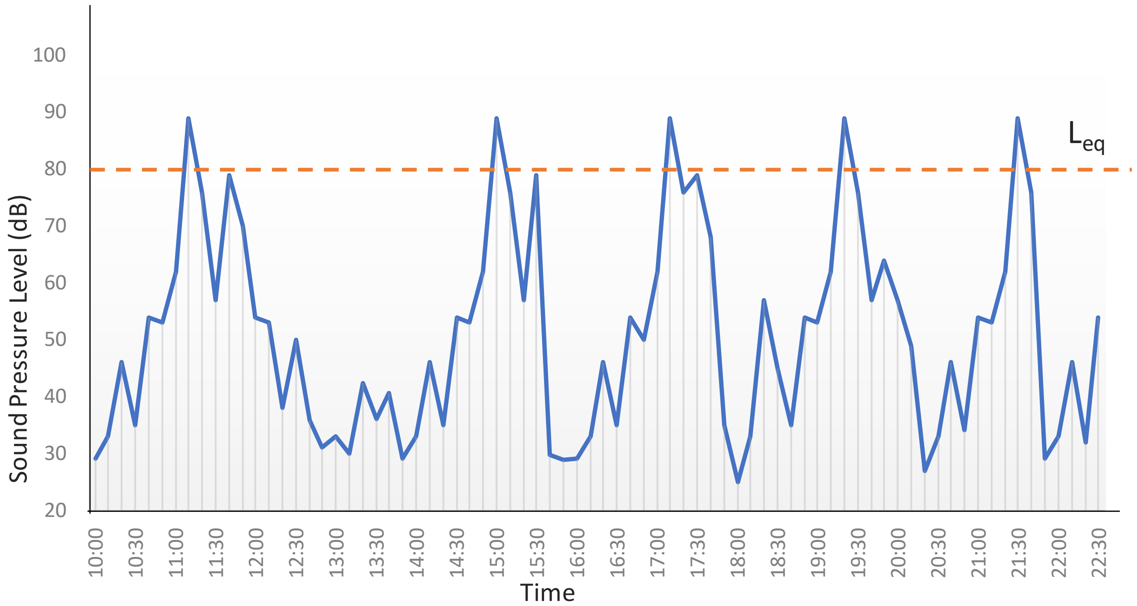

Figure 6: Equivalent continuous noise level, L_{eq}. See paragraph 3.19 below.

3.19 Equivalent continuous noise level is a type of metric used to describe the average sound level over a specific period. It is intended to cover multiple individual noise events and considers the varying levels of sound throughout a specific time period and provides a single value that represents the average noise level for the same time period. Because the vertical scale in Figure 6 is a logarithmic decibel scale, the average must be calculated in a special manner, sometimes referred to as

[8] Spectral irregularity: Sound is energy distributed through a medium. A sound signal can be described as a sum of various individual frequency components.

[9] International Civil Aviation Organization (2017). Environmental protection: International standards and recommended practices: annex 16 to the Convention on International Civil Aviation. Vol. 1. Aircraft noise. Montreal, Quebec, Canada: International Civil Aviation Organization.

logarithmic averaging. Note that while the arithmetic mean treats all data points equally, the logarithmic mean assigns greater weight to the higher values, which is why the L_{eq} line in Figure 6 is shown towards the high end. For instance, to calculate the noise over an 8-hour period, the measurements could be taken at regular intervals throughout the period. By calculating the average sound level over the entire duration, the L_{eq} value is obtained which represents the equivalent continuous noise level experience in that location during the 8-hour period. *Figure* 6 shows the equivalent continuous noise level of a noise measurement taken between 10:00 to 22:30.

3.20 Equivalent continuous noise level, L_{eq} can be calculated from the following equation:

$$Leq = Average\ SEL + 10 \times \log_{10}(Number\ of\ aircraft\ operations) + \log_{10}(time)$$

Where,

SEL =Sound exposure level, expressed in dB
L_{eq} = Equivalent continuous noise level, expressed in dB
Time = Duration of averaging period, expressed in seconds

3.21 Doubling the number of movements, doubles the total noise energy and adds 3dB to the L_{eq}. Spreading the number of movements over twice the time duration halves the energy and reduces the L_{eq} by 3dB.

3.22 The Average SEL is the logarithmic average SEL of all aircraft noise events. For example, the typical daytime period assumed for calculating the daytime noise effects in the UK is from 07:00 to 23:00. Hence for a 16 hour L_{Aeq} noise metric, the duration is calculated as:

16 hours x 60 minutes x 60 seconds = 57,600 seconds.

i. A-weighted Equivalent Continuous Sound Level, L_{Aeq}

A-weighted equivalent continuous sound level is a type of L_{eq} which incorporates the A-weighting, the frequency filter which adjusts the sound measurements to match the sensitivity of the human ear. The L_{Aeq} is calculated the same way as L_{eq}. For aircraft noise assessments, L_{eq} is almost always A-weighted. A-weighted equivalent continuous sound level can also be written as L_{eq} with the weighting denoted in the units as dB(A). It is best practice to define it as L_{Aeq} in units of dB.

ii. A-weighted Equivalent Continuous Sound Level, LAeq,T

$L_{Aeq,T}$ represents the A-weighted equivalent continuous sound level over a specific time period, denoted by ‘T’. It is an extension of L_{Aeq} that provides the average A-weighted sound level over a defined duration.

Some of the commonly used durations for noise exposure assessments in the UK are shown in Table 2 and are described below:

Table 1: Description of different LAeq-based metrics

L_{Aeq}-based metric	Description	Duration	Measurement hours	Assessment period
$L_{Aeq,16h}$	Average summer's day level	16 hours	07:00 - 23:00	92-day between the 16 June - 15 September
	Average annual day level			Full calendar year
$L_{Aeq,8h}$	Average summer night level	8 hours	23:00 - 07:00	92-day between the 16 June - 15 September
L_{night}	Average annual night level			Full calendar year
L_{day}	Average annual day level	12 hours	07:00 - 19:00	Annual, to calculate L_{den}
$L_{evening}$	Average evening level	4 hours	19:00 - 23:00	As required, and to calculate L_{den}
L_{den}	Day-evening-night level	24 hours	07:00 - 07:00	L_{day} + 5 dB penalty on $L_{evening}$ + 10 dB penalty on L_{night}
$L_{Aeq,6.5h}$	Night Quota Period level	6.5 hours	23:30 - 06:00	Applicable to the designated airports

- $L_{Aeq,16h}$ - The $L_{Aeq,T}$ averaged over a 16-hour period. Conventionally, for aviation noise, that time period is 07:00 hours to 23:00 hours local time. An average summer's day $L_{Aeq,16h}$ is averaged over a 92-day between the 16 June and 15 September, and annual day $L_{Aeq,16h}$ is averaged over the full calendar year.

- $L_{Aeq,8h}$ - The $L_{Aeq,T}$ averaged over an 8-hour period. Conventionally that time period is 23:00 hours to 07:00 hours local time (i.e. the night period). An average summer's night is averaged over a 92-day between the 16 June and 15 September.

- $L_{Aeq,6.5h}$ - The $L_{Aeq,T}$ averaged over a 6.5-hour period from 23:30 to 06:00 hours. Also known as the Night Quota Period level, these hours are primarily applicable to the designated airports (Heathrow, Gatwick & Stansted)[10]. The environmental objective of this is to "limit or reduce the number of people significantly affected by aircraft noise at night, including through encouraging the use of quieter aircraft, while maintaining the existing benefits of night flights".[11]

- L_{night} - The $L_{Aeq,8h}$ averaged over the period of one year, also known as annual average night level.

[10] Night-time noise abatement objectives for the designated airports from October 2025. (27 March 2023). Available at https://www.gov.uk/government/consultations/night-time-noise-abatement-objectives-for-the-designated-airports/night-time-noise-abatement-objectives-for-the-designated-airports-from-october-2025

[11] For the current night flight regime, one of the methods to measure the achievement against the night-time noise abatement objective is by: "*the area of and number of people in the 48dB $L_{Aeq\ 6.5hr}$ night contour - this refers to the noise levels at night between 11:30pm and 6am*".

- L_{day} – The $L_{Aeq,T}$ averaged over a 12-hour period, conventionally between 07:00 hours and 19:00 hours local time.

- $L_{evening}$ – The $L_{Aeq,T}$ averaged over a 4-hour period, conventionally between 19:00 hours and 23:00 hours local time.

- L_{den} - also known as Day-evening-night level is a metric which has a time-of-day weighting applied to the noise levels. This is used to reflect the heightened sensitivity to noise during the evenings and night-time. L_{den} is the $L_{Aeq,T}$ averaged over a 24 hour period, but with the $L_{evening}$ value weighted by the addition of 5dB and the L_{night} value weighted by the addition of 10dB. The L_{den} per day is then averaged over the period of one year. The L_{den} per day is calculated using the flowing equation:

$$L_{den} = 10.log\left(\frac{1}{24}\left(12.10^{\frac{L_{day}}{10}} + 4.10^{\frac{L_{evening}+5}{10}} + 8.10^{\frac{L_{night}+10}{10}}\right)\right)$$

3.23 In the UK, the Environmental Noise (England) Regulations 2006 define the measures relating to the assessment, management, and control of environmental noise.[12] The Regulations require airport operators to produce strategic noise maps. The strategic noise maps for aircraft noise must include data containing the values of L_{den}, L_{night} and supplementary noise indicators, which are $L_{Aeq,16h}$, L_{day} and $L_{evening}$. Figure 7 shows the various hourly durations of the day used for aviation noise assessment within the UK.

[12] The Environmental Noise (England) Regulations (2006) (UK Statutory Instruments, 2006) As Amended (2018) (UK Statutory Instruments, 2018)

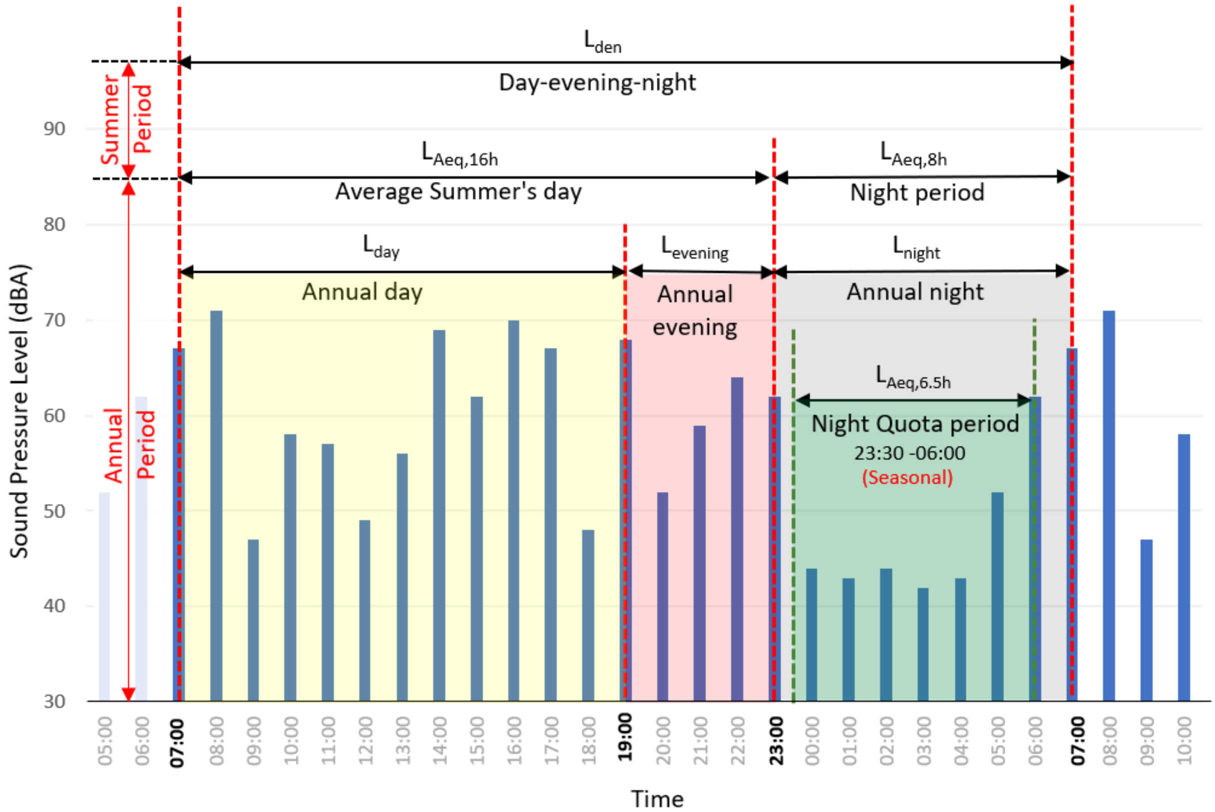

Figure 7: The different aviation noise assessment periods in the UK. See paragraph 3.23.

Number Above, Nx

3.24 The Number Above metric represents the number of noise events where the maximum noise level (L_{ASmax}) is higher than x dB. This is a useful metric as it is a count of the number of noise events, so it is a linear metric, unlike a decibel value which is a logarithmic indicator. The Nx metric is simply a representation of the number of flights above a certain level of noise and does not reflect the noise levels of individual events. Nx metrics are expressed in dB L_{Amax}.[13] For example, if the threshold is 65 dB, one event at 66 or 86 dB L_{Asmax} counts simply as one event, regardless of the fact that an event at 86 dB L_{ASmax} is far louder than one at 66 dB.

3.25 For example, to calculate N70, if a particular area experiences 100 flights during a given time period, and out of those flights, 50 of them exceed 70dB, the N70 value for that area would be 50. Figure 8 shows the Nx metric showing events during a time period.

[13] Airspace Change: Environmental requirements technical annex. CAP 1616a. (2020). Available at https://publicapps.caa.co.uk/docs/33/CAP1616A%20Environmental%20requirements%20technical%20annex%20second%20edition.pdf

• N65 – This metric counts the occurrences or events where the noise level exceeds 65dB.

• N70 - This metric counts the occurrences or events where the noise level exceeds 70dB. This is usually used for daytime.

• N60 - This metric counts the occurrences or events where the noise level exceeds 60dB. This is usually used for night-time .

3.26 The Air navigation guidance recommends the use of N65 for 16 hour daytime noise and N60 for 8 hour night time noise as supplementary metrics which should be used to inform communities about the impact of any proposed airspace changes.

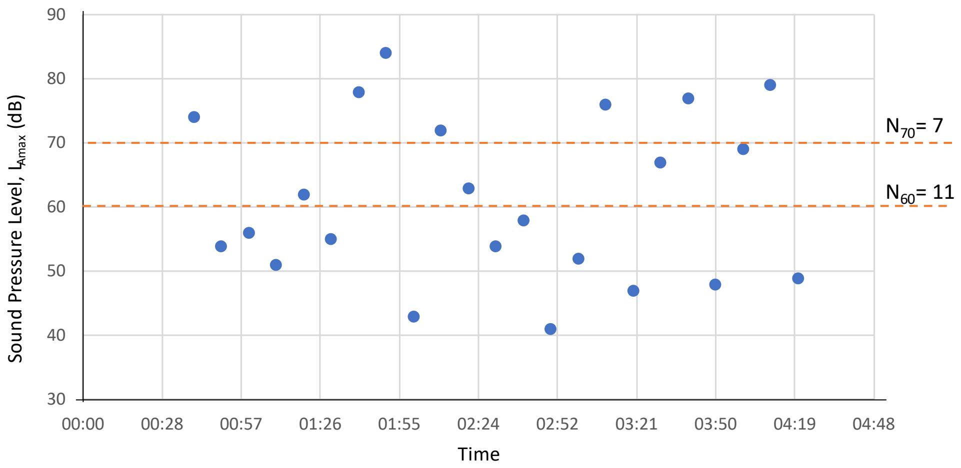

Figure 8: Number above, Nx metric showing events during a time period. See paragraph 3.25 above.

Time varying noise

3.27 All sounds change in their characteristics over time and these are usually referred to as time varying noise.

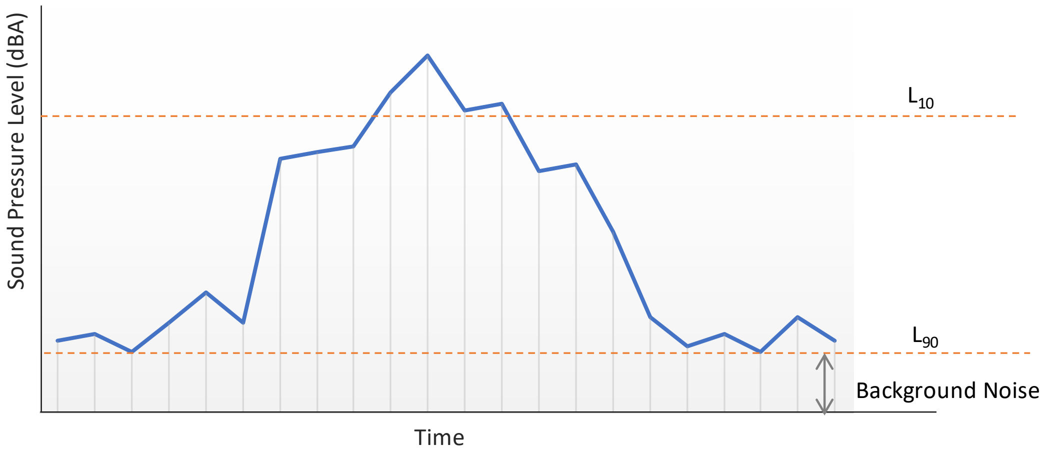

Figure 9: L_{90} and L_{10} for a measured sound. See paragraph 3.28 below.

3.28 The level of many sounds varies with time and it is not easy to find a measure that can accurately quantify this with a single number. Metrics like L_{90}, L_{50} and L_{10} are used to convey information on how much noise levels vary over time. Figure 9 shows the different L_{90} and L_{10} calculated over a specific time period. They were originally common with road and railway noise, and are rarely used in aviation.

- L_{90} - Sound level in dB(A) which is exceeded for 90% of the time. L_{90} is a measure of the background noise.
- L_{50} - Sound level in dB(A) which is exceeded for 50% of the time.
- L_{10} - Sound level in dB(A) which is exceeded for 10% of the time.

How is Noise Used within Aviation Reports?

Aviation Reports

3.30 Effective noise management is a cornerstone of the government's overall policy on noise.[14] [15]

3.31 Aviation noise takes into account the noise created by aircraft on approach, during take-off and landing, taxiing, engine testing and during level flight. It does not include the noise generated by vehicles other than aircraft, such as airport ground vehicles.

3.32 Aviation noise is further separated into 'air' noise and 'ground' noise. Aviation 'air' noise relates solely to the noise generated during take-off and landing and excludes other forms of aviation noise. Aviation 'ground' noise includes taxiing and engine testing. The majority of aviation noise reports focus on aviation 'air noise', since its exposure and impacts are generally greater than those associated with aviation 'ground' noise (although there may be situations where ground noise is significant).

3.33 In the UK, 'noise metrics' are used in a variety of documents issued by the CAA, airports, airlines and other consultants. This is because noise metrics are needed to quantify aviation noise as part of regulatory processes, including airspace change, aircraft noise certification and noise action planning.

Noise Contours

3.34 Noise contours are contour lines used to help represent noise exposure across large geographical areas. Noise contours are similar to those found in topographical maps; except they are drawn to highlight areas with similar noise levels rather than elevation.

3.35 A noise contour map can be found in Figure 10. The noise contours tend to follow the source of the noise, in this case the flight path. Maps like these are used to illustrate aircraft noise exposure amongst communities surrounding airports.

[14] The Noise Policy Statement for England sets out the long term vision of Government noise policy: "Promote good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development"

[15] Noise Policy Statement for England (NPSE). (2010). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69533/pb13750-noise-policy.pdf.

3.36 There is no universally recognised definition for noise contours, maps or footprints, and they tend to be used interchangeably. However, as a general rule, noise contours and maps tend to be used to refer to average noise generated over the course of multiple flights, whereas a noise footprint usually only takes one flight into consideration.

3.37 In theory, noise contours could be produced through direct measurement. However, it is impractical to deploy enough noise monitoring stations to accurately measure aviation noise, as it impacts a wide area. In practice, almost all aviation noise contour maps are produced through noise modelling.

3.38 In the UK, the CAA's Environmental Research and Consultancy Department (ERCD) develops and maintains the UK aircraft noise contour model (ANCON) on behalf of the Department for Transport (DfT). Other noise models used for aircraft noise assessment include the US FAA Aviation Environmental Design Tool (AEDT)[16] and the EUROCONTROL IMPACT model[17].

3.39 Noise modelling consists of calculating long-term noise exposure (L_{Aeq}) by adding all individual noise events (SELs). As it is impractical to calculate noise for every single flight, aircraft operations by the same type of aircraft over similar geographic areas are grouped together, and a statistical representation is made for these flights. The representative lateral flight path and statistical variations around this are then calculated using extensive radar analysis tools.

3.40 Some airports collect noise, radar and operational data through a Noise and Track Keeping (NtK) system. However, these systems are expensive, so not all airports have them.

Noise Contour Maps

3.41 A 3dB increase in noise equates to a doubling of sound energy. In the UK, noise contour maps are typically plotted using 3dB intervals.

3.42 The figures below are from Heathrow's report 'Heathrow Airport 2021 Summer Noise Action Plan Contours, ERCD Report 2201.[18]

3.43 Figure 10 shows the Heathrow 2021 and 2020 average summer day actual modal split[19] $L_{Aeq,16h}$ noise contours. Further information on these metrics can be found under Equivalent Continuous Sound Level, L_{eq}, in the previous section. As can be seen, the noise contour lines tend to follow flight paths.

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[16] FAA: AEDT Support Website.

[17] Integrated aircraft noise and emissions modelling platform (IMPACT) | EUROCONTROL

[18] ERCD REPORT 2201 - Heathrow Airport 2021 Summer and Noise Action Plan Contours

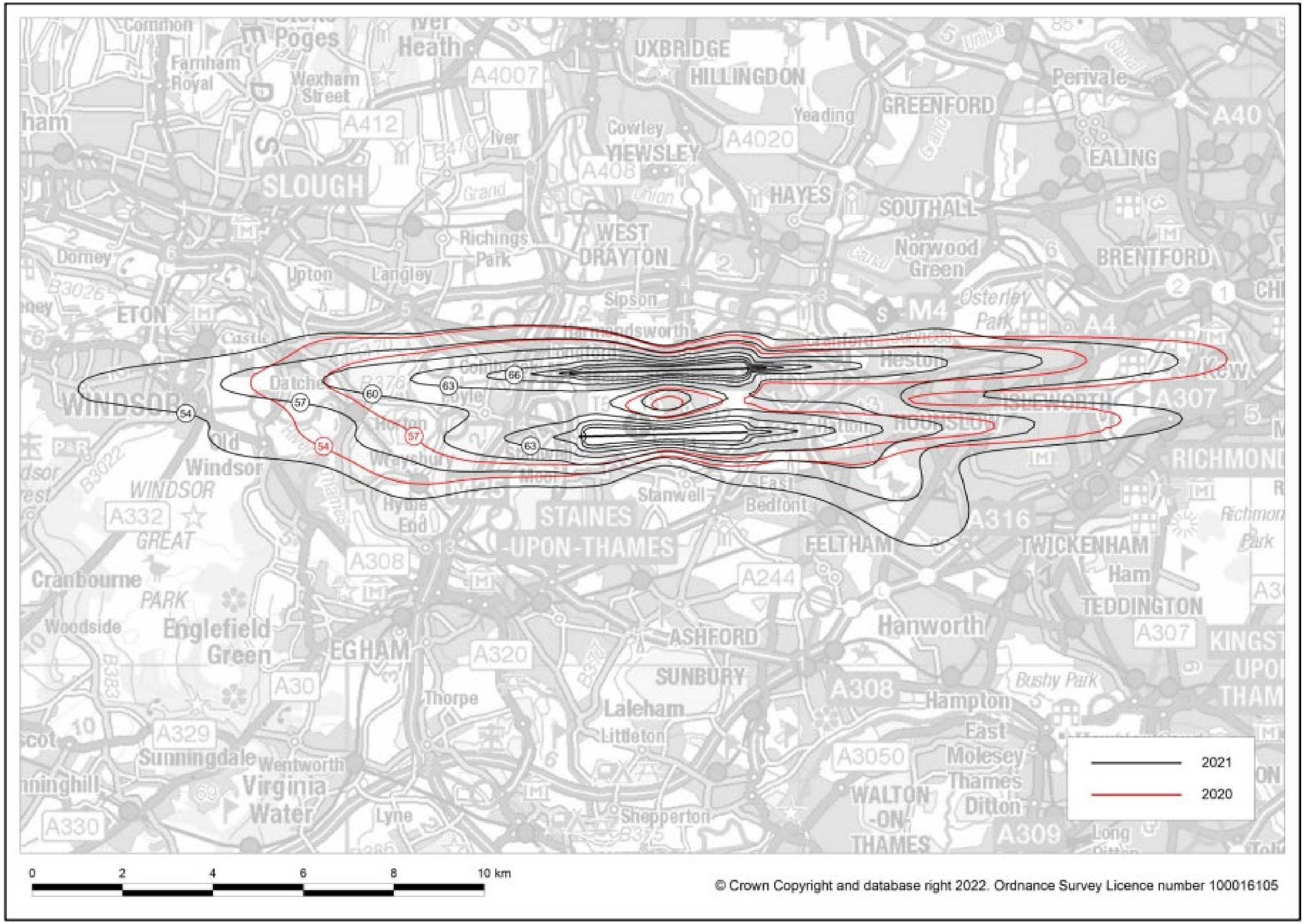
[19] A modal split is the percentage of flights that has used a particular runway direction during a particular period.

3.44 The direction of departure and arrival operations at any airport is determined by a variety of factors, including runway directions and weather conditions. Aircraft generally take-off and land *into* the wind. Exceptions occur when an airport has a runway preference system that requires operations in a specific runway direction with a light tailwind.

3.45 In Figure 10, it is mentioned that the 2021 summer day actual modal split was 55% W/ 45% E. This means that 55% of flights flew in the western direction. The impact of this can be seen in the noise contour map, as the contour lines on the left hand side (West) are larger than on the right (East). This is because take-off noise is generally higher than the noise produced on approach.

3.46 The $L_{Aeq,16h}$ refers to the A-weighted equivalent noise level over a period of 16 hours during an average summer's day period. Further information on this metric is given in section Equivalent Continuous Sound Level, L_{eq}.

3.47 Figure 10 contains the noise contours for two separate years, overlaid on top of each other for visual comparison. The contours have been generated through noise modelling, which was done based on the actual modal split (the proportion of use of each runway direction) throughout the summer for each year.



Note: the 2021 summer day actual modal split was 55% W / 45% E (2020: 83% W / 17% E).

Figure 10: Heathrow 2021 and 2020 average summer day actual modal split $L_{Aeq,16h}$ noise contours. source: Heathrow Airport 2021 Summer and Noise Action Plan Contours. See paragraphs 3.35, 3.43, 3.45, 3.47.

SID and NPR

3.48 To standardise departures, the Air Traffic Control (ATC) at some airports publish and utilise predefined departure routes called Standard Instrument Departure (SID) routes. An airport may have several of these which airlines can choose from, subject to flight plan acceptance by ATC. This allows ATC to expediently direct traffic towards their destination.

3.49 Due to weather conditions and individual aircraft navigation performance, some aircraft drift to the left or right of the SID centreline.

3.50 Noise Preferential Routes (NPR) are designated routes for departing aircraft, often at the start of a SID. They are designed strategically to ensure minimal noise impact on populated areas.

3.51 Some airports may have SIDs but not NPRs and vice versa. However, when they both exist, SIDs are always set to follow the NPRs.

3.52 For monitoring purposed, some airports define NPR swathes, which typically extend up to 1.5 km either side of the NPR. The proportion of aircraft that remain within an NPR swathe is used to measure departure track-keeping performance. This metric is reported by month, NPR, and aggregated for entire airports.

3.53 Figure 11 shows the NPR/SID route for Heathrow for both Easterly and Westerly directions.[20]

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[20] Heathrow Airport 2021 Summer and Noise Action Plan Contours, ERCD Report 2201,September 2022

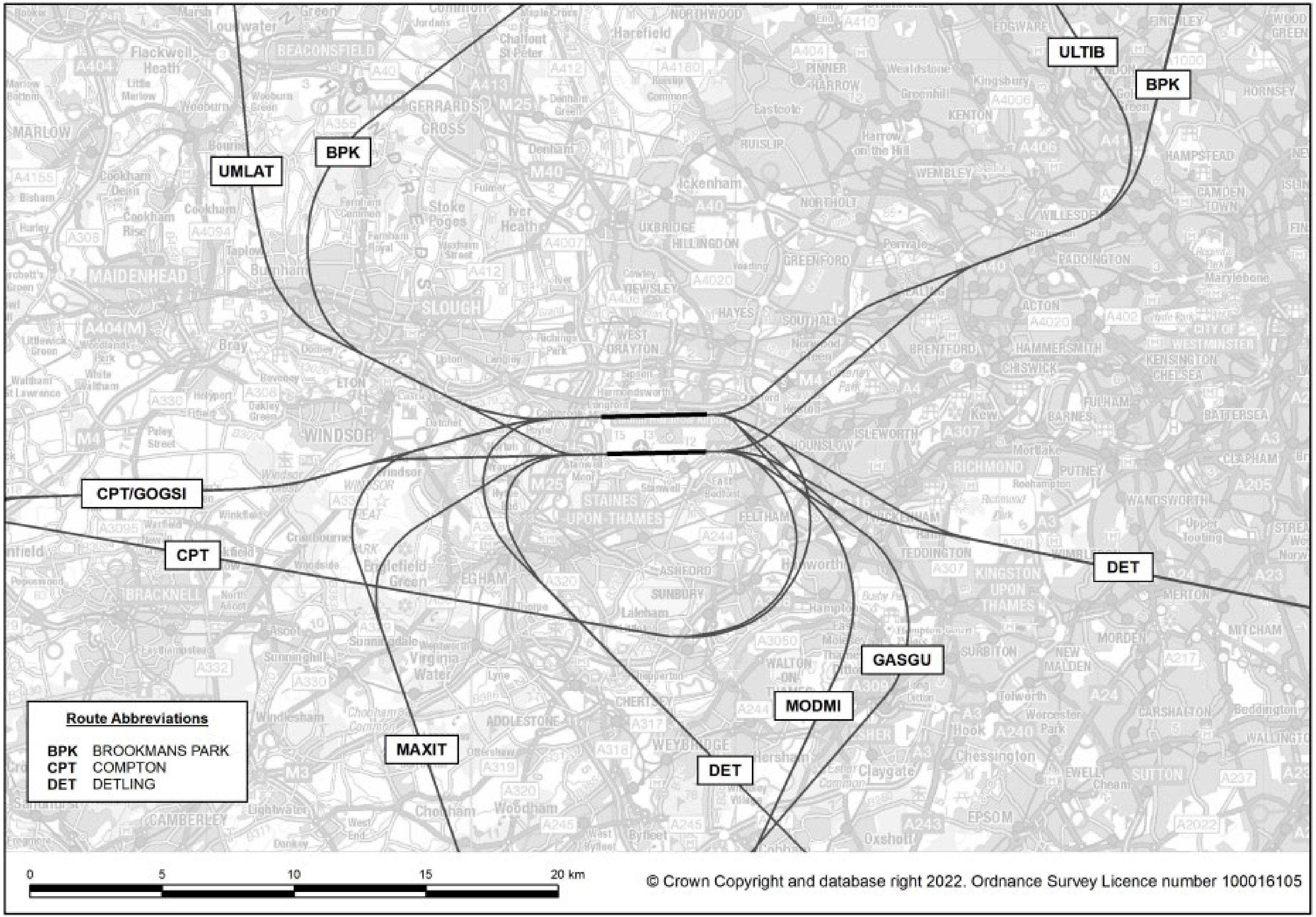

Figure 11: NPR/SID route for Heathrow. source: Heathrow Airport 2021 Summer and Noise Action Plan Contours. See paragraph 3.35.

Airports Operations Diagram

3.54 An 'operational diagram' shows what aircraft tracks were flown over a 24-hour period for 92 consecutive days during the average summer period (16 June – 15 September inclusive). When present, NPR swathes may be overlaid onto operational diagrams to show how aircraft comply with departure track-keeping requirements.

3.55 Figures 12 and 13 show the average number of aircraft departing and arriving at Runway 04 at London Stanstead Airport over a summer 24-hour day respectively.[21]

3.56 The tracks in the figures are colour coded to show height above mean sea level (AMSL).

3.57 The path nomenclature can be seen in the bottom left corner of the figure. The average number of daily departures for route DET is significantly lower compared to other routes. Environmental conditions, like changes in wind direction, often dictate the route taken by a flight.

[21] Arrivals and departures maps (no date) London Stansted Airport. Available at: https://www.stanstedairport.com/community/noise/noise-in-your-area/arrivals-and-departure-maps/

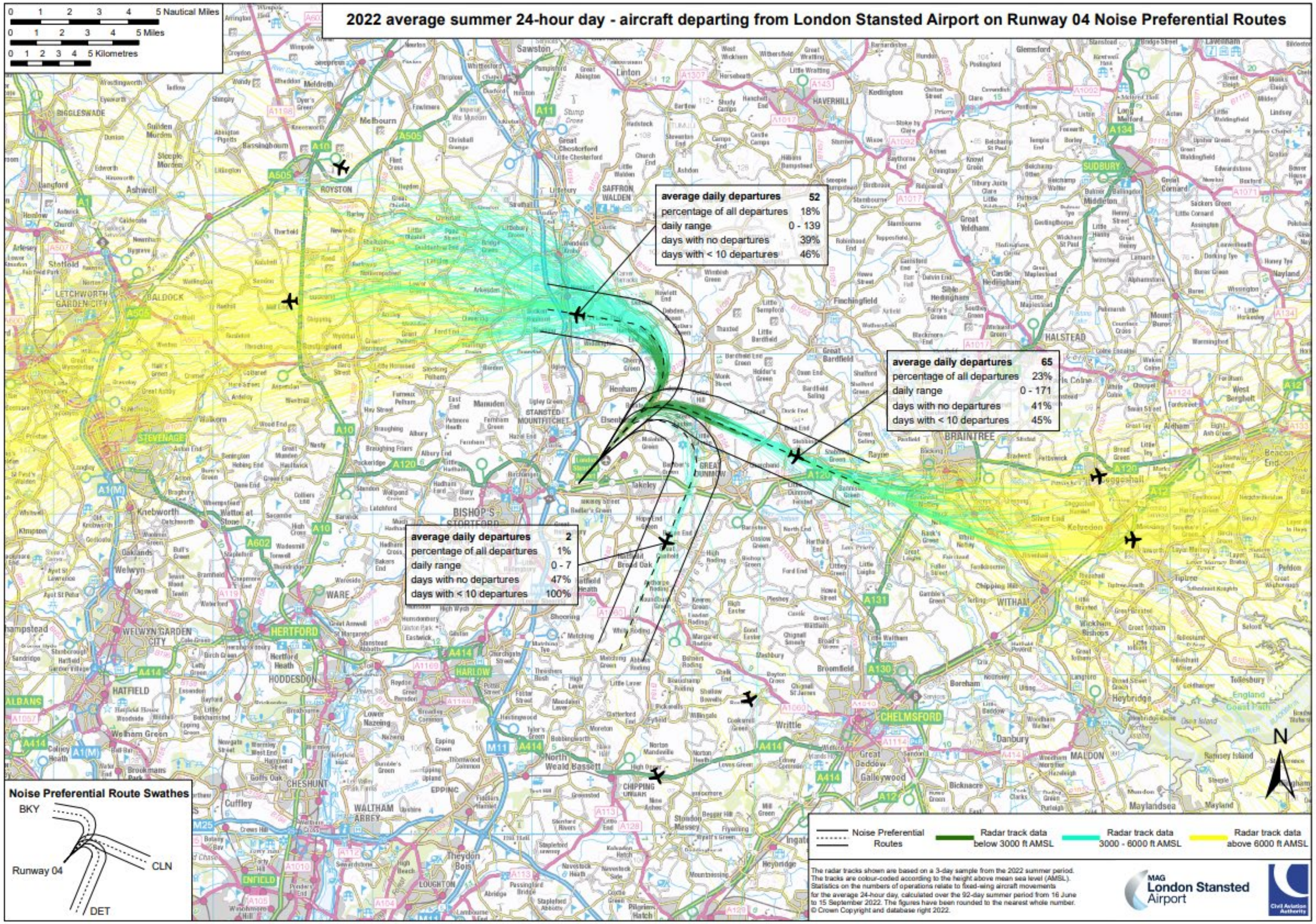

Figure 12: Average summer 24-hour day- aircraft departing from London Stansted Airport on Runway 04. The figure shows both Noise Preferential Routes and the paths taken by departing aircraft. Source: www.stanstedairport.com

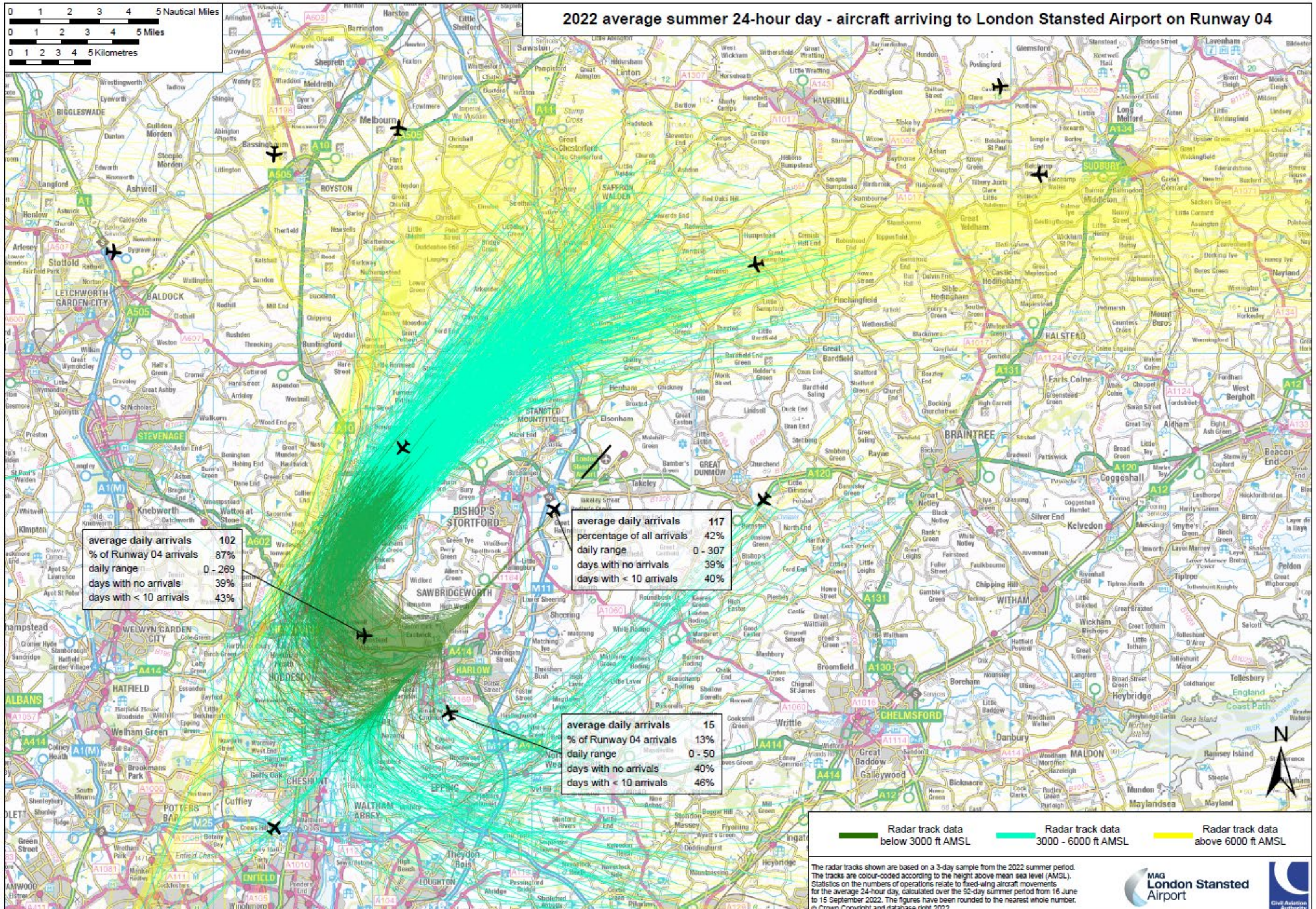

Figure 13: Average summer 24-hour day- aircraft arriving to London Stansted Airport on Runway 04. This figure shows the routes taken by aircraft arriving at London Stansted Airport on Runway 04. Source: www.stanstedairport.com

Summary

4.1. This guidance document was written to help facilitate greater accessibility amongst noise documents produced within the CAA and the wider aviation industry.

4.2. This document meets the DfT's request to the CAA that we produce a noise guidance document to de-mystify noise metrics amongst relevant stakeholders.

4.3. Sound refers to any aural sensation triggered by pressure fluctuations that reaches an individual's ear. Noise is a sound that is *unwanted* or *unpleasant*.

4.4. Sound has both subjective and objective properties. Loudness is a subjective property. 'Level, or magnitude,' is objective.

4.5. Sound is measured using a Sound Level Meter, which converts fluctuations in local air pressure to voltage, which is then used to provide a measurement in decibels (dB).

4.6. Sound Level Meters have weighting filters that repress or amplify certain frequency bands. The most commonly used weighting filter is A weighting, which reflects the 400Hz to 4000Hz mid-frequency sounds that humans are most sensitive to.

4.7. Time weighting is used to account for the rapid measurement changes that occur as pressure fluctuates. There are two commonly used time weights. Fast (F) and Slow (S). Slow weighting is almost always used in aviation.

4.8. Noise metrics are mathematical units of measurement, or indices, used to quantify environmental noise.

4.9. A detailed set of definitions and explanations for various noise metrics used by the CAA is provided under the section 'Noise Metrics Definitions'.

4.10. Aviation noise only includes noise created by aircraft.

4.11. There is a distinction between 'air' noise and 'ground' noise. Air noise is usually the focus of aviation noise reports.

4.12. Noise contours and noise contour maps are used to help illustrate the impact of noise from aviation on local communities.

4.13. SID routes are defined routes which aircraft follow as they depart an airport.

4.14. NPRs are routes specifically designed to reduce noise exposure in populated areas.

4.15. Operational diagrams are used to identify where aircraft flew during 24-hour periods for a given period (e.g. 92 consecutive days in the average summer period).

Future Recommendations

4.16. During the creation of this document, we identified several accessibility issues within noise reports. We recommend that future noise reports incorporate the following suggestions:

4.17. It is imperative that diagrams in documents where noise is the principal topic include keys defining acronyms and metric symbols used. This practice ensures clarity and facilitates accessibility for diverse audiences with varying levels of familiarity with the subject.

4.18. Summaries and conclusions should be structured in an easily understandable format that is intelligible for all audiences, irrespective of their technical proficiency. The overall findings of the noise reports should be understandable to lay readers, and clearly broken down within the summary section, reserving technical language for the parts of the reports where it is required.