ICCAN

Independent Commission on Civil Aviation Noise

A review of aviation noise metrics and measurement

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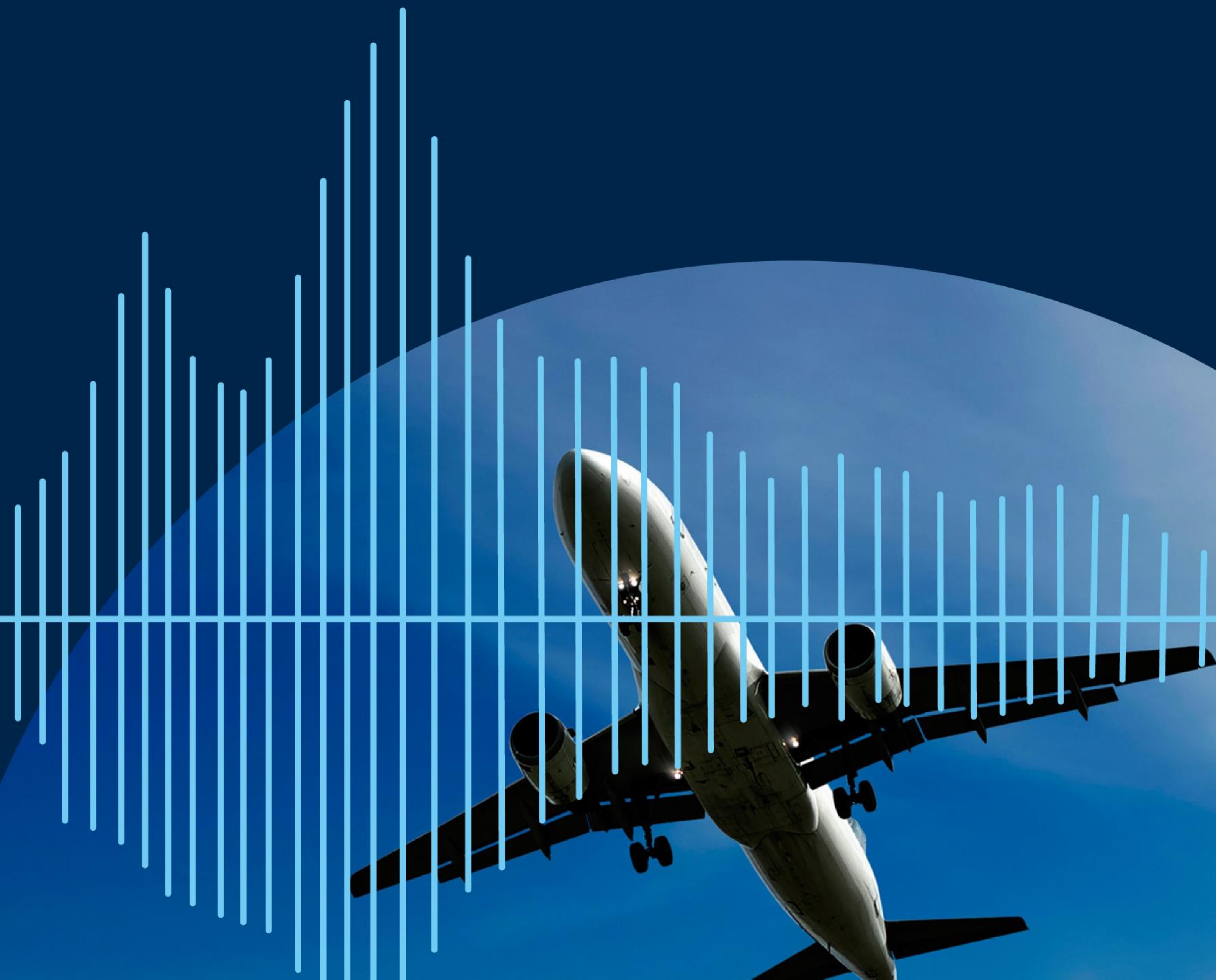

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Foreword

How noise is measured and what happens to the information collected is a significant part of the aviation noise debate. From the outside, that debate can appear to be experts talking to experts with little reference to real impacts on communities that live with aviation noise.

We recognise that the language of acoustics is exceptionally complex; however, technical accuracy means nothing if it can't be translated into meaningful language, which communities can relate to their experiences.

We know there is a wealth of aviation noise data from different airports collected in good faith but often in different ways against different criteria. We accept that this has often been because of attempts to address local factors – with some being tied to regulation or guidance, and some not. This all paints a picture of aviation noise management that is inconsistent and ineffective. The reality is that, without a real ability to compare noise management performance between airports, assessing what is effective and what is not becomes more difficult.

In our first look at the issue of noise metrics we offer an opinion on how we can move noise management forward. We recognise changes will not fix issues overnight and it will take time to develop a system that is fair, proportionate and has the confidence of all parties. Our further work will develop our proposals into a set of implementable actions and we look forward to working with the industry and communities to achieve this.

We are very clear that the rebuilding of the aviation industry after the Covid-19 pandemic must be done in a sustainable way, which will ensure future aviation can contribute to the economic and social ambitions of the UK. Having an aviation noise management process which is consistent, transparent and accountable is crucial to building that sustainability.

Improving aviation noise management is an important way for the industry to develop its social licence to operate, instil greater confidence and build trust with people and communities. I hope everyone will recognise ICCAN's recommendations on noise metrics and measurement as a route forward for the future.

Rob Light
Head Commissioner, ICCAN

Chapter 1 : Context

The collection, analysis and publication of noise data is key to assessing and managing the impact of aviation noise. Without adequate data collection, a clear understanding of the effects of noise exposure cannot be adequately assessed, which can lead to frustration among communities. Opaque processes and practices in noise collection, and communication of the outputs from noise metrics, can result in tensions between the aviation industry and people who are affected by aviation noise.

Since ICCAN's establishment at the start of 2019, we have met with a range of stakeholders to gain an understanding of the issue of aviation noise from all perspectives. We know that noise metrics are a contentious issue. Communities can feel disempowered by metrics that are too complex and do not appear to express what they experience.

By assessing the way noise is currently monitored, measured and reported by airports, and recommending how it can be improved and made more consistent and transparent, we aim to help increase the level of trust between airports and their communities on the topic of noise management.

The objectives of this review of aviation noise metrics and measurement are:

- To increase wider understanding of different noise metrics and what they represent;
- To review the current use of noise metrics; and
- To make recommendations on how the clarity and consistency of noise metrics can be improved.

This report looks at the many metrics that are used to assess noise exposure, and asks which ones relate best to annoyance and how readily they can be understood. We explore the background to the policy and legislation surrounding aviation noise metrics, as well as the data collection processes for producing them.

Based on our findings, we make a number of recommendations for how the measurement, monitoring and reporting of aviation noise can be improved. In particular, we think more can be done to communicate information to affected communities in an open, clear and transparent way. We also believe that improvements to noise collection and processing can be made, which are important for improving both how aviation noise is monitored and how it is managed.

ICCAN's key findings and recommendations on noise metrics

A full version of our findings and recommendations can be found in Chapter 6. In summary, we propose that:

- L_{Aeq}-based metrics currently used for noise monitoring should continue, but we recommend that supplementary metrics should routinely be published by airports to better reflect the way in which noise is experienced on the ground;
- The approach to noise monitoring around the UK is neither consistent nor clear to stakeholders; we will develop best practice guidance for UK airports on the approach, standards and quantity of aviation noise recording and monitoring;
- We will develop best practice guidance for airports on the temporary provision of noise monitors for local communities;

- Noise data transparency should improve. Our best practice will include standards for the publication of data to enable communities to track changes and trends around airports;
- The Air Transport Movement (ATM) threshold of 50,000 which acts as a trigger for the publication of prescribed noise data should be lowered but applied proportionately and, potentially, tiered;
- ICCAN will provide national leadership and set standards for metrics by developing and publishing such best practice guidance in the months to come.

The publication of this report precedes the Government's anticipated Aviation 2050 strategy, which is likely to consider the use of metrics and noise envelopes. While we do not have powers to enact or introduce our recommendations, we will work closely with the aviation industry, regulators and Government to encourage their adoption.

We hope to make further recommendations on how aviation noise is managed in the UK as part of our future work. We also hope that our recommendations will be helpful to communities and other industry stakeholders who will benefit from access to better, more reliable noise data.

Only by having high quality information, which people can trust, can the UK progress to become a world leader in monitoring and effectively managing aviation noise.

Our approach

Responses we received to a survey on our first Corporate Strategy (ICCAN, 2019) showed that noise metrics are a key priority area, where ICCAN can provide meaningful insight for stakeholders, the aviation industry and communities (ICCAN, 2019, p. 10). We began by conducting extensive desk research into the background of noise metrics. A framework was developed comparing existing noise metrics and other related areas were identified which required a greater understanding, including how noise data is collected, processed and published. After reviewing existing literature, input and engagement was sought from key stakeholders to develop our understanding of these topics against our framework and on emerging concepts. Our expert panel assisted us with quality assurance of our work, but any errors in the report remain our responsibility.

We identified five key questions to help us assess the suitability of different aviation noise metrics:

1. To what extent does the metric represent perceived annoyance?
2. Does the metric have a correlation with other health effects?
3. What aspects of the noise impact does the metric represent (and what does it not include)?
4. How practical is it to collect and process the data for the metric?
5. Does the metric have a correlation with quality of life/well-being (there currently isn't any published research specifically linking a metric to quality of life/well-being)?

In addition, we considered what information communities want to know and which aspects of aviation noise have the greatest impact on annoyance.

These might include:

- What is the frequency of flights going overhead?
- What time will the flights be?
- How noisy will the flights be?
- Is there a difference in effect between summer/winter, day/night, weekend/weekday?
- Are there predictable respite periods?

To fully explore these topics, further research beyond the scope of this initial review is recommended. Future work to follow could include the assessment of noise metrics using data from UK airports, as well as the development of best practice guides. These aspects haven't been included as part of this review because such tasks are resource-intensive or require complex modelling. Much of this proposed work will require us to engage with a range of experts and stakeholders. Noise monitoring standards, including setting the thresholds of exposure, or showing the impacts of using different metrics on noise contour positions around an airport, will be the subject of further best practice guidance we intend to develop and issue in the coming months.

We did not set out to create a new single catch-all metric for the assessment of aviation noise. Developing any new metric would necessitate years more research to prove specific links to noise annoyance and associated health impacts. Since aircraft noise has been systematically assessed for approximately 60 years, such a single metric probably will never be appropriate and agreed by all within the sector. We believe it is better to focus on using existing long-standing data, coupling this with a clear understanding of what each metric represents, as well as an appreciation for the scope and limitations of the various metrics and an acceptance of the subjective and very personal nature of experiencing noise.

There are several aspects of aviation noise, one of which is ground noise. This includes noise generated from aircraft such as taxiing or using auxiliary power units while on a stand at a terminal or engine testing. This noise is different in its character and propagation from that of a flying aircraft (CAA, 1998). Different metrics and ways of recording the noise may therefore be needed to investigate ground noise. This was not covered in this review.

Another aspect is sonic booms, which some military aircraft are capable of creating, where an aircraft breaks the sound barrier. Sonic booms are currently not applicable to civil aircraft noise, since the decommissioning of Concorde in 2003, and so are beyond the scope of considerations for ICCAN.

Similarly, military aviation noise in general is beyond the scope of ICCAN's work as it is exempt from the same regulatory processes, even if the aircraft sometimes share the same airfields as civil aviation aircraft.

Our review focuses on metrics used for air noise from fixed wing aircraft (jet or propeller driven aeroplanes) and not rotary winged aircraft (helicopters and drones). This is because metrics relating to annoyance for fixed winged aviation are generally accepted to not be applicable to rotary wing aircraft, making links to annoyance unclear. This is due to the different sound properties of these aircraft types (CAA, 2020) (ICAO, 2019).

Chapter 2 : Why do we measure aviation noise?

To understand why we measure noise, it is helpful to distinguish the difference between noise and sound.

Everyone encounters sound every day. Sound is measured by sound level meters. It is only when the sound causes an adverse effect on the listener that it becomes noise. That adverse effect can be conscious, i.e. a sense of displeasure or irritation caused by the sound, or it can be unconscious, i.e. there is no subjective disliking of the sound, but there is, nevertheless, an adverse physiological reaction occurring.

What causes a sound to become a noise depends on many factors. The magnitude of the sound must be loud enough so it is heard, but it is more than its loudness that affects whether it is experienced as noise. There are other factors including its character (i.e. is it continuous, intermittent or impulsive?); its frequency content (is the sound high pitched, low pitched or tonal?); its duration; the time of day it occurs; the day of week it occurs; whether it was unexpected; what the listener's view is about the source of sound and what the listener is trying to do when the sound occurs. Even if the sound level of an aircraft and another source, such as a washing machine in operation, were the same, the annoyance generated is likely to be completely different.

These reasons are why 'noise thermometers', which try to equate specific decibel (dB) levels to everyday events, are unhelpful or even misleading. Hence noise metrics have been developed to try to create a more representative way to quantify noise exposure as it is experienced by a person or community. Similarly, this is why it is so difficult to identify a single metric that captures all these various factors so that a measurement of the sound can be used to determine whether it is perceived as noise, as well as determining the degree of adverse effect that it is causing.

There are differences in the way that noise and sound are interpreted. For example, the EU's Directive 2002/49/EC (Official Journal of the European Communities, 2002) defines noise as 'any sound' and does not distinguish between pleasant and unpleasant sounds, although it is generally recognised that there are differences.

What do we mean by aviation noise?

Aviation noise is unwanted sound from aircraft which causes disturbance and has an adverse effect on those who hear it. The main adverse effect that occurs is a sense of annoyance. To determine the annoyance from aviation noise, the noise level from aviation needs to be measured. The noise level is then correlated to levels of annoyance, as determined by research. Measuring aircraft noise and its effect on the people who experience it is a complex task. There are several reasons for measuring aviation noise, including: determining the levels of annoyance it is causing; comparing the noise generated by different aircraft types; and checking the effectiveness of any noise mitigation strategies for reducing the impacts of aviation noise. Arguably, the most complex to measure is determining the levels of annoyance.

Noise modelling

It would be ideal to be able to use physical measurements of aviation noise in all cases i.e. using a microphone to measure the noise and generate a value wherever it is required.

This approach, however, is not practical over the vast geographical areas that can be affected by aviation noise. Consequently, many of the ‘measurements’ are generated from sophisticated computer models. These models can either produce values which are retrospective or predictive, depending on the input data used. In all cases, the values generated from models tend to be termed ‘measurements’ regarding aviation noise.

The use of modelled noise metrics as evidence for expansion or airspace change, while understandable given the scale and resources required for constant and geographically spread ‘live’ noise monitoring, can be controversial and disputed by local communities. For instance, it may not be based on aircraft flight paths or behaviour at the specific airport in question.

Decibels

Sound and noise are measured in decibels (dB). Although the physical properties of sound are fluctuations in air pressure, it is impractical to measure sound in the standard units of pressure such as Pascal (Pa). This is because the human ear can detect such a wide range of sound pressure fluctuations from around 0.00002 Pa to 200 Pa. It is also easier to describe a range of sound levels using dB; e.g. 40 dB to 80 dB instead of 0.002 Pa to 0.2 Pa.

The dB scale is logarithmic (see Endnote 1), meaning that each increment increases by a given factor. A logarithmic scale is used as it better represents how we hear sound levels, although the relationship between hearing and dB is not exact due to the way that the brain processes sound.

When examining sound, an apparently small numerical increase in dB values can represent large increases in noise energy. For example, an increase of 3 dB is equivalent to a doubling of the sound energy. In relation to aviation noise this could be from a doubling of aircraft overflights, or a doubling of the sound energy generated by the aircraft for the same number of overflights.

However, the human ear can barely detect a change in sound level of 3 dB if all other features are the same. Conversely, a change of 10 dB in either direction is generally regarded as a doubling (or halving) of subjective loudness.

These features can make it challenging to appreciate how changes in decibel levels relate to changes in the actual noise perceived and is a significant complication when trying to communicate noise metric outputs to the public.

Noise generation by aircraft

Aircraft noise is a combination of engine noise (sound generated by moving parts of the engine and air passing through it) and airframe noise (sound generated by both friction between the aircraft’s body and the surrounding air, and the resultant turbulence). All flying aircraft (including motor-free gliders) produce some noise. The noise produced varies between aircraft types and even between aircraft of the same type.

The CAA lists the following factors known to affect the level of aircraft noise heard on the ground (CAA, 1992):

- the aircraft type
- the type of engines and propulsion system
- the aircraft's total loaded weight
- whether it has just taken off or is about to land
- its power settings
- flight path taken (i.e. straight, curved, climbing, descending)
- speed
- altitude
- atmospheric conditions (temperature, humidity, wind speed - direction and turbulence)
- the surrounding terrain, ground cover and the presence of absence of buildings or other obstacles.

The way that sound travels away from an aircraft is known as noise propagation. This is influenced not only by the distance between the aircraft and the receiver (whether that be a person or microphone), but also by other factors affecting how the sound waves travel. These include atmospheric conditions and the presence or absence of obstacles in the sound's path.

What do we gain from measuring aviation noise?

Measuring aviation noise enables us to understand both who is exposed and what potential impact it may have on their health and quality of life. Understanding these impacts is crucial to managing aviation noise in a way that balances these adverse effects with the positive economic and social benefits that aviation can bring.

To determine what we want to measure, we first need to decide what it is that we want to know. To determine annoyance, at its simplest, we need to ask the question: '*What is the level of annoyance experienced by an individual at a given location because of aviation noise?'*

The first step requires the relationship between the noise impact and the annoyance to be determined. This includes finding the noise metric that best correlates with the annoyance. This is achieved by undertaking social survey studies to determine the annoyance occurring and relating that result to various noise metrics. Statistical analysis not only identifies the most appropriate noise metric of the range examined, but also the relationship between that metric and annoyance. This means for a given value of the noise metric, it can be estimated what the typical extent of annoyance is occurring by the affected community and therefore the degree of impact.

A similar approach is used when trying to determine the effect of aircraft noise on other health outcomes such as increased levels of stress (Schreckenberg, 2016) and sleep disturbance (WHO, 2018), the increased risk of cardiovascular disease (CAA, 2016) (WHO, 2009) and other adverse social impacts, such as delays in learning to read in young children who are exposed to aviation noise (WHO, 2018).

By selecting the right metric(s), and gathering data on aviation noise, along with expert advice and research, we can make progress in answering important questions surrounding annoyance, health and social impacts, in a meaningful way. For communities, they need to be engaged fairly so that they can contribute to the discussions, understand proposals and have their views heard. This means that the metrics need to be reflective of what they experience and also be understandable. In short, choosing the best metric is crucial for effective engagement between all parties who need to understand aviation noise.

Metrics and data evidence are also important for developing effective policy on issues such as airspace change and airport expansion. Evidence-based policy allows the fair setting of regulatory values, which balances the needs between what is achievable by airports and operators and what is reasonable for affected communities (ICAO, 2008). For example, airports use measured noise data to develop their noise insulation schemes, by identifying residents that are likely to be most adversely affected by aviation noise and provide mitigation schemes to reduce the noise impacts in their homes. Noise predictions are also an integral part of an assessment of any proposal by an airport to extend or materially change its operations.

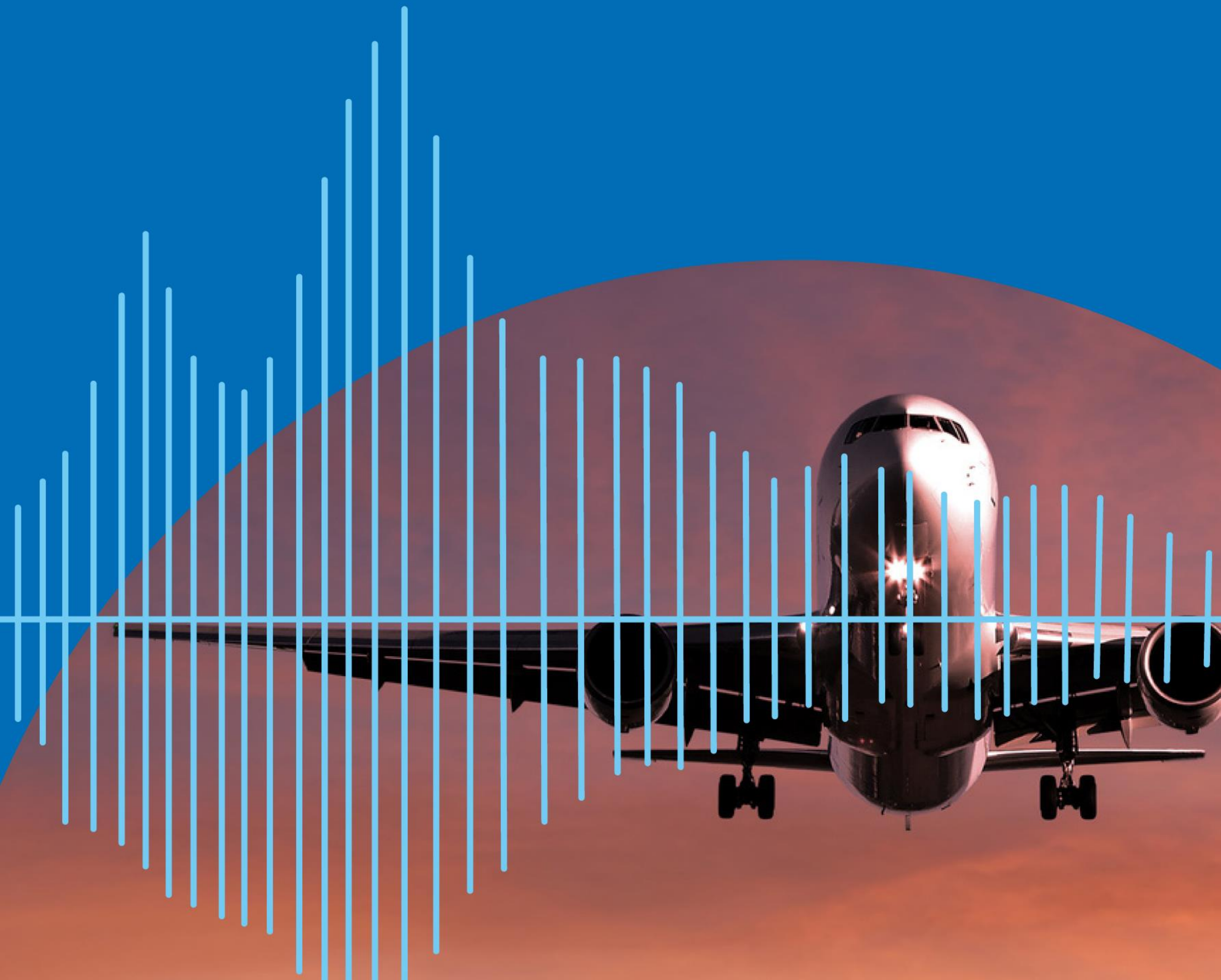
In England, the over-arching policy on the management of noise is set out in the Noise Policy Statement for England (NPSE) (Defra, 2010) (see Endnote 2). Drawing on toxicological concepts used by the WHO, the NPSE describes the Lowest Observed Adverse Effect Level (LOAEL). The LOAEL is the noise exposure at which, on average, adverse effects start to be detected. As the exposure increases above the LOAEL, the adverse effects increase. The NPSE extended this principle by introducing the concept of the Significant Observed Adverse Effect Level (SOAEL). This is the exposure at which, on average, significant adverse effects start to be detected. As the NPSE states: *'It is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times.'*

The Department for Transport has defined the LOAEL for day and night aviation noise (DfT, 2017). For some proposed airport expansion schemes, however, various values for SOAEL for aircraft noise have been used. The Government has not defined a single value that should be used for all aviation applications.

In an attempt to improve the consistency and quality of aviation noise measurement, there is now a wide range of legislation, recommendations and guidelines in place to govern both the measurement or calculation of aviation noise, and publication of the resulting data. One consequence is that there is now a range of metrics that are used to report aviation noise in the UK. This is a legacy from the EU and UK Government having differing opinions on which are the most effective metric(s) to measure and understand noise impacts. It is important to have a means of quantifying noise for monitoring purposes, which can then be put into legislation. It is essential that the required metric(s) named in policy is correctly applied and any outputs should be clear, not only for policy makers but also for effective public engagement.

A summary of the current legislation and policy surrounding aviation noise within the UK can be found in Annex A (also see Endnotes 3 and 4).

Chapter 3 : What are noise metrics?



There are a wide range of metrics used internationally, which have evolved over time, and which can be used to describe noise exposure from aircraft. They have been developed to try and understand the effect of noise exposure upon an individual or community by capturing different aspects of aviation noise over time.

Communicating about aviation noise is a challenge for all. The complexity of noise metrics can make it difficult to appreciate what the different values represent and how these relate, or should relate, to experiences of aviation noise. This can be for a variety of reasons, such as difficulties interpreting logarithmic scales, or being unaware of what a metric represents and how the results should be interpreted- The challenge is between using metrics which offer simplicity – which risks making them unrepresentative if not enough factors are included to reflect people's experiences – and those that reflect complexity – which risks making them too difficult to communicate and interpret.

Metrics aim to quantify noise in a meaningful way. In terms of trying to determine the effect caused by noise, there are two ways to look at noise measurements:

- The absolute value of the noise exposure
- The relative change or difference between the noise of the source of interest (i.e. aircraft) and the other sound occurring at the same time.

These have different uses. Absolute levels are important from a regulatory point of view, whereas the relative change in noise might be more informative for assessing annoyance, because of the way the human ear perceives sound.

In an ideal world, a single metric would be able to capture all the factors that influence a person's experience of aviation noise and produce a definitive measure of annoyance. As mentioned in Chapter 2, however, the likelihood of this being achieved is extremely low because annoyance is different for individuals within affected communities.

There is increasing evidence that sensitivities to aviation noise have changed over time (CAA, 2017). Consequently, not only might the relationship between the value of a metric and the associated annoyance change with time, the factors that cause annoyance may also change requiring a different metric to be found.

The array of noise metrics developed to date reflects both the complexity of acoustics and measuring noise, and the difficulty in coupling the subjective experience of noise annoyance with sound exposure levels.

A background to noise metrics in the UK

Some of the UK's noise metrics can be traced back to the 'Wilson' report of 1963 – 'The Final Report of the Committee on the Problem of Noise' – chaired by Sir Alan Wilson. The purpose of the Committee was '*to examine the nature, sources and effects of the problem of noise and to advise what further measures can be taken to mitigate it'*. Though not solely focused on aviation noise, the Wilson report broadly aimed to define quantitative noise levels that could be used to set reasonable noise exposure limits and eventually develop this into statutory noise limits. It did this by assessing annoyance in affected communities. In many ways the challenges around noise annoyance have remained unchanged since the publication of the Wilson report. Research continues to be done into identifying the suitability of metrics and the annoyance caused by airplane noise, such as the ANIS (CAA & DfT, 1985), ANASE (MVA Consultancy & DfT, 2007) and SoNA14 (CAA, 2017) studies.

Noise contours showing the impact of operations at Heathrow Airport were included in the Wilson report. Actual contours were shown for 1961, and predicted contours shown for 1970. The noise metric used was the Noise and Number Index (NNI) based on a social survey study carried out in 1961, with the results being associated with corresponding measurements. The NNI was used to describe the impact of aircraft noise until 1990 when it was replaced by L_{Aeq}.

It was in the 1930s when technology permitted the development of what is known as equal loudness contours (Fletcher & Munson, 1993) (see Endnote 5). This research established how the human ear had different sensitivity to sounds in different frequencies. To reflect this variation, the A-weighted adjustment was developed which altered the values of the measured sound in different frequencies so that the result would better reflect what we actually hear. The A-weighted curve was standardised, and most sound level meters today measure the sound in terms of the A-weighted decibel.

It was also found that the variation in hearing sensitivity with frequency varied with sound pressure level. Therefore, other weighting curves were developed (known as B-weighting and C-weighting), so that A-weighting applied to sound pressure levels of around 40 dB; B-weighting applied to levels around 70 dB and C-weighting to levels around 100 dB. In the 1960s, the use of a D-weighting curve was proposed specifically in the context of measuring aviation noise in order to improve the correlation with the subjective response. It was broadly similar to the B-weighted curve but with the values in some higher frequencies being enhanced.

It was increasingly recognised that changing the weighting used whenever the sound pressure level changed was impractical. Furthermore, it was found that A-weighting correlated very well with the subjective response across the normal range of sound pressure level. Consequently, the A-weighting became commonly used.

Since the early 1970s, research found that the L_{Aeq} metric was most closely associated with subjective response. The $L_{Aeq,T}$ is a notional continuous A-weighted sound level over a given time period, T, that contains the same sound energy as the actual time varying signal over the same time period. With the advent of sound level meters in around 1980, which could measure the value of L_{Aeq} directly, it has become the most prevalent metric in noise management. As shown in Table 1 on page 25, the time period over which the L_{Aeq} is measured has to be defined. The most common periods used are the 16 hours between 07:00 and 23:00 ($L_{Aeq,16h}$) and the eight hours between 23:00 and 07:00 ($L_{Aeq,8h}$). The other definition that is required is whether the $L_{Aeq,T}$ applies to an annual average day (or night) or a summer average day (or night), or an average weekday (weeknight) etc. So, whenever a sound exposure is stated in terms of L_{Aeq}, it is essential that the various averaging periods are also defined. Other L_{Aeq} based metrics that can be found are L_{den}, L_{day}, $L_{evening}$, and L_{night} (CAA, 2009, pp. 7-9).

Most of these metrics are well-established within the aviation sector, with an extensive existing knowledge base. This makes them useful for research into annoyance, as well as other health and social issues (WHO, Environmental Noise Guidelines for the European Region, 2018).

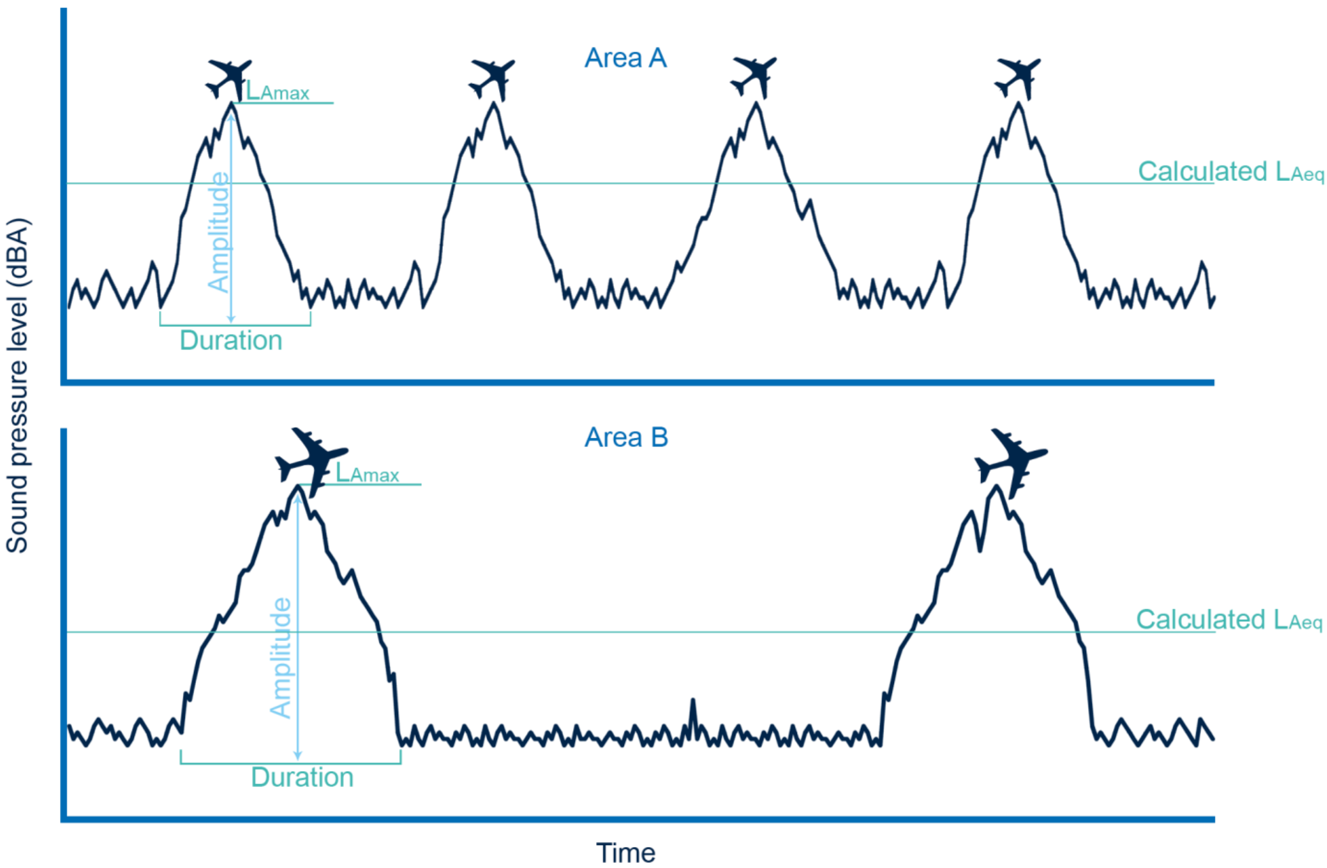
The way that metrics are being used continues to evolve. There has been concern that the averaging calculation in the L_{Aeq} metrics masks some of the impacts perceived in the community. Consequently, other noise metrics have emerged such as N70, N65 and N60. These are the number of aircraft events overflights (CAA, 2017) (see Endnote 6) at a location in a given time period where the maximum sound level of the event is at least 70 dB(A), 65 dB(A) and 60 dB(A) respectively. A drawback with this indicator is that the value of, for example, N60 would increase by the same amount regardless of whether the maximum level of the noise generated by the aircraft was 61 dB(A) or 91 dB(A). The effect of those two events would, however, be likely to be very different.

Key concepts for noise metrics

Averaged results

As mentioned above, there is concern that using average values to quantify the sound exposure does not properly represent the impact and effect experienced. Flights can vary in number over the course of a day, week or year. This can be due to a range of factors including emergency events, switching runways due to the prevailing wind direction or changing flightpaths to give some communities a respite period. The type of aircraft used can also vary, which will also have an impact on the noise exposure.

Another issue with average noise exposure metrics is that areas with very different noise events contributing to the overall noise exposure (e.g. a few noisy flights compared with a higher number of quieter flights) will result in similar average noise exposure values, but the noise experiences may be very different. In this context, an average noise level can feel unrepresentative of what is experienced, and difficult to interpret by those who are affected by aviation noise (see Graph 1).



Graph 1 Two graphs showing a hypothetical difference between two areas with different overflight experiences resulting in similar L_{Aeq} values. This shows how L_{Aeq}, as a highly averaged time metric, can disguise differences of what is experienced by different communities (graphs show illustrative values only).

Weightings

In addition to the sound frequency weighting mentioned above, some metrics also apply a time of day weighting. This reflects the greater sensitivity to noise that exists during the evening and night compared with the daytime.

An example of this type of metric is the $L_{den.}$ This provides a single figure value for the noise exposure but is calculated with the evening and night periods, attracting additional decibel values to the actual measured result and the day period receiving no additional weighting. It was developed by the European Commission to support the Environmental Noise Directive (Official Journal of the European Communities, 2002). The 24-hour period is divided into a 12-hour day (07:00 – 19:00), a 4-hour evening (19:00 – 23:00) and an 8-hour night (23:00 – 07:00). The annual average L_{Aeq} is determined for the three time periods. Once this has been done, 5 dB is added to the evening period levels and 10 dB added to the night period levels. The levels from the day, weighted evening and night periods are logarithmically added to obtain the L_{den} value.

Alternative weighting methods are used by other countries which can reflect the annoyance experienced at certain times of day, week or even across a year. This makes the L_{Aeq} metric potentially flexible. The UK does not use its own variation of L_{Aeq} weightings to include factors such as week days.

A metric should reflect the consequent impact/effect on people to be determined. Research is used to determine the appropriate weightings, but these may often appear arbitrary and the method assumes that everyone experiences the same amount of variation in annoyance across different times. Therefore, it is a challenge to define noise sensitive times and what level of weighting should be applied.

Many view weightings as subjective and there is uncertainty about the usefulness of this practice. There is an argument that time-of-day weightings generally underrepresent, or don't accurately reflect, annoyance and merely add complexity. It has also been suggested that it may be appropriate to also change the times and weights used throughout the year as day length changes, though this may be unlikely to occur as it would add even more complexity (European Commission, 2000) (ANIMA, 2019).

In terms of noise sensitive times of day, levels of noise which correlate with annoyance are typically different during the night compared to the daytime (CAA, 2017) (European Commission, 2000). This is mainly due to the effects of sleep disturbance (WHO, 2009). Poor sleeping patterns are widely known to be associated with worse physical and mental health outcomes, and are the reason why additional weightings are often added to night-time periods (WHO, 2009) (CAA, 2016).

Noise can become more noticeable at night because background noise levels usually drop, making the difference between background noise and an intrusive noise greater. This can make the noise event more noticeable to those experiencing it. The times defined as night aren't necessarily representative of a communities' lifestyle. Not everyone has the same sleeping hours (duration or time of day). Weighting may also be biased against people that don't leave their homes during the day (e.g. the retired, those caring for children or the self-employed).

Noise sensitive days of the week are inherently included in most metrics but tend not to attract any specific weightings. Twenty years ago, the EU did recommend that Sundays should be considered separately (European Commission, 2000) but nothing has come of that suggestion since then. In other areas of noise management, the impact at weekends is often separately considered rather than trying to identify a weighting to include in a metric for that period.

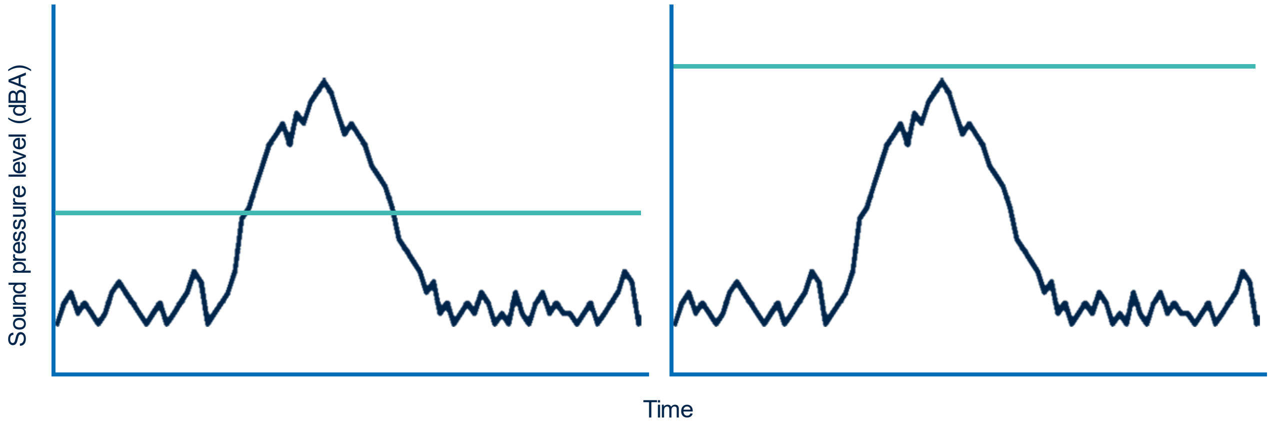
The argument against using weightings at weekends is that they may not reflect the lifestyles, working patterns or preferences of individuals. Conversely, weekdays may be considered as noise sensitive periods. For example, evidence suggests that exposure to aviation noise is associated with delays in learning to read for primary school pupils (CAA, 2016) (WHO, 2018). Although it might be tempting to try to include a weighting for the school day, it is much better to specifically measure the impact when the school is operating.

Grouping values

When presenting the outputs from measuring noise, values from separate overflight events are sometimes grouped together, for example, the events that occur above or below a threshold level. Though this simplifies the data into discrete categories, the additional insight from capturing the values of individual noise events is lost.

The threshold used also has a significant influence over how the data is perceived. This is important for metrics such as the Number Above (see Table 2: Exposure/Time-averaged/Cumulative noise metrics not based on L_{Aeq}), where the choice of threshold determines whether a noise event constitutes a significant change in noise levels. For these metrics, some noise events that may have contributed to community annoyance will not be counted because they have failed, perhaps only marginally, to reach the threshold value (see Graph 2, below).

Such problems could theoretically be overcome by setting multiple thresholds, but this adds complexity. Identifying which threshold will be most informative and useful to understand the effect on local communities is a difficult decision made by policy makers.



Graph 2 Thresholds can be used to determine whether a noise event constitutes a significant change in noise levels. How thresholds are set can be important in interpreting the results. In the left-hand graph, the noise event crosses a threshold and so is defined as significant and is counted. In the right-hand graph, the same event does not cross a higher threshold and so the noise event is not incorporated into the results.

Factors that influence annoyance

Annoyance is usually cited as the main negative impact from aviation noise and is caused by several different factors. The relative importance of these factors is likely to vary between individuals and communities, but they are nevertheless important when considering the suitability of potential noise metrics. These factors include:

- What is the frequency of flights going overhead?
- What time will the flights be?
- How noisy will the flights be?
- Is there a difference in effect between summer/winter, day/night, weekend/weekday?
- Are there predictable respite periods?

Different metrics will include and therefore convey different types of information by the way that the metric is calculated. There is no formal way of categorising metrics, but they broadly fall into two types of metric.

Comparison of aviation noise metrics

There are generally considered to be two types of noise metric:

1. **Exposure/Time-averaged/Cumulative noise metrics** all refer to metrics which try to quantify the noise impact from multiple aircraft movements during a given time frame. These tend to be the most complex metrics and are more challenging to communicate and interpret. For accessibility, we have divided these up into L_{Aeq}-based metrics (Table 1) and non-L_{Aeq}-based metrics (Table 2).

2. **Single event metrics** describe the noise impact of a single aircraft movement or over-flight in terms of its intrusiveness, loudness, or noisiness. These can be simpler to present and understand (Table 3). Some single event metrics are also used as the basis to produce the time-averaged L_{Aeq} metrics.

Set out in the tables below are lists of metrics used in the UK and internationally to monitor aviation noise, for ease of comparison.

It is important when comparing metrics is to understand what is and isn't represented in terms of characteristics of overflight events. For instance, no single metric would be appropriate to assess all aspects of aviation noise that cause annoyance. We assess which metrics are most useful on their own merits as well as identifying which metrics may be the most complementary to give a fuller representation of noise exposure.

The below summarises the tables, which follow each section in turn.

Exposure/Time-averaged/Cumulative noise metrics

The most commonly used international noise metric is L_{Aeq} (sometimes shown as $L_{Aeq,T}$ or L_{eq}) (Table 1) (CAA, 2017). L_{Aeq} is the basic International Organization for Standardization (ISO) indicator (see Endnote 7) and has been used in the UK for aircraft noise assessment since 1990.

L_{Aeq} measurements show the total energy of a varying noise source. This makes L_{Aeq} a useful tool to compare different noise sources and health effects. Links with L_{Aeq} and aircraft annoyance are unclear, but some of the derivative metrics are considered to have a reasonable correlation (European Commission, 2000) (CAA, 2017) (WHO, 2009). L_{Aeq} metrics are also used by the WHO to assess health effects.

L_{Aeq}-based metrics do not take into account all aspects of aviation noise that could influence annoyance. Factors excluded are:

- The number/frequency of events
- The duration of the events
- The maximum noise level of the events

- Tones and frequencies of the noise
- The difference between the peak noise and the ambient background noise
- Values from the less-busy winter period
- Times of day that may correlate with increased annoyance.

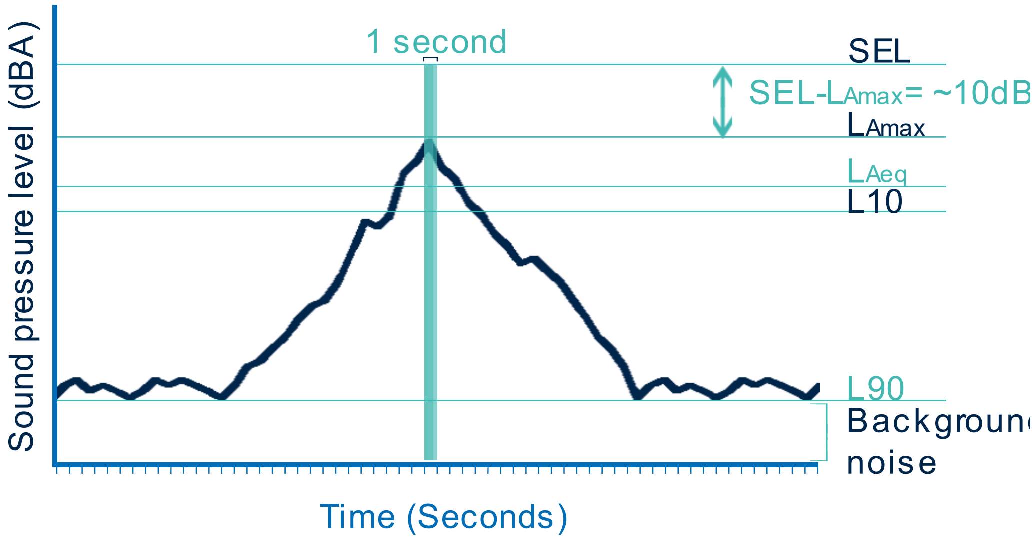
L_{Aeq} can be adapted to account for different time sensitivities and have different weightings applied (see Table 1). This means that it has the potential to be tailored to the preferences or characteristics of a community or noise source. A limitation of making specific adjustments to fit a local community is that research into how effective the new L_{Aeq} variant metric is in reflecting annoyance, or other health or special impact, will take years to gather enough evidence to assess its effectiveness.

The major advantage of L_{Aeq} metrics is how widespread their use is currently. This has resulted in a substantial volume of consistent noise data over a long time, which can be used to provide more informed insight of annoyance, and also the health implications associated with noise annoyance. It seems fruitless to add further L_{Aeq} metrics into the existing mix. If there was to be a move away from these metrics it might result in a significant amount of research becoming redundant. In reality, no correlation between a metric and annoyance, or any other factor, is going to be perfect.

Determining which of the L_{Aeq} metrics is most representative, and therefore most suitable upon which to base policy, is challenging. This is because, as discussed above, not everyone within the affected community around an airport will experience noise annoyance in the same way. For example, those doing shift work may value undisturbed sleep at different times to those who are not. This doesn't mean that individuals in an affected community are best served by being assigned the most relevant metric. It means that the most typically reflective metric needs to be selected for the community and this is difficult to do.

The disadvantage of the L_{Aeq} metrics is that they are not easily understood and interpreted by affected communities. Since they are based on dB, the logarithmic scale of the metric can make them difficult to grasp. This is because small changes in dB can correlate with significant differences in noise exposure. The values are also averaged over long periods of time, whether it be over a year or the 92-day summer period. Communities and individuals can feel that the resulting values are not reflective of their real-life noise experience. Subsequently, the forecast L_{Aeq} values produced for an airport give communities no real idea of what to expect in terms of aviation noise exposure and the potential impact of this on their quality of life. This level of averaging means that anticipated airspace changes, such as the number of flights, timing of the flights or composition of the aircraft fleet, may not be reflected through significant changes to the values.

Forward-looking information is becoming an increasingly important part of engaging communities in these issues and communicating potential noise exposures, which can help to mitigate against some annoyance (Australian Government, Department of Transport and Regional Services: Going beyond noise contours – local approaches to land use planning around smaller Australian airports, 2003) (Australian Government, 2019). This is seen as a shortcoming of L_{Aeq} metrics for communicating with affected communities.



Graph 3 This graph is of a hypothetical overflight noise event, recorded by a sound meter. The relative values from different metrics are shown. The Single Event Level (SEL) value over one second is the same total noise energy shown in the event duration. The reason that it appears significantly smaller is due to the logographic scale of Decibel. If a linear scale were use, the SEL would appear to be much higher than peak noise (L_{Amax}). The difference between the SEL and the L_{Amax} for aircraft noise events is approximately 10 dB.

Table 1: Exposure/Time-averaged/Cumulative noise metrics based on L_{Aeq}

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
L_{eq}	The equivalent continuous noise level that contains the same sound energy as the actual varying sound.	Provides an average value of the sound energy contained in the sound measured.	None	Does not appear on its own as it requires information about the time period over which the averaging occurs to be meaningful.	None
L_{Zeq}	The L_{eq} with the Z indicating that all the frequencies contained in the sound are measured as they are.	Provides an average value of the sound energy contained in the sound measured.	None	Does not appear on its own as it requires information about the time period over which the averaging occurs to be meaningful.	None
$L_{Zeq,T}$	The L_{Zeq} averaged over the time period T.	Provides an average value of the sound energy contained in the sound measured over the period T.	None	None. Occasionally used for other areas of environmental noise.	None

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
$L_{Aeq,T}$	The L_{eq} with the A indicating that the frequencies in the sound have been adjusted using the A weighting curve.	Provides an average value of the A-weighted sound energy contained in the sound measured over a period, T.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in various legislation, policy and standards associated with different time periods (T).	Generally felt to be a good indicator of likely annoyance and other health effects. Values can be influenced by a few very noisy events which could give a similar score to a large number of quieter events.
$L_{Aeq,16h}$	The $L_{Aeq,T}$ averaged over a 16 hour period. Conventionally that time period is 07:00 hours to 23:00 hours local time.	When determined for an average summer's day between the 16 June and 15 September, it is the main measure of aircraft noise impact (see Endnote 8).	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in British Standards, such as BS 8233:2014. The summer average day value appears in Government policy on aviation noise management (DfT, 2013) (DfT, 2017) (DfT, 2017). This metric has been used by the UK for examining aircraft noise since 1990.	An Exposure Response Function (ERF) exists between this metric and annoyance. This is thought to have changed over time. Also, some ERFs exist for other health effects.

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
$L_{Aeq,8h}$	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).	When determined for an average summer's night between the 16 June and 15 September, it is one of the measures of aircraft noise impact at night.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in British Standards, such as BS 8233:2014. The summer average night value appears in Government policy on aviation noise management (see Endnote 9).	The summer average night value is used to determine the percentage of people expressing self-reported sleep disturbance – although strictly, the correct measure to use is L_{night}.
$L_{Aeq,6.5h}$	The $L_{Aeq,T}$ averaged over a 6.5 hour period from 23:30 to 06:00 hours.	It has a specific application in aviation noise management and describes the noise exposure in the Night Quota Period.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Has been mentioned in Government aviation policy documents and is sometime used a control metric at some airports.	Nothing specific, although sometimes used to determine the percentage of people expressing self-reported sleep disturbance – although strictly, the correct measure to use is L_{night}.
L_{night}	The $L_{Aeq,8h}$ averaged over the period of one year.	Provides a measure of the annual average night noise impact, measured outside.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in the regulations that transpose EC Directive 2002/49/EC, the Environmental Noise Directive (END) (see Endnote 10).	There is an ERF between this measure and determining the percentage of people expressing self-reported sleep disturbance for aircraft noise (and road and rail noise).

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
L_{day}	The $L_{Aeq,T}$ averaged over a 12 hour period, conventionally between 07:00 hours and 19:00 hours local time. It is then averaged annually.	Provides a measure of the annual average daytime noise impact.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in the regulations that transpose EC Directive 2002/49/EC, the Environmental Noise Directive (END).	Some evidence of an ERF between this metric and some health effects.
$L_{evening}$	The $L_{Aeq,T}$ averaged over a 4 hour period, conventionally between 19:00 hours and 23:00 hours local time. It is then averaged annually.	Provides a measure of the annual average evening noise impact.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in the regulations that transpose EC Directive 2002/49/EC; the Environmental Noise Directive (END) which is translated into English legislation: (UK Statutory Instruments, The Environmental Noise (England) Regulations, 2006), as well as for the devolved nations.	None
L_{den}	The annual average $L_{Aeq,T}$, combining L_{day}, $L_{evening}$, and L_{night} but with the $L_{evening}$ value weighted by the addition of 5 dB and the L_{night} value	Provides a single measure of the overall annual average noise impact.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in the regulations that transpose EC Directive 2002/49/EC; the Environmental Noise Directive (END) which is translated	There is an ERF between this measure and annoyance for aircraft noise (and road and rail noise).

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
	weighted by the addition of 10 dB.		$L_{evening}$ has been weighted by the addition of 5 dB. L_{night} has been weighted by the addition of 10 dB (see Endnote 11).	into English legislation: The Environmental Noise (England) Regulations 2006 (UK Statutory Instruments, The Environmental Noise (England) Regulations, 2006), as well as for the devolved nations.	Also, some ERFs with other health effects.
$L_{Aeq,30mins}$	The $L_{Aeq,T}$ averaged over a 30 minute period.	Provides a measure of the average noise impact in a 30-minute period.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in “Building Bulletin 93 - Acoustic design of schools: performance standards”.	Some links with the impact of noise on teaching and learning.
$L_{Aeq,1h}$	The $L_{Aeq,T}$ averaged over a 1 hour period.	Provides a measure of the average noise impact in a 1-hour period. For aircraft noise, sometimes used to describe the impact during the period 06:00 – 07:00.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Can be found in BS 4142:2014+A1:2019 and BS 8233:2014. The value in the period 06:00 – 07:00 is sometimes used a control metric at some airports.	No formal relationships exist.

Table 1: A table showing Exposure/Time-averaged/Cumulative noise metrics based on L A e q

L_{Aeq} provides the basis for which other secondary metrics can be developed. This can be seen in the versions that are used in the UK, as discussed in Table 1. There are also other variants that are used around the world that are similar, but have been modified to try and represent annoyance for the local populations. Some of these international variations include (CAA, 2009):

L_{dn} **(Day-Night average Sound Level) (DNL / LDNL / LDN):** This L_{Aeq} based metric is similar to L_{den}, but divides the 24 hour period into two periods: Day (07:00 – 22:00) and Night (22:00 – 07:00). It was produced in 1973 by the US Environmental Protection Agency. It is currently used in America, Belgium and New Zealand. 10 dB weighting is added to the night time values (22:00 – 07:00). This weighting reflects a time window when it is considered that people's sensitivity to noise is greatest.

Californian Community Noise Exposure Level (CNEL): This metric, developed in the USA, is similar to L_{den}, in that it identifies three periods over 24 hours. Two of the periods have weightings applied to represent increased annoyance. A 10 dB weighting is added to the night period (22:00 – 07:00) and a 4.78 dB weighting is added to the evening period (19:00 – 22:00). The reason for using 4.78 dB is that it is the equivalent of exactly three-day flights, unlike the 5 dB weighting in L_{den} which is the equivalent of 3.162 day flights.

FBN: Similar to the CNEL, used in Sweden.

Störindex (Q): Similar to L_{dn} but has a different night time weighting. It also takes into consideration the number of flights by using a trade-off factor, giving a greater emphasis to the number factor ≈ 13.3. Developed in Germany, it has also been adopted by Luxembourg. Uses a night time weighting factor of 5 dB.

Hourly L_{Aeq} around the shoulder hours: Developed in Switzerland, this is based on a 16-hour L_{Aeq} daytime period (06:00 – 22:00) and three different one-hour night sessions of 22:00 – 23:00, 23:00 – 24:00 and 05:00 – 06:00. During the period of 24:00 – 05:00 night flights have been banned in Switzerland. The rational for these three 1-hour blocks is to impose limits on the maximum sound from a single event and to also take into account the number of overflights. This is to try and correlate with sleep disturbance.

Equivalent Aircraft Noise (EFN): Also based on L_{Aeq}, but uses different weighting factors. Used in Norway. It uses a continuous time weighting factor. It also has a Sunday daytime penalty.

L_{VA}: This Italian metric calculates is based on the SEL. It applies a 10 dB weighting to night movements (Goretti & Cotana, 2014).

Non-L_{Aeq}-based exposure metrics

A comparison of other exposure metrics, not based on L_{Aeq} (set out in Table 2 below) shows that none offers a viable alternative for assessing aviation noise or annoyance.

The Person Events Index (PEI) and Average Individual Exposure (AIE) have both been used as metrics in Australia, but limitations such as not factoring in quieter aircraft and underrepresenting annoyance for less densely populated communities, coupled with a lack of history in Europe and the UK, limits their value for measuring aviation noise in other countries. There is little evidence available on the overall effectiveness of these metrics and they are unlikely to add much further insight to the issue of noise annoyance.

Similarly, the Noise Exposure Forecast or Australian Noise Exposure Forecast are unlikely to contribute significantly to the overall picture of noise, with little UK data available (see Endnote 12) and no significant improvement on predicting community annoyance (Mestre, Schomer, Fidell, & Berry, 2011).

The Noise Number Index (NNI) was used in the UK until 1990. The UK's move from NNI followed recommendations from ANIS and the EU to move toward L_{Aeq}-based metrics. The NNI is no longer supported by health and annoyance response surveys.

Quota limits, the summed noise quota values an aircraft's noise certified values, are mainly used as an administrative tool by the DfT for setting noise limits for the designated airports (DfT, Night flight restrictions at Heathrow, Gatwick and Stansted: Consultation Document, 2017) (DfT, 2017) (see Endnote 13). The problem with a metric that sets a quota is that it is unlikely to be the most incentivising process to reduce overall aviation noise and may have unintended consequences such as increased flight numbers of quieter category aircraft. This is because quota systems allow operators to work up to the maximum level of the quota, rather than encouraging developing approaches which sees a sharing of costs and benefits between industry and communities.

It is worth noting, however, that there is a cap on total ATMs, encouraging airports to find a balance. There is also currently little evidence linking the relationship between annoyance, health or social aspects, which makes this metric of limited use beyond administration levels, when used alone. It can, however, have some utility when used as part of a suite of measurements.

Table 2: Exposure/Time-averaged/Cumulative noise metrics not based on L_{Aeq}

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
PEI	The Person-Event Index (PEI), is the sum of the value of Number Above (Nx) multiplied by the number of people experiencing that Nx over a given time period. It requires population densities to be known (see Endnote 14).	Provides a measure of the total noise load or burden from an airport for a given population.	Yes, insofar as X is usually defined as the $L_{Amax,S}$ (See table 3).	None (see Endnote 15)	No formal dose-response relationship exists
AIE	The Average Individual Exposure (AIE) is the PEI divided by the total number of exposed population.	Gives the average number of noise events (above X dB) per exposed person in a given time period. It helps indicate how much the noise is concentrated or shared.	Yes, insofar as X is usually defined as the $L_{Amax,S}$ (See table 3).	None	No formal dose-response relationship exists

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
Quota	A summation of the Quota Counts (QC) (See Table 3) of various aircraft events in a given time period (see Annex B and Endnote 16).	Provides a measure of the total aircraft noise generated by an airport in a given time period.	Yes – the frequencies of sound and the duration of the event have been weighted according to the definition of EPNdB (See Table 3). Departures and arrivals are given different weightings. Arrivals are adjusted downwards by 9 EPNdB (see Endnote 17).	Quota Limits are applied, usually to the Night Quota Period (23:30 hours to 06:00 hours) on a seasonal basis, at various airports to control night noise (see Endnote 18).	None
L_{AN}	The A-weighted sound pressure level exceeded for N% of the time.	Depending on the value of N, provides a measure of higher or lower or average sound levels in the actual varying sound.	Yes. The various frequencies in the sound have been weighted according to the A weighting curve.	Does not appear on its own as it requires information about the time period over which the averaging occurs to be meaningful.	None
$L_{A10,T}$	The L_{AN} where N = 10% over the time period T.	Provides a measure of the higher sound levels	Yes. The various frequencies in the sound have been weighted according	When averaged hourly between 06:00 hours and 24:00 hours it is	Some historic relationship with annoyance.

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
		occurring in the time period T.	to the A weighting curve.	used a measure of road traffic noise impact.	
$L_{A90,T}$	The L_{AN} where N = 90% over the time period T.	Provides a measure of the lower sound levels occurring in the time period T. It is sometimes described as the background sound level and tends to represent the level of sound when there are no particular discrete sound sources occurring.	Yes. The various frequencies in the sound have been weighted according to the A weighting curve.	Can be found in BS 4142:2014+A1:2019, used in planning conditions for fixed mechanical plants.	None
NNI	Noise and Number Index. A measure of aircraft noise exposure.	Combines the sound level (see Endnote 19) of an aircraft movement with the number of movements over the time period 07:00 hours to 19:00 hours for an average summer day between 16 June and 15 September.	Yes, the sound level is defined as the Perceived Noise decibel (PNdB) (see Table 3).	Was the standard measure of aircraft noise impact from the early 1960s until 1990 (CAA & DfT, 1985) (see Endnote 20).	There were historic relationships with annoyance based on surveys from residents living around Heathrow.

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
Noise Exposure Forecast	The Noise Exposure Forecast (NEF) aims to predict the number of complaints at a given noise exposure (see Endnote 21).	The sound level (expressed as the Effective Perceived Noise Level (EPNL) - see Single Event Metrics section below) is combined with the number of overflights. Only flights above a certain EPNL level are taken into account.	None	None	Some historical research with reading ability and annoyance, not relating to UK experiences
Australian Noise Exposure Forecast	This metric aims to predict the number of complaints at a given noise exposure.	The sound level (expressed as the EPNL - see Single Event Metrics section below) is combined with the number of overflights. Only flights above a certain EPNL are taken into account. A weighting is applied depending on time.	Yes. includes a weighting for flights between 19:00 – 07:00, where a higher trade off factor is applied to night movements than for day-time flights.	None	A study from Sydney airport in 1998 found that the majority of noise complaints (90%) came from residents outside of the lowest AENF noise contour lines, indicating that lower noise exposure levels aren't reflecting annoyance well.

Table 2 A table showing Exposure/Time-averaged/Cumulative noise metrics not based on L A e q

Single event noise metrics

The Nx metric is a logical and easy to communicate metric. It includes both loudness and frequency information, which are significant factors for annoyance for aviation noise. The metric is flexible in what information can be reported including over shorter time scales. It reflects key aspects of aviation noise that aren't covered by L_{Aeq} based metrics. It can be used for forecasting and reporting actual events with equal clarity. The number of events is an important aspect of noise exposure and therefore the Nx is more likely to be reflective of aviation noise and the annoyance it causes than L_{Amax} which only takes into account the maximum recorded noise. Hence, the Nx metric is more powerful, as it gives an indication of frequency of loud events, while still being a simple metric to generate and communicate. A consideration, however, is that once a noise event exceeds the Nx threshold there is no way to identify any further nose increases, so this metric is less likely to identify incremental aircraft changes and could result in the flights that exceed the Nx threshold to be even louder, as there is no cap on the maximum loudness.

The L_{Amax} is the oldest and simplest noise metric. It is frequently used in noise disturbance research as it has been found to correlate well with levels of both sleep disturbance (WHO, 2009) (CAA, 2016) (WHO, 1999) and reading and speech interference for school children (WHO, 2018). The L_{Amax} could potentially be useful in noise mitigation by applying a cap to the maximum noise exposure from an individual aircraft moment, i.e. an aircraft cannot exceed a given max dB level. This method of noise control can be popular with communities as it is easy to understand and gives a sense of reassurance that noise won't become too loud from individual planes. By recording only the maximum dB level in a given time period, however, L_{Amax} is not able to reflect the number of or frequency with which very noisy events occur.

The Effective Duration L(t) captures the total amount of time that a community is exposed to certain noise levels, but does not account for annoyance resulting from high frequencies or a few exceptionally loud overflights. Similar arguments can be made for the Time Above metric. Neither of these metrics provides significantly further insight to the issues than what the L_{Aeq}-based metrics already provide.

Although the SEL metric attempts to capture the total noise energy of an overflight, it is very difficult to accurately account for differences in background noise. Even if this metric used an average noise profile for each kind of aircraft at different heights, the perceived noise would still be different due to variations in background noise. The additional complexity of this metric does not result in significantly more information but does make it much more challenging for communities to understand and interpret the measurements.

Aircraft are designed to be able to take-off and fly even in the event of engine failure for safety. That means that aircraft have spare energy which isn't necessarily used in a typical take-off. Some aircraft can take off with as little as 50% of their full engine power. For aircraft noise certification, aircraft are flown at full power for take-off, so they achieve the greatest possible height in the shortest time, before noise is measured at 6.5 km from the start of roll position (see Endnote 22). This is not how aircraft are routinely flown, as many aircraft are flown at less than full power for fuel efficiency and also to prolong the life of the aircraft, as it reduces wear and tear. As a consequence, the operational Effective Perceived Noise Level (EPNL) is usually greater than the certificated values, which is particularly noticeable for departure noise levels. This means the EPNL is unlikely to be representative of the noise experienced by communities surrounding an airport. Coupled with the tone corrections that are thought to be subjective, the EPNL and related metrics, are less powerful than other single event metrics, as well as being more complex to communicate.

Table 3: Single Event Metrics

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
L_{Amax}	The maximum A-weighted sound level of an aircraft event. It is derived from the root mean square of the varying sound pressure. To be meaningful, a response time has to be defined.	Gives the value of the maximum sound level from an event.	Yes. The various frequencies in the sound have been weighted according to the A weighting curve.	Does not appear on its own as it requires information about the response time to be meaningful.	Frequently used in noise disturbance research. Some correlation found with sleep disturbance and speech interference. Strength of correlation unclear. Can be modified to the maximum noise experienced in the bedroom ($L_{Amax,inside}$) (CAA, 2009).
$L_{Amax,F}$	The L_{Amax} measured with a fast response time (see Endnote 23).	Gives the value of the maximum sound level from an event.	Yes. The various frequencies in the sound have been weighted according to the A weighting curve.	Does appear in some standards and guidelines.	Research tends not to differentiate between fast or slow response times

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
$L_{Amax,S}$	The L_{Amax} measured with a slow response time (see Endnote 24).	Gives the value of the maximum sound level from an event.	Yes. The various frequencies in the sound have been weighted according to the A weighting curve.	Is used to define the maximum level from aircraft noise events.	Research tends not to differentiate between fast or slow response times
Nx	The number of events (flyovers or movements) that cause the maximum noise to be X dB or higher. It needs to have a time period associated with it, but at present does not regularly have that in the way it is described.	Provides an indication of the number of events likely to cause disturbance. The extent of the impact depends on the value chosen for X (see Endnote 25).	Yes, insofar as X is usually defined as the $L_{Amax,S}$ (See Table 3).	Does not appear on its own as it requires information about the time period over which the value applies to be meaningful (see Endnote 26).	Depending on the value of X, there is some implied relationship with annoyance.
N70	This is Nx with X = 70 dB(A)	Provides an indication of the number of events likely to cause disturbance.	Yes, insofar as the 70 dB is expressed in terms of the $L_{Amax,S}$ (See Table 3).	None, although when defined over a given time period it is sometimes used a control metric at some airports.	Some limited evidence linking to annoyance

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
N65	This is Nx with X = 65 dB(A)	Provides an indication of the number of events likely to cause disturbance.	Yes, insofar as the 65 dB is expressed in terms of the $L_{Amax,S}$ (See Table 3).	None	Some limited evidence linking to annoyance
N60	This is Nx with X = 60 dB(A)	Increasingly being used at night (over the period 23:00 hours to 07:00 hours) to provide an indication of the extent of potential sleep disturbance.	Yes, insofar as the 60 dB is expressed in terms of the $L_{Amax,S}$ (See Table 3)	None	Assuming 15 dB(A) sound reduction through a partially open window, it can be related to advice in the WHO Community Noise Guidelines (1999/2000).
PNdB	The Perceived Noise decibel.	A metric specifically designed to measure an aircraft noise event that takes account of the frequency content of the source including tonality.	Yes. The frequencies of sound have been weighted according to the definition of PNdB.	Was an intrinsic part of the calculation of NNI (see Table 2).	Was designed to reflect how the sound of an aircraft event sound was perceived.
EPNdB	The Effective Perceived Noise decibel (also referred	Similar to the PNdB but which also takes	Yes. The frequencies of sound and the duration of the event	Is the metric used in the formal noise certification of	Was designed to reflect how the sound

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
	to as the Effective Perceived Noise Level (EPNL)).	duration of an aircraft event into account.	have been weighted according to the definition of EPNdB.	different aircraft types.	of an aircraft event sound was perceived.
Quota Count (QC)	A Quota Count which describes the noise of an individual aircraft departure or arrival based on the formal noise certification values in the EPNdB metric.	Provides a means of ranking aircraft according to how much noise they generate on departure or arrival.	Yes. The frequencies of sound and the duration of the event have been weighted according to the definition of EPNdB.	Quota Counts are summed over a particular time period to provide Quota limits at various airports (NATS, 2019).	None
Single Event Level (SEL)	The continuous sound level which, over a period of 1 second, contains the same sound energy as in the actual aircraft overflight event. It is usually determined by the energy within the actual event measured from when the sound level of the event first rises above the value 10	Provides a measure of the total sound energy contained in a single aircraft overflight event (see Endnote 28). It is used along with the number of movements in the time period T to generate the $L_{Aeq,T}$ metrics (see Endnote 29).	Yes. The various frequencies in the sound have been weighted according to the A weighting curve.	Not specifically although it is implicit in $L_{Aeq,T}$ metrics.	Some research done in the past in the UK. More research exists internationally. Generally considered to have a weak correlation with annoyance and sleep disturbance (Airport Commission, 2013).

Metric	What it is	What it does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
	dB(A) below the $L_{A\ max,S}$ value of the event until it drops below the value 10 dB(A) below the $L_{Amax,S}$ at the end of the event (see Endnote 27).				

Table 3 A table that shows Single Event metrics

Some other single event metrics are used in other countries, but they do not appear in UK legislation or guidance:

Kosten Index (Ke) (CAA, 2009): This metric was used in the Netherlands from 1963 until 2003, when it was replaced by L_{den}. It represented a yearly averaged of noise levels and looked at the dB and frequency curves of a sound to examine inside environmental aspects including hearing, speech communication and annoyance.

The effective duration: L(t): This is the duration of time (t) that a sound level is recorded as being at or above a given dB level during a single noise event. It is based on L_{Amax}. There are two variants of this metric;
1. The effective duration: This is the duration of a noise event with the constant level L_{Amax} that contains the same sound energy as the noise event described by the level-time-history L(t).
2. The 10 dB-down-time (t10): This is the time period during which the sound level L(t) occurs within 10 dB of the maximum sound level (L_{Amax}). The 10 dB-down-time is typically twice as long as the effective duration.

Time Above (TA): This metric reveals the total time duration that a noise is experienced above a given threshold. TA contours can be superimposed onto L_{den} contours to indicate noise durations as well as the average noise level (i.e. number of peaks of noise). The metric can be sensitive to the type of aircraft that is creating the noise, as different models will have different noise signatures.

Perceived Noise Level / Effective Perceived Noise Level / Weighted Equivalent Continuous Perceived Noise Level (CAA, 2009) (European Commission, 2000): To try and accommodate the different types of sound in a noise, the PNL was created, which has units of PNdB. This attaches a value to different noise frequencies depending how irritating the frequency is perceived to be. The different frequencies that make up the sound are added up to create a total noisiness value and is presented as a single maximum level (PNLmax).

The PNL scale was modified to include other sound parameters which involved tone-correction over a 10 second period to form the EPNL. The EPNL and SEL metrics are similar in that they integrate all the noise energy of a given event into a single event session (EPNL: 10 seconds, SEL: 1 second). The EPNL is regarded as more representative for aircraft noise and is therefore used for aircraft noise certification limits. The EPNL is, however, more subjective as its tone correction gives different emphasis to different frequencies. The EPNL tends to be more accurate at high noisier events than quieter events. Often the EPNL yields values 3-5 dB greater than those from the SEL (which is at least a doubling of the noise energy). There is no direct mathematical relation between the SEL and EPNL.

The calculations were based on the noise performance of 1980s aircraft. Modern aircraft typically have better climb performances in take-off, which would shrink departure footprints (see Endnote 30).

The WECPNL takes the EPNL but adds a weighting reflecting annoyance for the time of day. It also has a seasonal correction to reflect temperature. This metric was used in Japan, although there is now a move towards L_{Aeq} metrics.

Psophic Index (IP) (CAA, 2009): This metric looks at the number of overflights of different aircraft types. It assumes annoyance is linked with the peak noise levels. It was used in France and Belgium until 2002 when it was replaced by L_{den}.

It assumes that one daytime overflight is equal in annoyance to 10 night overflights. Therefore, it adds an extra 10 dB to night flights.

It is considered to be a poor representation of noise annoyance from light aircraft.

Chapter 4 : The practicalities of noise monitoring

The majority of noise monitoring guidance comes from non-aviation specific best practice guides produced by other bodies, such as the Institute of Acoustics (IOA), International Organization for Standardization (ISO) and The British Standard (BS). Although such guidance is not part of UK legislation, as these documents are issued under the banner of British Standards, they are likely to be considered the ultimate authority, and so these standards provide a means of implementing UK legislation and policy.

The first guidance on collecting noise data from airports was produced by the ICAO Council in 1971 (ICAO, 2019). In 1978 an International Standard was published entitled: ISO 3891:1978 Acoustics – Procedure for describing aircraft noise heard on the ground. A corresponding British Standard was published the following year: BS 5727:1979 Method for describing aircraft noise heard on the ground. These standards were updated in 2009 and the current version is BS ISO 20906:2009+A1:2013 Acoustics – Unattended monitoring of aircraft sound in the vicinity of airports.

There are also standards for sound level meters and calibrators, and quality calibration systems are used so that there can be certainty that the sound pressure fluctuations at the microphone are properly translated into decibel values. Airports usually use "Class-1" meters (see Endnote 31). This should result in the quality of data acquisition by the sound level meter being the same between airports. There is likely to be some variation, however, in the overall data collection between UK airports as there may be subtle variations in the practices for noise monitoring due to factors such as different contractors, age of monitoring equipment, budgets for number of meters per area etc. In part this is unavoidable, but the situation could be improved by providing additional specific guidance. Therefore, whenever any monitoring of sound levels occurs, if the various processes are followed, there is consistency in the quality of what is actually measured at the microphone. Whether what is captured is useful depends on other factors, some of which are set out below.

As mentioned in Chapter 1, the noise impact of an airport's operations tends to be expressed through noise contours generated by computer modelling. However, many airports undertake physical noise monitoring as well.

Physical noise monitoring

Many airports choose to conduct noise recording for their own monitoring purposes. There are three main reasons why airports physically measure noise:

1. **To implement a noise infringement regime**. This applies only to departures. Due to the noise certification process, the measurement points tend to be located at 6.5 km from the start of roll position (see Endnote 22) (CAA, CAP 1875: Consultation on CAA Minimum Requirements for Noise Modelling, 2020). Monitors should be placed under every departure flight path. Some airports, such as Luton, use two monitors as a kind of gateway to capture the variation in track used. Discussions have been held about having similar control limits for arrivals, however the general consensus is that pilots should concentrate on landing the plane safely rather than worrying about complying with a noise limit. Hence fixed monitors tend to be under departure routes in the UK.

2. **Environmental**. Mobile monitors tend to be used to measure the overall impact of an airport's operations on a particular locality over a shorter term, of varying duration. This type of monitoring enhances the data derived from the contours. For example, monitoring at a location that shows an average mode of 60 dB L_{Aeq} from the contours can show how that 60 dB occurs – e.g. is it mainly westerlies, mainly easterlies, a few noisy movements; more noisy movements – as well as the diurnal pattern (changes over a 24-hour period, including day and night).

3. **Monitoring individual aircraft**. This is not only to calibrate the noise contour modelling, but also to check how the certificated values (see Endnote 32) of an aircraft relate to that aircraft using a particular airport.

Fixed position unattended noise monitoring

For fixed position unattended monitoring, several issues have to be addressed. These are (CAA, 2005):

Other sound sources

It is important to try and avoid other sound sources that could affect the data. In the past this was achieved by setting a threshold that the sound level had to rise above for the noise monitor to start capturing the data and registering an aircraft overflight event. Current analysis still works on the same principle. This approach is more effective if you are closer to the airport, where the noise from aircraft is louder as they are flying lower and so there is a greater distinction between the background noise and the noise from the aircraft. Even so, it would not be sensible to put a meter close to a busy road for example.

Permission from the landowner

If the monitoring is to be effectively permanent, permission needs to be obtained from the landowner before placement and planning permission might also be required. Issues around access and inconvenience to the landowner also must be considered (CAA, 2005). Consequently, once a monitoring station has been established, it tends to remain. Additional permanent monitoring sites are not frequently established and take time to put in place.

Noise Track Keeping systems

Relating the noise data to Noise Track Keeping (NTK) systems is important so that the sound event detected can be correlated, with a reasonable degree of certainty, to being from an aircraft. There are features of aircraft sound events that can help in this identification; the shape of the rise and fall of the time history curve as well as the duration and the level of the sound can all help to confirm whether it is an aircraft event (CAA, 2005).

Attended and unattended monitoring

Whether a monitor is fixed or temporary, it is necessary to identify when an aircraft overflight event occurs. For unattended monitoring, this can be done using a NTK system.

Sometimes NTK systems cannot be used. In such circumstances, a person needs to be watching the meter, listening and making careful records to enable aircraft events to be properly identified. This approach, however, is labour intensive and the number of data points gathered are fewer than with unattended monitoring. For locations where the number of overflights in a given period is not high, it takes a lot of attended monitoring to obtain a reasonable sample of noise from the different aircraft types at a single location (CAA, 2005).

Other factors for consideration

The number and spread of noise monitors around an airport varies significantly. This is partly because noise monitoring is expensive, and it depends on the benefit that the airport believes would be achieved by the installation of monitoring. Airports also need to balance prioritising monitoring in areas that they believe are likely to be greater affected as well as areas from where there are higher number of complaints.

Differences in monitoring are also driven by differences in the concentration of populations around airports. For example, some airports are surrounded by continuous and densely populated areas, whereas others are near a coast or estuary. This affects availability of locations to install monitoring systems, as well as affecting the relative need of monitoring by the airport.

Having a standardised practice for where to carry out noise monitoring has both advantages and disadvantages (CAA, 2005).

On the plus side, it allows better quality and uniform data to be used for decision making. This is especially true for noise modelling. This is also important information for anyone living, or considering moving to, an area affected by aviation noise.

The disadvantage is that a standardised method for allocating where to monitor noise could be challenging for a number of reasons, as outlined above. Furthermore, it may result in resources being expended which don’t have adequate need or purpose. For example, if there were a requirement to monitor noise under a flight path 10 km from the airport, assuming that a suitable location could be found, the affected area could be either in the middle of an urban area, in a field, or out to sea, depending on the airport. Having a greater number of sound monitors could also be prohibitively expensive for smaller airports. Not only is the set up and running of monitors costly, but the cost of processing the data can be significant, and would increase with more noise monitors.

Identifying where to put a noise monitor to capture low dB level aviation noise is difficult due to the reduced difference between background noise and the low dB level of the overflight event (CAA, 2019). This is because the aircraft are higher, less noisy and the difference between their noise and the ambient sound is lower. The expected increase in accuracy resulting from more monitoring may not be proportionate to the additional costs incurred.

It is therefore impractical to consider that standardisation of noise monitoring to this degree should be implemented.

An important factor to consider that is noise monitors don't necessarily capture what people experience. This is because all noise monitoring occurs outside, but for many affected communities, it is the inside sound levels from aviation noise that are more important. The inside noise levels will vary depending on the level and quality of the sound insulation of the building, as well as factors such as the building's age and whether, and for how often, the windows are open. In cases where the aircraft do not fly directly overhead for people living in houses, they will experience less noise on the side away from the aircraft. For single aspect flats, residents on one side of a building may be differently affected from those on the other side.

Requesting noise monitoring

It is becoming increasingly common for airports to respond positively to members of the public or communities requesting temporary noise monitoring in their local area. This practice serves two purposes. Firstly, to provide airports with additional information about noise, which may identify badly-affected areas not previously detected through noise modelling. This information can then be used to improve the accuracy of noise model outputs and may be used to identify potential locations for permanent noise monitors to be installed. It should be noted, however, that for assessing noise it is not always necessary to physically measure the noise at a location. This leads to the second purpose, which is to provide reassurance to members of the public that their concerns around aviation noise are taken seriously by airports. Comparing periods with and without aircraft give an indication of the contribution of aircraft noise to the overall sound environment.

For mobile unattended monitoring, the same site location issues arise as fixed monitoring. Also, the NTK system needs to be used to detect when there are aircraft in the vicinity of the monitor or, alternatively, the monitor needs to be attended in person.

Currently there are no guidelines available for best practice of temporary noise monitoring by airports (British Standard & International Organisation for Standardization, 2009) (see Endnote 33) (although the guidelines mentioned previously would still apply) that are not required to provide this service. This means that approaches are not consistent between airports for factors such as how long the monitor is in place, whether it is attended or unattended, the metrics to be captured, how applications are made and prioritised for monitoring etc. Some airports instead choose to use hand-held devices for temporary monitoring.

As with any other type of noise recording, this service can be costly. It is therefore important that the best quality service and outcomes are achieved for both parties. This can be achieved by the production of a best practice guidance.

Noise contours

Airports covered by the requirements of the Environmental Noise (England) Regulations, 2006, as amended, and the equivalent regulations in Scotland, Wales and Northern Ireland have to produce noise maps every five years (see Chapter 2). These are published as part of the airport's Noise Action Plan (NAP).

The production of noise contour maps for airports has been standardised by ECAC (European Civil Aviation Conference, 2016). This includes standardised methodologies that must be used by all software packages that are used to generate noise contour maps. There are different software programmes that are used throughout the industry (CAA, 2019) (see Endnote 34).

The noise contour maps in the NAP do not need to be based on physical noise monitoring data captured by the airports themselves, but instead often rely on the published Noise Certificate NPD data combined with the airport's data for flight movement information. The data used to calculate noise impacts through computer generated models comes from three main sources, detailed below.

1. Noise Certificates (Noise-Power-Distance data):

This is the most commonly used data for generating noise contour maps. It is required by The Aeroplane Noise Regulations (1999) (UK Statutory Instruments, The Aeroplane Noise Regulations 1999, 1999) (see Endnote 35) and reported as part of the noise certificates produced by the manufacturers for every model of aircraft. The data is maintained and made freely available on The Aircraft Noise and Performance (ANP) Database (Experimental Centre, 2020),under the guidance of ECAC Document 29 and ICAO Document 9911. This data is often referred to as Noise-Power-Distance data (NPD) (CAA, 1999). These values are calculated from large volumes of data showing the noise emissions from the aircraft as a function of the altitude and the engine power settings. They also incorporate the effects of atmospheric conditions on sound propagation. NPD curves are created for a given aircraft model during both its take-off and landing (CAA, 2016). This standardised approach to collecting data allows comparisons to be made between airports, both in the UK and internationally.

To make the data set more reflective of specific airports and the actual noise exposure experienced, the modelled data outputs are calibrated by physical monitoring noise data that has been collected by the airport. This is done by both the airports for their own monitoring purposes, as well as by the CAA (CAA, 2019). Such an approach is seen as making the methodology robust and a good check that local circumstances do not cause local variations.

2. Noise recording:

As discussed above, many airports record aviation noise directly using noise monitors. This data has a number of uses, but a key use is to validate the noise contour maps produced by computer models. These noise monitors may be either fixed position monitors designed for long-term use, or mobile monitors for short-term use. Both types of monitor can be left unattended and the recorded data is processed at a later date. Sometimes an attendant is used to record the time when noise from a plane can be heard so that it can be identified more accurately from the data. This tends to be a more expensive process than having an unattended monitor and so is now used only where necessary (CAA, 2019).

3. Noise Track Keeping:

Noise Track Keeping (NTK) monitoring systems are also deployed at the larger airports. NTK monitoring systems are expensive and so are currently not available at some smaller UK airports. These are able to combine radar data with recorded noise data to determine more accurately whether a noise is coming from a plane or other source (CAA, 2003).

NTK monitoring systems are useful for noise modelling, as they can generate more accurate and detailed data about the flight paths used by aircraft. This may be particularly useful when it is difficult to distinguish between the background noise and the aviation noise when carrying out unattended monitoring. NTKs also have the advantage that they can provide additional information that is important for noise modelling, such as the type of aircraft generating the noise and the aircraft's average flight path, both vertically and horizontally. This can then be used to determine the power (thrust) needed for an aircraft and therefore the likely output of noise, dependent on the aircraft model. It also gives a better idea of where the aircraft would have been heard using the principles of overflight (CAA, 2017).

These calculated values can then be validated and calibrated against the noise recordings that have been made by the noise monitors (CAA, 1999) (CAA, 2019). However, these monitors produce much larger datasets and so a greater amount of processing power is needed for noise modelling (CAA, 2019) (CAA, 2020). It should be noted that it is not usually the case that the data from every aircraft is used in model generation and/or validation. The standard practice is to look at the data from the dominant aircraft types that operate from an airport. This is in part because it reduces costs and processing times, but also because adding in a small number of relatively quiet aircraft is unlikely to affect the calculated position of the noise contours.

Currently, even with NTK technology, the further an aircraft is from an airport, the greater the uncertainty of the exact location of the aircraft. This could affect the output readings for where aircraft are affecting and result in greater dispersion and therefore greater inaccuracies for noise exposures further from airports. Where NTK systems aren't available to capture the exact routes taken by aircraft, models can allow for notional dispersion around flightpaths. In the future it is possible that the requirements for noise contour models will change as navigational technologies technology improves and becomes increasingly widespread, allowing aircraft to follow their flightpaths much more precisely.

Models used to generate noise contour maps

There are two main models used to calculate noise contours in the UK. These are ANCON (Aircraft Noise CONtor model) and AEDT (Aviation Environmental Design Tool). Generally, AEDT and ANCON appear to be relatively similar in many respects, although there are slight differences (CAA). Both noise models adhere to guidance produced by ECAC Doc 29 (European Civil Aviation Conference, 2016) and are appropriate for use in the UK. There are some key differences between the two packages including the availability of NPD (Noise-Power-Distance) data, approaches to determining noise from the flight trajectory, and the calculation of helicopter noise.

ANCON is not commercially available, being operated solely by the CAA (Lubrani, Jelinek, & Cavadini, 2009) (CAA, 1992) (CAA, 1999). AEDT is a commercially available noise modelling package, created in the U.S. by the FAA (Federal Aviation Authority) (FAA, 2019) and used by some airports in the UK. Much like ANCON, AEDT delivers noise modelling capabilities, including the creation of noise contours and aircraft trajectories (Behere, Lim, Kirby, & Marvis, 2019). AEDT can express noise in the form of various metrics including L_{Aeq}, L_{den}, and number-above calculations (FAA, 2019, p. 30).

Noise-Power-Distance (NPD) data is used by both packages to determine the association of aircraft thrust and height with noise emission for specific aircraft types. The NPD data is supplied by the aircraft industry. To use ANCON effectively at the London airports, the CAA were required to create their own database since many of the aircraft (> 33%) had no available NPD data (Rhodes, White, & Havelock, 2001).

To determine flight trajectories, AEDT creates flight profiles, using estimates of aircraft weight, engine power settings and airline operating procedures based on assumptions. ANCON bases it estimations of engine power settings and airline operating procedures from real-time observations of aircraft using Heathrow, Gatwick and Stansted airports (Lubrani, Jelinek, & Cavadini, 2009).

There are many factors that can affect the noise exposure on the ground, though capturing all of these within one model would be challenging. The models used to produce noise contour maps concentrate on the most important factors, such as (CAA, 1992):

- flight paths followed by arriving and departing aircraft
- volume and model of aircraft
- altitude and noise emission profiles
- effects of the atmospheric conditions and the ground surface (topography) upon the propagation of sound.

Within these key factors there is significant variation, which necessitates using averages. For example, two aircraft of the same type, flying at similar heights may produce different noise due to factors such as the age of the aircraft, how well it has been maintained, and how heavily loaded it is, among many other factors. This means that the results from noise contour map models produce results for average noise exposure. Some simplifications that are assumed by models include homogenous weather across the area and over time (CAA, 1992).

Challenges of collecting noise data

The CAA have previously highlighted the difficulties of recording aircraft noise accurately (CAA, 2019).

External factors such as wind, humidity and temperature, can distort or invalidate noise measurements. For example, all measurements made in wind speeds greater than 10 m/s (19 knot) are removed from the data sets as the wind noise will significantly affect the measurements (CAA, 2019).

Processing noise data

All data from noise monitors needs to be processed to be useable. Processing noise data can be complex, and depending on the analysis being undertaken, costly and time-consuming. There are a huge number of potential aircraft noise events to extract from the recorded data. To compare the measured data with the prediction models, not only does the noise signature of the overflight need to be picked out, but the aircraft also needs to be identified with information such as the aircraft type and the airline, in case the data is needed for analysis in other ways. It should be noted that such a practice would only apply if there was interest in the noise from a particular aircraft, for example, following a complaint. (Such information is usually only possible when using NTK data).

Flights might also trigger more than one monitor along its flight path, so they need to be correlated. To give an indication of the scale of the work, Heathrow recorded around 475,000 ATMs in and out of the airport in 2018. Each of these will have triggered several noise monitors along its flight path, producing large datasets that require processing and analysing. The use of NTK systems by airports for monitoring noise – including Heathrow – compounds this problem by capturing even more data, such as details of the flight path.

As more airports adopt NTK monitoring systems this challenge of processing large and complex data sets is likely to get bigger. Automated data processing may become an option in the future, which is likely to speed up processing and reduce costs. At present this isn't an option that is available, as computers are not able to reliably distinguish between aviation noise and noise from other sources.

To address this issue, intelligent automated data processing (CAA, 2019) is increasingly used to extract airplane noise events from noise recordings. This is where computer programmes are used to identify overflight events, with a reasonable degree of certainty, based on the signature noise pattern for an aircraft overflight event. Features of aircraft overflight noise events typically include a predictable rise and fall time-history curve. Identifying events accurately becomes more challenging the further away the microphone is from the airport.

External noise interference becomes increasingly challenging when monitoring at the 54 dB $L_{Aeq,16h}$ or below (for example, to include data for the 51 dB LOAEL threshold set by the government). At this point, other sounds, such as traffic noise or even bird song, may distort the dataset to such an extent that aircraft noise events cannot be identified with a high degree of certainty (CAA, 2019). This is because aircraft are higher and therefore less noisy, making the difference between the noise event and the ambient background noise smaller. Other sounds may disguise the sound pattern from an aircraft, so it is not picked up by a computer. This means that automated programmes could overlook some aircraft overflight noise events and incorrectly identify others. In general, non-aviation noise interference tends to be small and infrequent close to the airport.

Even with the most accurate automated processing, there must be some manual quality assurance of the outputs. Currently there is yet to be an independent standardised method across the aviation industry for processing and quality checking data in the aviation industry to ensure consistency. Due to the large volume of data, it is not necessarily practical to check that every aircraft noise event has been correctly identified. Instead, a reasonable practice for assuring such datasets would be to examine outliers (i.e. the loudest and quietest events) and a random selection of the other events.

Chapter 5 : The publication of noise data

Data published by airports currently takes the form of noise contour maps and the calculated noise metrics. The raw numerical data is not usually made publicly available. This is due to the size of the data sets, but there may also be commercial confidentiality issues. Nor is this data required to be made available to regulators.

The closest to raw data that is reported online is the live information from noise monitors. This can be made available through airports' websites through systems such as WebTrak and Casper. But these platforms are limited in the data that they present and that can be extracted by members of the public. It should be considered, however, that the metric used and how it is published depends on the purpose of the monitoring.

These websites, associated with particular airports, combine the near-live flight tracking of aircraft with the instantaneous and unprocessed data from NTK monitoring systems. Some airports also show continuously updated noise level information, showing the changes in noise level over time. They will also allow retrospective noise and flight data tracking, but this is highly variable between platforms and airports.

The information from the noise monitors and flight activity gives users as an estimate of the change in noise level as a result of overflying aircraft at a given location as well as the altitude of the aircraft. Also included is information identifying the aircraft, such as the type, speed, departing airport and destination. There are individuals who might find this web-based tool useful, as it can be give a sense of the aircraft noise impact. It can also be used to identify aircraft that are particularly noisy, which can be fed back to airports and airlines for investigation. This tool could, however, be improved to make it more useful and user-friendly.

One of the limitations to this approach is the way that the data is presented. This varies between airports: some use L_{Aeq}, others dB and others do not state any units. Although the primary purpose of live flight tracking technology is to identify noisy aircraft, the lack of consistency between airports, and the different units used on the website, may make it more challenging for communities to interpret the information that they are given. Another consideration is the appreciation that noise contour maps present the long-term averaged values from noise metrics, rather than the unprocessed readings depicted on flight tracking websites. This means that values from the two sources are not cross-comparable, should it be desired.

A further obstacle is that the graphs displaying the noise data are small. The larger graphs on flight tracking websites use scales that are in increments of 5 dB, while noise contour maps have their contours separated by 3 dB. This small scale also makes determining the maximum dB level reached during an overflight event difficult to identify. Some variants of noise reporting show the current dB reading in a circle, but it is difficult to keep track of the details of the noise from the overflight event.

The horizontal axis is very unclear in what it represents as there is no running time scale and therefore the duration of an event cannot be estimated from the graphs. Such websites also need to be watched in real-time to get any sense of data, should communities wish to try and gather their own evidence. The information shown cannot be retrospectively downloaded, but can be reviewed. This again is variable, anything from four months to several years' worth of data can be accessed.

Where is noise data published?

Noise action plans (NAPs) and noise contour maps

Most noise contour maps are available as part of the noise action plans published on individual airport websites in England (See Annex C for a list of airports required to produce NAPs as well as links to their current NAPs). NAPs are a description of the existing noise control frameworks that are used by an airport. Airports are required to publish a noise contour map that is intended to provide an insight into the noise impact around the airport (Defra, Guidance for Airport Operators to produce noise action plans under the terms of the Environmental Noise (England) Regulations 2006 (as amended) (July 2013), 2013).

The aim of assessing the noise around an airport on a regular basis is to identify whether additional measures might be needed to meet the Government's aim, as set out in the Aviation Policy Framework (DfT, 2013): '*To limit and, where possible, reduce the number of people in the UK significantly affected by aircraft noise'*.

Airports covered by the requirements of the Environmental Noise (England) Regulations, 2006, as amended, and the equivalent regulations in Scotland, Wales and Northern Ireland, have to produce noise maps every five years. An airport must produce a NAP if they meet one or more of the following conditions:

- *Designated airports:* The CAA are required to collect and monitor data from three designated airports (Heathrow, Gatwick, Stansted). The NAP is published on the airport's own website (see Endnote 36).

- *Non-designated airports with more than 50,000 ATMs per year* (Official Journal of the European Communities, 2002)*:* This currently applies to 12 airports in the UK (shown in Table 4 below).

- *Overflying an agglomeration:* If an airport's flight paths overfly an agglomeration which has been identified by DEFRA (see Endnote 37) (UK Statutory Instruments, The Environmental Noise (England) Regulations, 2006) (Defra, 2019).

Table 4: Data from CAA (2019) showing the airports which have more than 50,000 air transport movements (ATMs)

Reporting airport group name	Reporting airport name	Total ATMs
London Area Airports	Heathrow	479,811
London Area Airports	Gatwick	282,896
Other UK Airports	Manchester	195,926

Reporting airport group name	Reporting airport name	Total ATMs
London Area Airports	Stansted	183,566
Other UK Airports	Edinburgh	127,335
London Area Airports	Luton	112,745
Other UK Airports	Birmingham	102,515
London Area Airports	London City	80,931
Other UK Airports	Glasgow	79,276
Other UK Airports	Aberdeen	78,209
Other UK Airports	Bristol	62,556
Other UK Airports	East Midlands International	56,219

If an airport in England meets one or more of these criteria, it is required to produce an updated NAP every five years, or when an airport is proposing to undergo a significant change (in terms of airspace or expansion) that will likely have an impact on the area affected by aviation noise. They are currently published on the airports' own websites. If an airport produces noise contour maps for their own internal use more frequently than the minimum as part of the NAP, they are not currently required to publish them.

Noise, including aviation noise, is a devolved issue in the UK. Scotland (Scottish Goverment, 2019), Wales (Welsh Government, Noise nuisance, 2019) and Northern Ireland (Northern Ireland Government, 2019) have separate policies for this, although they currently follow the same EU legislation as England and have the same requirements for the production (but not publication) of NAPs.

Publications

The extent to which the data is made available by airports on their websites varies considerably. Usually only the outputs (for example, noise contour maps and some descriptive statistics) are published. This may be only available in the form of a NAP which tend to only publish forecasts, with very limited comparisons between noise contour maps.

This is because the airports are following the process required for producing their NAP, which is every five years. The underlying data used to generate the outputs is rarely made publicly available. Airports often try to publish annual data, but there can be considerable lags between the data being collected and its publication. This is also possibly less impactful for community members who are trying to understand the noise that they experience on a daily basis.

In part these differences in the content and speed of data release will be due to factors such the different noise impact issues at each airport are likely to vary, and the resources that airports have will determine the range and speed of publication updates. There is still, however, potential for more useful information to be made available.

It should be noted that many of the larger airports have Airport Consultative Committees, with noise sub-committees. They often present a selection of noise data from the airports, usually on a quarterly basis. Such meetings are a useful opportunity to show the findings and give an opportunity for communities to raise questions and concerns about noise. They are, however, limited to those who are able to attend the meetings.

Accessibility

A significant problem for noise data transparency is the ease with which the public can access the information. Currently data and information can be published across one or more separate websites, sometimes without links to previous publications, or even entirely changing location between years. This makes it difficult for users to both find the information they need and understand how this issue has evolved over time. For example, the designated airports' annual noise contour maps were published on the DfT website (DfT, 2017) until 2015, after which they were published on the individual airports' websites.

Websites could be made easier to navigate so that publications could be more easily accessed. ICAO has international minimum standards for aircraft technical data and modelling, but these standards do not extend to the accessibility of data for affected communities. Airports should consider how best to translate the technical data into accessible information for communicating noise impacts on stakeholders. It is crucial that any published data should meet the stakeholder's needs in providing all the information clearly, including being accessible for those with additional needs. The specifics of what this should entail shall be considered as part of ICCAN's future work on engagement.

Livestreaming community meetings would be a way to broaden participation, but this still precludes those who do not have access to the internet (currently 7% of UK households have no access to any form of internet (ONS, 2019)) and those who are unable to be available for the meeting, due to reasons such as caring or work commitments, unless the meeting is recorded.

Spatial averaging of noise metrics

As we have seen earlier in this report, there are several different subgroups of metrics, which all have a role in managing noise. Often, noise metrics tend to be those that give values in some form of decibel (dB). There are also metrics based on frequency – e.g. N65 (see Table 3, Chapter 3). The value produced from this metric is just a number, not a decibel. And then there are metrics related to managing the noise impact, e.g. percentage of time that Continuous Descent Approach procedures are followed, or compliance with track keeping.

Another area of metrics are those that assist in understanding the noise impacts over an area. These can be referred to as spatial averaging metrics, which are discussed below, and often take the form of annotated maps. This refers to ways of showing the values of metrics in a visual way, rather than a purely numerical output. This is often the most informative and engaging way to communicate noise outputs to members of the public and non-experts.

Map-based data presentation

There are currently three main ways to present information relating to noise exposure and overflights over a geographic area: Noise Contour Maps; Flight Track Charts; and Flight Path Movements Charts. The information contained in these maps varies and therefore they have different potential uses. These are examined further below.

Noise contour maps

Noise Contour Maps are the most common approach to presenting how noise is distributed over a geographic area, both in the UK and internationally. The levels of estimated aircraft noise around airports are depicted on maps using lines called contours. These lines represent equal noise exposure. The area between two lines is known as a contour band.

As well as being a useful visual tool, noise contour maps can be used to calculate the estimated area and population numbers affected by noise at different thresholds, estimated noise exposure for noise sensitive locations or buildings (e.g. schools and hospitals), and the predicted effects from planned changes to airports expansion and airspace changes such as flightpath changes. And from the population information, the number of people likely to be highly annoyed or annoyed.

A significant problem is that the contours themselves may give a misleading picture of how aviation noise exposure occurs. They appear to indicate a significant step change in noise exposure (and therefore annoyance) between different sides of the contour, so accompanying text must make it clear that this is not the case. In reality, the change in noise exposure over an area is much more gradual and communities either side of a contour may have similar experiences.

Currently noise contours are typically published for L_{Aeq} ranging between 57 dB and 72 dB (CAA, 2020), although down to 54 dB L_{Aeq} day / 48 dB L_{Aeq} night are becoming increasingly common and now even 51 dB and 45 dB given the DfT pronouncements on LOAEL. Noise beyond the lowest value is not shown beyond these thresholds. These outer contour values are high compared to the recommended minimum aviation noise levels from the WHO (45 dB L_{den} and 40 dB L_{night}). Similarly, for average noise exposure, the Guideline Development Group (GDG), set up by the WHO to help to develop their 2018 noise guidelines, strongly recommends reducing noise levels produced by aircraft below 45 dB L_{den}, as aircraft noise above this level is associated with adverse health effects. For night noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft during night-time below 40 dB L_{night}, as night-time aircraft noise above this level is associated with adverse effects on sleep. These reports, however, ignore other important considerations, such as the social economic consequences and gains that can be brought from aviation. In a modern European urban area, achieving noise levels as low as the WHO recommendations would also require significant decreases in noise from other transport, as well as aviation (WHO, 2018).

The problem with having the outer contours set at a higher dB value is that this can give the impression that areas below this exposure level are unaffected by aviation noise. In fact, aviation noise is heard well beyond the outermost contour, but the flights are either too infrequent (as the flight paths are likely to have diverged by this point) or not quite loud enough, to be included within the map. Outside the outermost contour, it is usually considered that there is little adverse effect from aviation noise. Also, it should be considered that not everyone will have an adverse reaction to aviation noise, even if they do fall within one of the contours of a noise contour map.

A frequent problem with published noise contour maps is that they are of a low-quality resolution. These convey little useful information for local authority planners or communities, for example, trying to understand the noise impacts over an area. Labelling of the outputs can also be unclear. In part this is because the maps are produced only as part of a report, scaled to A4 paper size. It would be simple to produce maps separately on the website alongside the publication, as a higher resolution file so that the details of the map can be zoomed in on.

Flight track charts and flight path movements charts

Another approach to presenting flight activity information for community use is to plot flight paths on a map. Rather than presenting the level of noise exposure, these provide information about the number and direction of flights over a given period and can be used to identify who is likely to be affected by aviation noise. There are currently two main approaches to this:

1. Flight track charts (FTCs)

The individual flight path of each aircraft over a given period is superimposed onto a map of the local area, using radar data. FTCs can be useful to identify which areas are most overflown and also to examine the spread of individual routes taken by aircraft along each flight path in and out of airports. FTCs are most effective when used to illustrate activity over shorter time periods, since the graphs become increasingly congested and difficult to interpret as more flight data is included.

FTCs can only show data that has occurred, not forecast events. The advantage of this data is that it shows exactly the flight as it occurred, making it simple to understand.

Current flight tracking software show these movements to a limited degree with current aircraft movements, but nothing longer term is shown. It might be possible to expand online flight trackers by selecting a window e.g. 24 hours or day / night movements which might be of interest to stakeholders. It is unlikely to be of value to request that FTCs are produced and published monthly or annually, for example.

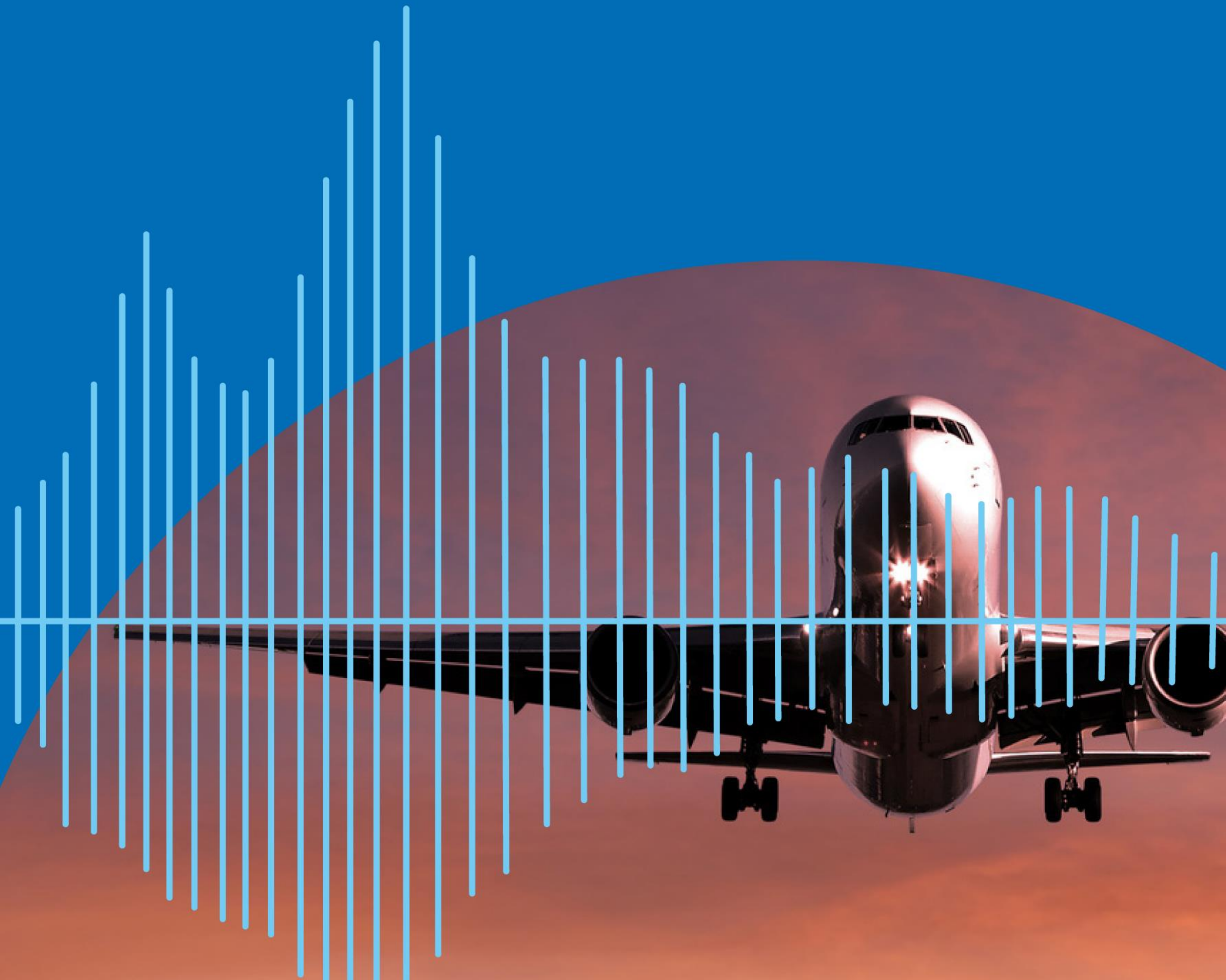
2. Flight path movement charts (FPMCs)

The typical range of paths taken by aircraft (and not the individual flight paths themselves) over a given period is superimposed onto a map of the local area (Australian Goverment, 2016). These ranges can be annotated with summary statistics including: the number of flights along that flight path, the proportion of total flights in the flight path, and the day/night split. Such information could be updated on a regular basis to illustrate short-term variations, though the flight path ranges would only need to be updated annually or following significant airspace changes. Presenting the flight path data in this way can be simpler for users to interpret and FPMCs also provide key information about the potential impacts of aviation activity. This can show communities what to expect in terms of overflight events and, in some instances, help to reduce annoyance when compared with unexpected noise exposure (Australian Government, 2003) (Australian Government, 2019).

FPMCs have been shown to be a useful tool for showing how flights are shared around an airport. They are visually simpler as they show the average flight area. It is also easier to see the map underneath the overlay. FPMCs don't show the same details such as the concentration of flights across a flight path showing in a FTC, though this could be partly achieved through the use of shading. With the reforms in air navigation due to come in, such as performance-based navigation, the number of outliers from the flight paths will likely decrease, possibly reducing the need for the detail provided by FTCs and making FPMCs more relatable.

FPMCs have been included in Sydney Airport's regular operational reports (see Endnote 38) to support its noise sharing scheme, by illustrating the proportion of total flights using each flightpath.

Chapter 6 : Key findings and recommendations



Our review of aviation noise metrics, noise monitoring and data publishing has identified some key areas where transparency and process can undoubtedly be improved. These include the lack of a consistent and unified approach to monitoring and processing noise data, a lack of data transparency, and opaque and inconsistent publishing practices surrounding noise metrics.

In an era when open and transparent data is rightly becoming the norm, it will become increasingly important that the aviation industry and its regulators publish and use consistent data to manage the adverse effects of aviation noise. This needs to be supported by the publication of noise metrics that are reflective of a community's actual experience of aviation noise exposure and should be published in an accessible way.

Only by de-mystifying the complex subject that is the measurement of noise can trust start to be re-built between the industry, regulators and the local communities around airports.

We believe our findings and recommendations, along with the next steps we propose, will be a positive move in the right direction to rebuild that trust.

Recommendation 1:

ICCAN supports the continued use of the L_{Aeq}-based metrics currently used for noise monitoring and statutory reporting where appropriate. However, we also recommend that supplementary Single Event metrics are routinely published by airports to better reflect the way in which noise is experienced on the ground.

We acknowledge that there is no one metric that can reflect annoyance, or associated health issues. Having considered the metrics available, and the concerns frequently raised by stakeholders, we conclude that the best approach at present is to use different metrics for different purposes, in order to cater for the different needs of stakeholders. The metrics need to strike the balance between being relevant, accurate and meaningful while also easily communicated to non-experts.

We conclude that continued use of the L_{Aeq}-based metrics that are currently required in UK legislation and policy are appropriate. Although the L_{Aeq}-based metrics have their disadvantages, they are useful due to the large data sets that have already been amassed. Furthermore, research has shown that they do correlate with some aspects of annoyance and health (as reviewed in Aircraft Noise and Health Effects: A yearly update (CAA, 2019) and Aircraft Noise and Annoyance: Recent findings (CAA, 2018)).

However, we acknowledge and agree that people do not experience noise as an average, and therefore reliance entirely on L_{Aeq} does nothing to aid public understanding, let alone trust, in the data being published. It is our view that the L_{Aeq} type metrics can be strengthened by coupling them with a complementary metric that represents different aspects of aviation noise.

Our initial opinion is that the Number Above (Nx) is the most appropriate complementary metric. This will enable communities to see official data relating to the frequency of significant noise events over their communities. We will do further work to analyse and determine/define at what noise level such a metric should be set, along with the time period covered for predictive flight information, and this will form part of future best practice guidance. We believe this would be an important step to help increase the transparency of noise measurements to stakeholders.

Recommendation 2:

The approach to noise monitoring around the UK is neither consistent nor clear to stakeholders; we will develop best practice guidance for UK airports on the approach, standards and quantity of aviation noise monitoring.

Noise data is at the heart of the discussion around aviation noise. However, the methodologies for recording noise data are set out in various publications drawing on a variety of sources dating back to 1971 (ICAO, 2019). This means that not only are some of the requirements in need of updating, but the best practice isn't a coherent narrative. It is also highly likely that there is some discrepancy in the practices for noise monitoring between UK airports due to factors such as different contractors, type and age of recording equipment, budgets etc.

All these factors mean that it is likely that noise monitoring quality is variable across the UK. In part this is unavoidable, but the situation could be improved to increase consistency. It is our opinion that there should be more explicit industry-wide codes of best practice, which will include tiered minimum standards, to ensure the quality of data gathering is adequate.

Our next step is will be to take the lead on providing that best practice guidance, and we will do this by working in partnership with credible partners and stakeholders. This approach would ensure that a robust and practical guidance is achieved which meets stakeholders' needs.

As UK airports vary significantly in their size and density of the affected population around an airport, and the number of flightpaths used, frequency of flights etc., we will ensure our guidance is tiered so it can be applied proportionately, based on their characteristics. This would help ensure that expectations and resources required are reasonable. If changes were implemented, it would necessitate a transition time to allow the airport to finance and install any required monitoring equipment.

Recommendation 3:

To help rebuild trust and ensure airports and communities work in partnership, we will provide best practice guidance on the provision of temporary noise monitors by airports to communities.

Many airports already provide a limited number of temporary mobile noise monitors. We believe that doing so helps airports understand better the impact on their surrounding communities, and specific impacts on certain individual communities which helps communities further trust that the airports are acting in their best interests.

To ensure that resources and effort by airports is best used, we intend to produce a code of best practice which will guide airports in the provision of such monitors. This will accompany the best practice guidance for noise recording and include minimum standards for the meters, along with extra information around the minimum duration that a noise monitor should be installed to make sure that a representative sample of data is collected.

Recommendation 4:

Noise data transparency needs to improve. Our best practice guidance will develop standards to enable comparable noise monitoring data to be published annually, so communities can track changes and trends around their airports.

Openness between airports and affected communities is an important aspect of noise monitoring. While we accept – and this report shows – that noise measurements and data are complex areas, we nevertheless advocate full transparency and sharing of data. This would bring about increased confidence of community stakeholders.

However, we recognise this would help but not fully restore confidence of community stakeholders unless the published data was independently verified. We suggest that airports should not be asking themselves ‘Why should we publish this data?’, rather the question should be ‘Why shouldn’t we?’. While we recognise it could take some time to develop processes that ensure accuracy and fairness we acknowledge it should be our ambition to have accessible data which enables airport noise management to be accurately and fairly compared. By being more open and transparent, airports can continue to build trust with their communities.

The presumption should be that data collected from airport noise monitors is made publicly available. It may be appropriate to have separate data publications aimed at different stakeholders, who will have different requirements. For example, data published in its raw format is large in volume and complex and therefore may be unusable to local communities. Raw data, however, may be of greater interest to bodies such as government, regulators or the academic community.

To facilitate this ambition, we will develop as part of our best practice guidance, clear guidelines with credible associates and stakeholders to ensure that it is ambitiously achievable and clear to all. By adopting this approach, we hope to ensure the guidance meets stakeholders’ needs and is suitably robust.

The guidance will include careful consideration of factors such as:

- Where should the data be published?
- What format(s) should be used?
- What is an appropriate processing level?
- Is the data understandable, useful, transparent and contain the relevant metrics?
- Is the data accessible in terms of volume and complexity?
- Has the data been quality assured and processed to an agreed standard?
- Is it comparable with other UK airports, or airports of comparable size internationally?

Recommendation 5:

The threshold for noise monitoring data from airports of 50,000 Air Transport Movements (ATMs) should be replaced with a lower threshold for publication of noise monitoring data, but applied proportionately and, potentially, with tiered requirements.

The impact of the COVID-19 pandemic on the aviation industry has been pronounced, and has led to significantly fewer numbers of ATMs across UK airports, as it has across the world. In light of this, we do not consider the threshold for noise monitoring data from airports of 50,000 ATMs (see Endnote 39) to be appropriate for the short to medium term.

We also do not believe it is helpful to have a hard threshold; we believe that there should be a lower threshold for publication of noise monitoring data, but applied proportionately and, potentially, in a tiered fashion that reflects the resources available to the different sizes of airports and the impact of their activity. It is logical to suggest that this data is should be published annually, on the same basis as the designated airports.

We believe that increased transparency will contribute to building a more detailed picture of the impacts of noise on affected populations. This is especially important as the UK's airspace will be undergoing modernisation and will continue to evolve (DfT & CAA, 2019). Greater transparency will also give stakeholders the opportunity to have a much more realistic grasp on how aviation noise is changing year-on-year.

It would also be important for planning authorities to have access to current and accurate information. Furthermore, by providing frequent forward-looking information (aircraft noise disclosure) about local aviation activity, this can play an important part in mitigating community annoyance (Australian Government, 2003) (Australian Government, 2019). Having more noise data available to examine, could also help feed into future studies around health and social impacts of aviation noise, which will be important for policy and legislation development in the future.

Recommendation 6:

Improving noise monitoring consistency and application requires UK-wide leadership. We see ICCAN's future role as providing that national leadership and standard setting.

As can be seen from our findings and recommendations, we see the potential for much improvement in the way in which aviation noise is measured, collected and communicated to the public. The piecemeal approach – some airports under statutory obligations and some not; some publishing certain data and others not – leads to the impression that the industry is not being honest with the levels of noise (whether or not that is the case).

Correcting this needs co-ordinated and expert leadership and we see ICCAN's role, as it evolves, as being to provide that leadership. This will be even more important as the industry recovers from the COVID-19 pandemic.

As with other aspects around how aviation noise is managed, we see opportunity in the resetting and restarting of aviation: the opportunity to improve processes, practices and behaviours of all involved in aviation, and in this case of those that capture, use and disseminate noise measurements.

Endnotes

Endnote 1: Other examples of logarithmic scales include pH and the Richter scale for earthquakes.

Endnote 2: A similar policy exists in Northern Ireland.

Endnote 3: In the UK noise is a devolved issue.

Endnote 4: Some of the regulations were introduced whilst the UK was part of the EU. Following the UK's exit from the EU on 31 January 2020, these regulations automatically became UK law, until such times as they are revisited, and have yet to be separately published.

Endnote 5: The current standard used to describe equal loudness contours ISO 226:2003: https://www.iso.org/standard/34222.html.

Endnote 6: A person may perceive that an aircraft is flying overhead, but it may actually be flying at a distance away from the observer. This is known as an overflight and has been formally defined by the CAA as: '*An aircraft in flight passing an observer at an elevation angle (approximately the angle between the horizon and the aircraft) that is greater than an agreed threshold, and at an altitude below 7,000 ft.'*

Endnote 7: ISO is the International Organization for Standardization. They are an independent, non-governmental organisation. They set global standards with the aim of making standards internationally relevant. L_{Aeq} has been identified as the means of measuring and describing environmental noise https://www.iso.org/standard/77035.html.

Endnote 8: Known as the 92-day summer period, this period is assessed as aviation activity peaks due to the summer holidays. People are also more likely to have their windows open or be outdoors.

Endnote 9: Originally called $L_{EU,N}$, as outlined in the Position Paper on EU noise indicators (European Commission, 2000).

Endnote 10: L_{night} had the working title L_{EU} in the EU Position paper of 2000 (European Commission, 2000) before L_{night} was adopted in the Environmental Noise Directive. Directive 2002/49/EC of 25 June 2002. The WHO Environmental Noise Guidelines for the European Region strongly recommended the LOAEL for night noise being set at 40 dB L_{night}, with 55 dB L_{night} suggested as an interim minimum target. If noise exceeds 50 db L_{night} for an agglomeration identified by DEFRA, it is requirement that the overlying airport produce Noise Action Plans and noise maps (UK Statutory Instruments, The Environmental Noise (England) Regulations, 2006).

Endnote 11: One evening flight becomes the equivalent of 3.162 day flights. One night flight becomes the equivalent of 10 day flights. Although the weightings are generally considered to be fairly appropriate for the three time periods, they aren't based on any scientific evidence. (CAA, 2009) (European Commission, 2000) (ANIMA, 2019).

Endnote 12: There are large data sets for Australian airports. See: Australian Government: Department of Infrastructure, Transport, Regional Development and Communications (2016) *Supplementary aircraft noise metrics* https://www.infrastructure.gov.au/aviation/environmental/airport_safeguarding/nasf/files/1.3_Guideline_A_attachment1.pdf

Endnote 13: For the designated airports there is a twice yearly official update on Quota Count (QC) allowance in the form of an AIP Supplement, published on the NATS website. This document includes and explanation of how the QC values are derived from the certification levels and a table showing the dB range correlating to the QC value. Arrival QC values have 9 EPNdB subtracted from their value, as arrivals are considered to be quieter than departures, as they require less engine power to generate thrust.

Endnote 14: It counts the total number of overflights above a specified dB level, in a given period of time, and multiplies this by the total affected population. It is regarded as a useful tool for comparing noise exposure across different flight paths and by different aircraft. However, a lower populated area will register a lower PEI value but the residents will be as equally annoyed as if they were living in a more densely populated area.

Endnote 15: The Person-Event Index (PEI) is mainly used in Australia. Sydney Airport used the PEI to develop a noise sharing programme aiming to limit noise exposure by spreading noise impacts more evenly around the surrounding populations. As this metric is a reflection of population density, it may not reflect annoyance for individuals e.g. A lower populated area will register a lower PEI value but the residents will be as equally annoyed as if they were living in a more densely populated area.

Endnote 16: Aircraft movements are allocated a QC classification (given in EPNdB – see section on Effective Perceived Noise Level) based on their certified NPD level. The DfT sets QC limits for summer and winter. These limits are regularly reviewed and reduced and the classification of aircraft are reviewed twice a year. As each flight carries a QC value, airports are incentivised to get airlines to use quieter planes if they wish to have more flights. But the maximum number of take-offs and landings are in turn capped. See Annex B.

Endnote 17: This correction has been criticised for not giving a true reflection of noise as the difference between arriving and departing planes is often under 1 dB, as much of an airplanes noise comes from airframe noise. The reason that take off is given a higher weighting is because the engines are working harder to generate the thrust needed for take-off.

Endnote 18: It is prohibited for any aircraft with the QC value of 4 or more to be scheduled take off or land during the night quota period (23:30 to 06:00) and no aircraft with a QC value of 8-16 may land or take off during the night period (23:00 to 07:00). Heathrow has also adopted a policy to not have planes which have QC values in category 2 or above to operate at night.

Endnote 19: The Noise Number Index (NNI) ran on a scale of 0-60. Scores of 50-60 was considered to be the level where noise became unreasonable, and a score of 35 marked the onset of community annoyance. An increase in 10 NNI units represented an increase of 10 dB in peak noise levels or a quadrupling of the number of overflights.

Endnote 20: A report by the ANIS in 1982 suggested moving towards the L_{Aeq} and the change was made following strong support from a public consultation carried out by the DfT, resulting in the replacement of NNI by L_{Aeq} in September 1990. This was because it was thought that the changes in how airspace was used (increasingly a greater number of quieter flights were being used) that the noise levels were being underestimated, and therefore annoyance as similarly being under represented.

Endnote 21: This metric was developed in the USA in the 1960’s from the CNR (Composite Noise Rating), used to assess the noise impacts from military aircraft. This metric is still used by commercial airports in Canada, Hong Kong, Spain and Greece.

Endnote 22: The start of take-off roll position is the point on the runway where a departing aircraft initiates moving forwards with the intention to take off. The positioning of monitors to capture take-off noise is specified by ICAO as 6.5 km from the start of take-off roll position on a runway.

Endnote 23: A fast response time corresponds to 125 milliseconds up and down. The needle would be moving much faster, showing you the varying noise levels quickly. Fast response times are usually used for measuring all the sound in an environment, especially if they vary widely over time.

Endnote 24: A slow response time corresponds to 1000 milliseconds up and down (i.e. at 1 second intervals). By slowing down the needle, the noise measurements are easier to read as the data is smoothed out and can give you a better indication of the average noise level in an environment where it is constantly changing.

Endnote 25: There is theoretically a link between the Nx value and the overflight frequency, as a doubling in the number of overflights would result in a doubling in the number of events over the given dB level. In reality, however, it is not that simple as there are a range of factors that affect aircraft noise. This is in part due to the weight of planes which affects the amount of thrust they need for flight, which can vary significantly between planes of the same model. As the loaded weight of an aircraft is commercially sensitive, this information is kept private and cannot be used to improve the accuracy of forecasting with this metric.

Endnote 26: It is recommended for consideration in the Air Navigation Guidance (DfT, 2017) using N65 (over 65 dB) to assess day-time noise and N60 (over 60 dB) for night noise.

Endnote 27: To create the Single Event Level (SEL) a reference threshold level is needed, usually the level of background noise. Where the background noise is higher, e.g. in urban areas, it means that the monitoring threshold must necessarily be set higher. This could bias SEL values to be smaller in urban areas compared to quieter rural locations, for an identical noise event. It is also possible that events are missed in areas with greater background noise.

Endnote 28: The advantage of the SEL method is that it takes into account virtually all the noise experienced (i.e. intensity and duration). This is because the SEL includes the total noise energy for the event, rather than just a peak sound event of an extremely short duration. This means that the calculated SEL values are typically around 10 dB higher for departures and 8 dB higher for arrivals than those calculated using L_{Amax}. SEL values are often calculated to be 3-5 dB lower than the EPNL metric.

Endnote 29: The SEL contours from an aircraft type, during take-off or landing, can then be presented graphically with noise contours of different dB levels. This is known as a noise footprint.

Endnote 30: See SEL for Noise Footprints.

Endnote 31: A Class 1 Sound Level Meter meets the performance requirements of IEC 61672-1:2002 (or the British Standard equivalent BS EN 61672-1:2003) to Class 1 performance. There are two levels of performance, with Class 1 being more accurate than Class 2.

Endnote 32: The full certificated values can be found on the EASA website.

Endnote 33: There is a general guide for unattended monitoring: (British Standard & International Organisation for Standardization, 2009).

Endnote 34: This CAA page provides a nice summary of some aspects of the process (CAA, 2020).

Endnote 35: It is a legal requirement under The Aeroplane Noise Regulations (1999) that these values are made available.

Endnote 36: Up to 2015 they were published on the government's website: Noise exposure contours around London airports

Endnote 37: DEFRA has published a list of agglomerations that are affected by aviation noise in England and gives some indication as to the airports that are likely to be causing any noise impacts, but the links are inconsistently provided. In 2019 DEFRA identified 65 agglomerations in England. DEFRA do not produce a list of which airports need to produce a NAP.

Endnote 38: Sydney Airport's operational reports

Endnote 39: The current threshold set by government legislation: EU Parliament (2014) REGULATION (EU) No 598/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC

Endnote 40: In the UK this is DEFRA.

Endnote 41: Airports other than Heathrow, Gatwick and Stansted, with more than 50,000 air transport movements per year.

Endnote 42: The 57 dB $L_{Aeq,16h}$ identified as the onset of significant community annoyance was first introduced in the DORA report.

Glossary

Acronym	Term	Definition
AEDT	Aviation Environmental Design Tool	A commercially available ICAO compliant noise model developed in the USA by the FAA (the Federal Aviation Administration).
ANASE	Attitudes to Noise from Aviation Sources in England	A 2002 survey, reported in 2007. Following Peer review, the findings were recommended to not be used in the development of government policy.
ANCON	Aircraft Noise Contour model	An ICAO compliant computer noise model owned and operated by the CAA.
ANIMA	Aviation Noise Impact Management through Novel Approaches	ANIMA is a European funded research project which addresses Aviation noise in Europe. It is supported by the Horizon 2020 Research and Innovation Programme of the EU. They focus on reducing annoyance, rather than reducing sources of aviation noise.
ANIS	Aircraft Noise Index Study	A DfT report published in 1985, following a survey in 1982. It focused on examining the links between annoyance and the NNI (Noise Number Index) metric and determining whether the use of L_{Aeq} would be a better metric for assessing aircraft noise.
ANMAC	Aircraft Noise Management Advisory Committee	A committee operated by the Department for Transport primarily for stakeholders involved with the Designated Airports
ATM	Air Transport Movements	Either an aircraft take-off or landing at an airport for commercial purposes.
CAA	Civil Aviation Authority	The statutory authority that maintains an aircraft register and oversees the approval and regulation of civil aviation.
dB	Decibel	The unit in which sound is measured. It is a logarithmic power ratio.
dBA	A-weighted decibels	A decibel measurement weighted by a frequency curve to represent the sensitivity of the human ear at normal speech levels.
Defra	Department for Environment, Food and Rural Affairs	The Government department with overall responsibility for noise management.

Designated Airports	Airports designated by the Economic Regulation of Airports (Designation) Order 1986 (S.I. 1986/1502)	There are three designated airports: Heathrow, Gatwick and Stansted.
DfT	Department for Transport	The Government department with responsibility for aviation in general and aviation noise management.
EASA	European Union Aviation Safety Agency	The UK is leaving the EASA. Its role will be taken over by the CAA as part of the Brexit process.
ECAC	European Civil Aviation Conference	ECAC or Conférence Européenne de l'Aviation Civile (CEAC) is an intergovernmental organisation, established by ICAO and the Council of Europe. The ECAC now totals 44 members. It publishes ECAC-CEAC Doc 29.
ECAC-CEAC Doc 29	Describes the method to be used for modelling aircraft noise	This is the method which the various software packages such as ANCON must follow.
END	Environmental Noise Directive	Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. This has been transposed separately into national legislation by England, Wales, Scotland and Northern Ireland.
ERF	Exposure Response Function	These describe quantitatively how much a health effect changes during exposure to a given agent by a specified amount.
FAA	Federal Aviation Administration	The governmental body in the USA's Department of Transportation responsible for aviation.
FPMC	Flight Path Movement Chart	The typical range of flight paths are superimposed onto a map. The flight paths are often annotated with useful information.
FTC	Flight Track Chart	Flight paths from radar are plotted onto a map to show where each plane, during a given period, flew.
GDG	Guideline Development Group	The GDG was a group set up by the WHO to help to develop their 2018 noise guidelines. The GDG is associated with the National Institute for Heath and Clinical Excellence (NICE) and is responsible for developing clinical guidance.

ICAO	International Civil Aviation Organisation	ICAO is a specialised agency of the United Nations. It develops the principles and techniques of international aviation, including its noise management.
ICCAN	Independent Commission on Civil Aviation Noise	Established in 2019, ICCAN is an advisory body looking at aviation noise and its impact.
INM	Integrated Noise Model	The INM was a commercially available computer model that evaluated aircraft noise impacts around airports. The INM was replaced by AEDT in 2015.
ISO	International Organization for Standardization	The ISO promotes worldwide proprietary, industrial, and commercial standards. It sets international standards and has representatives from various national standards organizations.
LOAEL	Lowest Observed Adverse Effect Level	This is a noise exposure used in the Noise Policy Statement for England (2010) The LOAEL identifies the noise exposure level where, on average, adverse effects to health and quality of life can begin to be observed. It is based on a toxicology term used for assessing health effects.
NAP	Noise Action Plan	Noise action plans provide a framework to manage environmental noise and its effects. The END requires noise sources to be evaluated every five years and action plans developed. The latest round of action planning was completed in 2019.
NATS	National Aeronautical Information Service	NATS is a part government, part private owned body. It provides air traffic and related services to UK and international airports, airlines and governments.
Noise Contour	-	A line of equal noise exposure, usually drawn on a map. A noise contour band is the area between two contours (and/or the people exposed within that area).
-	Noise Contour Map	A noise contour map is a graphic representation of the sound exposure distribution from a given source, in a given region, for a defined period.
NORAH	Noise of Rotorcraft Assessed by Hemisphere	This is the new EU helicopter noise assessment model.
NORAH	Noise-Related Annoyance, Cognition, and Health	NORAH is an extensive study on the subject of noise impact from road, rail and air transport sources. The scientists involved in the study come

		from a wide range of different disciplines: medicine, psychology, social science, physics and acoustics.
NPD	Noise-Power-Distance	Data for the noise generated by different aircraft types, depending on the engine power being used and the distance from the receiver during take-off or landing. This data is used for noise modelling.
NPSE	The Noise Policy Statement for England	The over-arching policy for the management of environmental, neighbour and neighbourhood noise sources in England.
NTK	Noise Track Keeping monitoring system	An NTK system matches radar data from air traffic control (i.e. flight paths) to measurements of noise collected by noise monitors.
Overflight	-	Detailed in the CAA's CAP1498 report, overflight is an aircraft passing an observer in flight, within a defined angle range and at an altitude below 7,000 ft. and when used as a metric is the number of overflights experienced by an observer over a given period of time at a given location.
PBN	Performance Based Navigation	PBN uses satellite navigation to improve the accuracy of where aircraft fly. It is being adopted world-wide. Airspace and new flight routes are being designed with PBN in mind.
QA	Quality Assurance	Quality assurance is a way of preventing mistakes and avoiding problems when delivering products or services to customers (defined by ISO 9000 as "part of quality management focused on providing confidence that quality requirements will be fulfilled").
SAE	-	SAE International is a global association of engineers and technical experts in aerospace, automotive and vehicle industries. A core principal is developing standards with voluntary consensus.
SOAEL	Significant Observed Adverse Effect Level	A concept introduced by the NPSE. It is the noise exposure at which, on average, significant adverse effects start to be detected.
SoNA	Survey of Noise Attitudes	A series of studies exploring attitudes to various noise sources. SoNA14 was conducted in 2014 and focused on aircraft noise. The results were set out in CAA report CAP1506, published in 2017. It provided information about attitudes towards aviation noise and how they relate to aircraft noise exposure metrics.
WebTAG	Web-based Transport	WebTAG is a suite of guidance published by the DfT on how to assess the expected monetary impacts of

	Analysis Guidance	transport policy proposals and projects. Defra and Public Health England were both involved in its development.
WHO	World Health Organisation	The WHO is a specialised agency of the United Nations that is concerned with world public health.

Glossary table A table providing terms used throughout this report and how they are defined

References

Airport Commission. (2013). *Discussion Paper 05: Aviation Noise.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/223764/airports-commission-noise.pdf

ANIMA. (2019). *ANIMA D2.6 – Overview of the use of noise footprints for different operational, planning and communication purposes.* Retrieved from https://zenodo.org/record/2659681#.Xme4AKD7Q2x

Australian Goverment. (2016). *Department of Infrastructure, Transport, Regional Development and Communications: Supplementary aircraft noise metrics.* Retrieved from https://www.infrastructure.gov.au/aviation/environmental/airport_safeguarding/nasf/files/1.3_Guideline_A_attachment1.pdf

Australian Government. (2003). *Department of Transport and Regional Services: Going beyond noise contours – local approaches to land use planning around smaller Australian airports.* Retrieved from https://www.infrastructure.gov.au/aviation/environmental/transparent_noise/files/going_beyond_noise_contours.pdf

Australian Government. (2019). *Department of Infrastructure, Transport, Regional Development and Communications: Aircraft Noise Disclosure-Avoiding 'Surprise Noise'.* Retrieved from https://www.infrastructure.gov.au/aviation/environmental/transparent_noise/index.aspx

Behere, A., Lim, D., Kirby, M., & Marvis, D. (2019). *Alternate Departure Procedures for Takeoff Noise Mitigation at Atlanta Hartsfield-Jackson International Airport. AIAA SciTech Forum, 7-11 January 2019, San Diego, California.* Retrieved from https://arc.aiaa.org/doi/abs/10.2514/6.2019-2090

British Standard, & International Organisation for Standardization. (2009). *BS ISO 20906:2009+A1:2013 Acoustics. Unattended monitoring of aircraft sound in the vicinity of airports.* Retrieved from https://www.techstreet.com/standards/bs-iso-20906-2009-a1-2013?product_id=1860724

CAA. (1992). *The CAA Aircraft Noise Contour Model: ANCON Version 1.* Retrieved from https://publicapps.caa.co.uk/docs/33/ERCD9120.PDF

CAA. (1998). *Night-Time Ground Noise.* Retrieved from http://publicapps.caa.co.uk/modalapplication.aspx?catid=1&pagetype=65&appid=11&mode=detail&id=756

CAA. (1999). *R&D Report 9842: The UK Civil Aircraft Noise Contour Model ANCON - Improvements in Version 2.* Retrieved from http://publicapps.caa.co.uk/docs/33/ERCD9842.PDF

CAA. (2003). *ERCD report 0207 Departure Noise Limits and Monitoring Arrangements at Heathrow, Gatwick and Stansted Airports.* Retrieved from http://publicapps.caa.co.uk/docs/33/ERCD0207.PDF

CAA. (2005). *ERCD report 0406: Techniques used by ERCD for the Measurement and Analysis of Aircraft Noise and Radar Data.* Retrieved from https://publicapps.caa.co.uk/docs/33/ERCD0406.PDF

CAA. (2009). *Metrics for Aircraft Noise.* Retrieved from http://publicapps.caa.co.uk/docs/33/ERCD0904.pdf

CAA. (2014). *Managing Aviation Noise.* Retrieved from https://publicapps.caa.co.uk/docs/33/CAP%201165%20Managing%20Aviation%20Noise%202.pdf
CAA. (2016). *Aircraft noise and health effects: Recent findings*. Retrieved from https://publicapps.caa.co.uk/docs/33/CAP%201278%20MAR16.pd
CAA. (2016). *CAP 725: CAA Guidance on the Application of the Airspace Change Process.* Retrieved from http://publicapps.caa.co.uk/docs/33/CAP%20725%20update%20March%202016%20amend.pdf
CAA. (2017). *CAP 1498 Definition of Overflight.* Retrieved from http://publicapps.caa.co.uk/docs/33/CAP_1498_V2_APR17.pdf
CAA. (2017). *Survey of noise attitudes 2014: Aircraft.* Retrieved from https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=7744
CAA. (2018). *Aircraft Noise and Annoyance: Recent findings.* Retrieved from http://publicapps.caa.co.uk/docs/33/CAP1588_FEB18.pdf
CAA. (2019). *Aircraft Noise and Health Effects: A yearly update.* Retrieved from http://publicapps.caa.co.uk/docs/33/CAP%201713%20(May2019).pdf
CAA. (2019). *Airport Data 2019.* Retrieved from https://www.caa.co.uk/Data-and-analysis/UK-aviation-market/Airports/Datasets/UK-Airport-data/Airport-data-2019/
CAA. (2019). *ERCD report 1006: Measurement and Modelling of Aircraft Noise at Low Levels.* Retrieved from http://publicapps.caa.co.uk/docs/33/ERCD%20Report%201006%20Low%20Level%20Monitoring%202nd%20Edition.pdf
CAA. (2019). *Features of the ANCON noise modelling process: Overview of how the aircraft noise contour (ANCON) process works.* Retrieved from https://www.caa.co.uk/Consumers/Environment/Noise/Features-of-the-ANCON-noise-modelling-process/
CAA. (2019). *The Air Navigation Order 2016 and Regulations.* Retrieved from https://publicapps.caa.co.uk/docs/33/CAP393_Fifth_edition_Amendment_13_March_2019.pdf
CAA. (2019). *Website Measuring and modelling noise – How aviation noise can be measured and modelled.* Retrieved from https://www.caa.co.uk/Consumers/Environment/Noise/Measuring-and-modelling-noise/
CAA. (2020). *Analysis of Flight Tracks and Profiles from Radar Data.* Retrieved from https://www.caa.co.uk/Consumers/Environment/Noise/Features-of-the-ANCON-noise-modelling-process/
CAA. (2020). *Aviation Noise and Health*. Retrieved from https://www.caa.co.uk/Consumers/Environment/Noise/Aviation-noise-and-health/
CAA. (2020). *CAP 1869: Quota Count validation study at Heathrow Airport.* Retrieved from http://publicapps.caa.co.uk/docs/33/CAP1869QuotaCountvalidationstudy31Jan2020.pdf
CAA. (2020). *CAP 1875: Consultation on CAA Minimum Requirements for Noise Modelling.* Retrieved from https://publicapps.caa.co.uk/docs/33/CAP1875NoiseModellingMinimumRequirementsConsultation.pdf

CAA. (2020). *Measuring and modelling noise: How aviation noise can be measured and modelled.* Retrieved from https://www.caa.co.uk/Consumers/Environment/Noise/Measuring-and-modelling-noise/

CAA. (n.d.). *Validating the CAA Aircraft Noise Model with Noise Measurements.* Retrieved from https://nap.edinburghairport.com/assets/documents/VALIDATING_CAA.pdf

CAA, & DfT. (1985). *United Kingdom Aircraft Noise Index Study: Main Report.* Retrieved from https://publicapps.caa.co.uk/docs/33/ERCD%208402.PDF

DAERA (Northern Ireland). (2020). *Noise.* Retrieved from https://www.daera-ni.gov.uk/articles/noise

DAERA (Northern Ireland). (2020). *Northern Ireland Noise Maps.* Retrieved from https://appsd.daera-ni.gov.uk/noisemapviewer/index.html

Defra. (2010). *Noise Policy Statement for England (NPSE).* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69533/pb13750-noise-policy.pdf

Defra. (2013). *Guidance for Airport Operators to produce noise action plans under the terms of the Environmental Noise (England) Regulations 2006 (as amended) (July 2013).* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/276226/noise-action-plan-airport-operators-guidance-201401.pdf

Defra. (2017). *Airport Noise Action Plans: Guidance for Airport Operators on how to revise Noise Action Plans under the Environmental Noise (England) Regulations 2006 (as amended).* Retrieved from https://www.aef.org.uk/uploads/2017/11/R3-Action-Plan-Guidance-for-Airport-Operators.pdf

Defra. (2019). *Noise Action Plan: Agglomerations (Urban Areas) Environmental Noise (England) Regulations 2006, as amended 2 July 2019.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/813663/noise-action-plan-2019-agglomerations.pdf

Defra. (2019). *Noise management.* Retrieved from https://www.gov.uk/government/collections/noise-management

DfT. (2013). *Aviation Policy Framework.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/153776/aviation-policy-framework.pdf

DfT. (2017). *Air Navigation Guidance 2017.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879173/air-navigation-guidance-2017-document.pdf

DfT. (2017). *Night flight restrictions at Heathrow, Gatwick and Stansted: Consultation Document.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/592391/night-flight-restrictions-at-heathrow-gatwick-and-stansted.pdf

DfT. (2017). *Night flight restrictions at Heathrow, Gatwick and Stansted: Decision Document.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/627890/night-flight-restrictions-at-heathrow-gatwick-and-stansted-decision-document.pdf

DfT. (2017). *Noise exposure contours around London airports.* Retrieved from https://www.gov.uk/government/publications/noise-exposure-contours-around-london-airports

DfT. (2017). *Review of the Quota Count (QC) System used for administering the night noise quotas at Heathrow, Gatwick and Stansted airports.* Retrieved from https://web.archive.org/web/20070717034806/http:/www.dft.gov.uk/pgr/aviation/environmentalissues/coll_nightnoisequotasatheathrowg/nightnoisequotasprintversio
DfT. (2017). *UK Airspace Policy (Collection).* Retrieved from https://www.gov.uk/government/collections/uk-airspace-policy
DfT. (2018). *Airports National Policy Statement: new runway capacity and infrastructure at airports in the South East of England.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/858533/airports-nps-new-runway-capacity-and-infrastructure-at-airports-in-the-south-east-of-england-web-version.pdf
DfT, & CAA. (2019). *Guidance: Airspace Modernisation.* Retrieved from https://www.gov.uk/guidance/airspace-modernisation
European Civil Aviation Conference. (2016). *ECAC Doc 29 Report on Standard Method of Computing Volume 1: Applications Guide.* Retrieved from https://www.ecac-ceac.org/ecac-docs
European Commission. (2000). *Position paper on EU noise indicators.* Retrieved from https://ec.europa.eu/environment/pdfs/2000/pub-2000-001-en.pdf
Experimental Centre. (2020). *The Aircraft Noise and Performance (ANP) Database : An international data resource for aircraft noise modellers.* Retrieved from https://www.aircraftnoisemodel.org/
FAA, U. D. (2019). *Aviation Environmental Design Tool, Version 3b Technical Manual. .* Retrieved from https://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/aedt/
Fletcher, H., & Munson, W. (1993). *Loudness, Its Definition, Measurement and Calculation.* Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1002/j.1538-7305.1933.tb00403.x
Goretti, M., & Cotana, F. (2014). *Footprint analysis concerning noise: approaches, tools and opportunities.* Retrieved from https://www.acoustics.asn.au/conference_proceedings/INTERNOISE2014/papers/p874.pdf
ICAO. (2008). *Guidance on the Balanced Approach to Aircraft Noise Management.* Retrieved from https://www.icao.int/environmental-protection/Documents/Publications/Guidance_BalancedApproach_Noise.pdf
ICAO. (2019). *50 years of Annex 16 – the Special Meeting on Aircraft Noise in the Vicinity of Airports.* Retrieved from https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg39-43.pdf
ICAO. (2019). *Aviation Noise Impacts White Paper, State of the Science 2019: Aviation Noise Impacts.* Retrieved from https://www.icao.int/environmental-protection/Documents/ScientificUnderstanding/EnvReport2019-WhitePaper-Noise.pdf
ICCAN. (2019). *Corporate Strategy 2019-2021*. Retrieved from https://iccan.gov.uk/iccan-corporate-strategy-2019-2021/
ICCAN. (2019). *Corporate Strategy 2019-2021 Published Survey Responses.* Retrieved from https://iccan.gov.uk/wp-content/uploads/2019_07_25_ICCAN_Corporate_Strategy_Summary_Responses.pdf

Lubrani, P., Jelinek, F., & Cavadini, L. (2009). *D2.4.4-03 - Required enhancements of existing assessment noise models to validate SESAR Operational Improvements steps. Version 2.0. Eurocontrol .* Retrieved from https://www.eurocontrol.int/sites/default/files/library/E3-WP2-D2.4.4-03-TEC-V2.00-environment-noise.pdf

Mestre, V., Schomer, P., Fidell, S., & Berry, B. (2011). *Technical support for Day-Night Average Sound Level (DNL) replacement metric research," Report Number: DOT/FAA/AEE/2011- 02.* Retrieved from https://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_modeling/noise_impacts/media/6-14-2011_FinalReport_MetricsMestre_etal_061411_part2.pdf

MVA Consultancy, & DfT. (2007). *Attitudes to Noise from Aviation Sources in England.* Retrieved from https://www.aef.org.uk/uploads/2007/11/Attitudes-to-Noise-from-Aviation-Sources-in-England-Executive-summary-.pdf

NATS. (2019). *London Heathrow, London Gatwick and London Stansted Airports Noise Restrictions Notice 2019.* Retrieved from https://www.aurora.nats.co.uk/htmlAIP/Publications/2019-03-31/html/eSUP/EG-eSUP-2019-012-en-GB.html

Northern Ireland Government. (2019). *Department of Agriculture, Environment and Rural Affairs: Noise.* Retrieved from https://www.daera-ni.gov.uk/articles/noise

Northern Ireland Statutory Rules. (2006). *The Environmental Noise Regulations (Northern Ireland) 2006.* Retrieved from http://www.legislation.gov.uk/nisr/2006/387/contents/made

Northern Ireland Statutory Rules. (2018). *The Environmental Noise (Amendment) Regulations (Northern Ireland) 2018.* Retrieved from http://www.legislation.gov.uk/nisr/2018/190/made

Official Journal of the European Communities. (2002). *Directive 2002/49/EC of the European Parliament and of the Council of June 2002 relating to the assessment and management of environmental noise.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0049&from=EN

ONS. (2019). *Internet access – households and individuals, Great Britain.* Retrieved from https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2019

Publications Office of the EU. (2014). *Regulation (EU) No 598/2014 .* Retrieved from https://op.europa.eu/en/publication-detail/-/publication/b6947ca7-f1f6-11e3-8cd4-01aa75ed71a1/language-en

Rhodes, P., White, S., & Havelock, P. (2001). *Validating the CAA aircraft noise measurement model with noise measurements.* Retrieved from https://nap.edinburghairport.com/assets/documents/VALIDATING_CAA.pdf

Schreckenberg, D. (2016). *NORAH- Noise Related Annoyance, Cognition and Health Effects of Aircraft Noise on Mental Health. Presented to Aircraft Noise and Mental Health Seminar 4th July 2016.* Retrieved from http://www.aef.org.uk/uploads/160704_NORAH_AEF.pdf

Scottish Goverment. (2019). *Policy: Pollution: Noise and nuisance.* Retrieved from https://www.gov.scot/policies/pollution/noise-nuisance/

Scottish Government. (2020). *Pollution: Noise and nuisance.* Retrieved from https://www.gov.scot/policies/pollution/noise-nuisance/

Scottish Statutory Instruments. (2006). *The Environmental Noise (Scotland) Regulations 2006.* Retrieved from http://www.legislation.gov.uk/ssi/2006/465/contents/made

UK Public General Act. (1982). *Civil Aviation Act 1982.* Retrieved from http://www.legislation.gov.uk/ukpga/1982/16/contents

UK Public General Acts. (1990). *Environmental Protection Act.* Retrieved from http://www.legislation.gov.uk/ukpga/1990/43/contents

UK Public General Acts. (2000). *The Transport Act.* Retrieved from http://www.legislation.gov.uk/ukpga/2000/38/contents

UK Public General Acts. (2006). *Civil Aviation Act 2006.* Retrieved from http://www.legislation.gov.uk/ukpga/2006/34

UK Statutory Instruments. (1999). *The Aeroplane Noise Regulations 1999.* Retrieved from http://www.legislation.gov.uk/uksi/1999/1452/contents/made

UK Statutory Instruments. (2006). *The Environmental Noise (England) Regulations.* Retrieved from legislation.gov.uk: https://www.legislation.gov.uk/uksi/2006/2238/made

UK Statutory Instruments. (2016). *The Air Navigation Order 2016.* Retrieved from http://www.legislation.gov.uk/uksi/2016/765/contents/made

UK Statutory Instruments. (2018). *The Environmental Noise (England) (Amendment) Regulations 2018.* Retrieved from http://www.legislation.gov.uk/uksi/2018/1089/made

van Oosten, N., Meliveo, L., Tuinstra, M., & Olsen, H. (2018). *The new EU helicopter noise model NORAH.* Retrieved from http://www.euronoise2018.eu/docs/papers/35_Euronoise2018.pdf

Welsh Government. (2018). *Noise and Soundscape Action Plan.* Retrieved from https://gov.wales/sites/default/files/publications/2019-04/noise-and-soundscape-action-plan.pdf

Welsh Government. (2019). *Noise nuisance.* Retrieved from https://gov.wales/noise-nuisance

WHO. (1999). *Guidelines for Community Noise (section 4).* Retrieved from https://www.who.int/docstore/peh/noise/Comnoise-4.pdf

WHO. (2009). *Night Noise Guidelines for Europe .* Retrieved from http://www.euro.who.int/en/health-topics/environment-and-health/noise/publications/2009/night-noise-guidelines-for-europe

WHO. (2018). *Environmental Noise Guidelines for the European Region.* Retrieved from http://www.euro.who.int/en/health-topics/environment-and-health/noise/publications/2018/environmentalnoise-guidelines-for-the-european-region-2018

Annex A

The following provides a summary of policy and legislation relating to aviation noise; specifically, noise metrics and noise reporting.

Noise management is devolved in the UK (Defra, 2019). In England, the following documents apply;

Legislation

Civil Aviation Act (1982) (UK Public General Act, 1982)

- Sets out the functions of the Civil Aviation Authority (CAA).
- The Secretary of State for Transport is given responsibility for policy relating to civil aviation noise in England.

Environmental Protection Act (1990) (UK Public General Acts, Environmental Protection Act, 1990)

- Aviation noise is made exempt from general nuisance noise controls which may have an impact on health.

The Transport Act (2000) (UK Public General Acts, 2000)

- The CAA must maintain high safety standards in its air navigation functions and air traffic services.
- When considering air navigation functions, the CAA must consider a range of factors including any environmental objectives that are set by the Secretary of State.

Directive 2002/49/EC of the European Parliament and of the Council of June 2002 relating to the assessment and management of environmental noise (Official Journal of the European Communities, 2002)

- Commonly referred to as the Environmental Noise Directive or END, this aims to create a European-wide approach to reducing the harmful effects of noise. This is not limited to aviation noise.
- A major airport is defined as one that has more than 50,000 ATMs per year.
- An agglomeration is defined as an urban area with a population of greater than 100,000 people.
- L_{den} and L_{night} are required to be plotted on noise contour maps. The calculation of the metrics are defined in the annexes of the Directive.
- Every 5 years, a summary report containing Noise Action Plans and noise maps shall be produced and the information is to be shared with the public.
- An appropriate authority must be set by each country to identify the agglomerations which need to be considered for the provision of noise action plans and the collect the noise action plans and maps (see Endnote 40).
- The minimum requirements for noise mapping are set out.

The Civil Aviation Act (2006) (UK Public General Acts, 2006)

- Builds upon the Civil Aviation Act 1982.
- Gives the managers of aerodromes the ability to introduce penalty schemes for infringements by aircraft that are either taking off or landing. These include noise control schemes as a means of mitigating aviation noise.

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

- These regulations apply to England, as noise is a devolved issue.
- The Secretary of State must identify agglomerations and major airports.
- Noise maps must meet the general requirements set out, including using the indicators L_{den} and L_{night}, as well as the supplementary noise indicators $L_{Aeq,16h}$, L_{day} and $L_{evening}$.
- Strategic noise maps must be produced every 5 years. The map will show the data for the preceding year. The map, along with the data used to create it, will be submitted to the Secretary of State.
- The airports that are required to produce these noise maps are the non-designated major airports (see Endnote 41) and non-designated other airports whose noise affects a defined agglomeration.
- Affected agglomerations are those who received air traffic noise equal to, or greater than, L_{den} 55 dB or L_{night} 50 dB.
- The general requirements for Noise Action Plans are laid out.
- Noise Action Plans must be produced every 5 years or whenever a major development occurs at an airport which affects its noise impacts.
- The public must be given the opportunity to submit feedback on consultations relating to proposals contained within noise action plans, as well as be informed of any final decisions made.
- Any noise action plan or noise map accepted by the Secretary of State must be published, along with a summary of key points.

REGULATION (EU) No 598/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC (Publications Office of the EU, 2014).

- Repeals Directives 2002/30/EC and 2006/93/EC, replacing them with an updated framework for managing aviation noise. It incorporates ICAO's balanced approach into UK legislation.
- The Balanced Approach consists of four "pillars", including;
    - The reduction of noise at source
    - Land-use planning and management
    - Noise abatement operational procedures
    - Operating restrictions
- Transposes EU regulation, including regulation 2002/49/EC, into UK legislation.

- All the data from noise performance certification of aircraft is to be gathered into a central data bank for Europe. The certification process is to follow the ICAO recommendations and be made suitable for computing noise contours.
- The data used to model noise contours should be accessible and validated via the agreed internationally accepted processes and following best practice.
- Sets out ways for managing aviation noise, including the withdrawal of noisier aircraft and offering economic incentives to encourage aircraft operators to use quieter models.

The Air Navigation order (2016) (UK Statutory Instruments, 2016) (as amended 2017, 2018, 2019) (CAA, 2019)

- The Secretary of State may prescribe the conditions under which noise and vibration may be caused by aircraft on a number of aerodromes.

Policy

The Department for Environment, Food and Rural Affairs: The Noise Policy Statement for England (NPSE) (March 2010) (Defra, 2010)

- Sets out the Government's overall policy on noise. It is high level and doesn't specifically refer to aviation noise.
- Building on the WHO recommendations to use NOEL and LOAEL, the concept of a SOAEL (Significant Observed Adverse Effect level) is introduced.

The Department for Transport: The Aviation Policy Framework (March 2013) (DfT, 2013)

- The three designated airports should produce annual NCMs to a level of 57 dB $L_{Aeq,16h}$ to assess the impacts of day noise.
- Contours should also be produced using $L_{Aeq,8h}$ to assess night noise.
- 57 dB $L_{Aeq,16h}$ is considered to mark the onset of significant community annoyance for daytime aviation noise (see Endnote 42).
- Airports are urged to "use alternative measures which better reflect how aircraft noise is experienced in different localities" to gain a better understanding of noise impacts, in order to develop mitigation measures.

The Department for Environment, Food and Rural Affairs: Guidance for Airport Operators to produce noise action plans under the terms of the Environmental Noise (England) Regulations 2006 (as amended) (July 2019) (Defra, 2019).

- Sets out the requirements for noise action plans and noise maps, as originally laid out in the END (Directive 2002/49/EC), which should be produced by airports in England.
- Provides overview of related government policies, such as the Noise Policy Statement for England (NPSE) and the Aviation Policy Framework (APF).

Department for Transport (2017) Air Navigation Guidance 2017 (DfT, 2017) as amended (2018, 2019)

- For aircraft flying at an altitude of less than 4,000 ft, the government's priority is to limit and where possible, reduce adverse effects on people from aviation noise.

- For aircraft flying between 4,000 and 7,000 ft, noise reduction is still the priority, unless there is a disproportional increase in CO_2 emissions.
- Above 7,000 ft, the priority changes to CO_2 emissions management.
- It is a priority to reduce the number of people and limit adverse effects on people from noise from aircraft flying below 4,000 ft.
- Sets out a LOAEL (Lowest Observed Adverse Effect Level) of 51 dB $L_{Aeq,16h}$ for daytime and 45 dB $L_{Aeq,8h}$ for night time.
- Recommends that overflights are considered for communities that fall outside of the LOAELs. The recommendation is to use N65 for daytime noise and N60 for night-time noise.
- Describes the role of ICCAN in the airspace change process.
  Provides guidance for noise preferential routes decided by the Secretary of State.

The Airports National Policy Statement: new runway capacity and infrastructure at airports in the south-east of England (2018) (DfT, 2018)

- Although this Policy Statement is published on the Government's website at the time of writing, a Ministerial Statement on 20 February 2020 stated that the Appeal Court ruled this statement has no legal effect, unless the Government were to carry out a review.

Devolved nations

In Wales no airport currently meets the requirements to qualify for producing noise maps, noise action plans or planning regulations under the Environmental Noise regulations (Welsh Government, 2018).

In Scotland the END regulation (Directive 2002/49/EC) was transposed into Scottish law in 2006 (Scottish Government, 2020): The Environmental Noise (Scotland) Regulations 2006 (Scottish Statutory Instruments, 2006). This follows the same guidance, as laid out above.

- The noise action plans for the airports which qualify under the terms of the regulations are published on the Scottish Government Website (Scottish Government, 2020).

In Northern Ireland noise is covered by The Air and Environmental Quality Unit (AEQ) within the Department of Agriculture Environment and Rural Affairs (DAERA (Northern Ireland), 2020).

- Northern Ireland also follow the END regulation (Directive 2002/49/EC), transposed into law: The Environmental Noise regulations (Northern Ireland) 2006 (Northern Ireland Statutory Rules, The Environmental Noise Regulations (Northern Ireland) 2006, 2006), as amended (2018) (Northern Ireland Statutory Rules, 2018) set out how noise action plans should be delivered, as required by the END.
- The noise action plans for Belfast International Airport and George Best Belfast City Airport are published on the Department of Agriculture Environment and Rural Affairs website (DAERA (Northern Ireland), 2020).

Annex B

The quota counts (QC) system was created in 1993 to manage Night Flying Restrictions at Heathrow, Gatwick and Stansted airports (DfT, 2017). The QC system is designed to limit the number of aircraft landing or taking off during the night quota period (i.e. between 23:30 and 06:00 hrs) and to encourage the use of quieter aircraft (CAA, 2020).

Each aircraft type is allocated a QC value for arrivals and departures in EPNdB, based on their certified NPD level. The classifications are reviewed twice a year by the DfT. The September 2019 classification table is given below in Table 5 (please see the NATS website for the latest QC classification values, which are published on behalf of the DfT).

Each of the three designated airports are allocated noise quota limits; therefore, each aircrafts' QC (arriving or departing) contributes to a given airports noise quota limit (NATS, 2019). This approach is hoped to incentivise airlines to reduce their number of aircraft with higher QCs, potentially replacing them with several quieter aircraft (DfT, 2017).

The number of flights is also capped, as set out in the NATS publication. Airports may carry over up to 10% of unused QC values and/or flight movements into the next regulatory period if they are unused. If an airport were to overrun on either their QC or movements allowances, up to 10% of their allowance, this equivalent value is removed from the next regulatory period. If an airport overruns its allowances by more than 10%, they will lose 10% of the allowance in the next regulatory period, along with a penalty of the excess above 10% which is doubled (NATS, 2019). E.g. an overrun of 12% will result in 14% loss of allowance in the next period.

Currently, aircraft with a quota count of 4 are forbidden to be scheduled to take off or land during the night quota period (i.e. 23:30 – 06:00 hours). Aircraft with quota counts of 8 or 16 (i.e. the noisiest aircraft) are prohibited from taking off or landing during the night period (NATS, 2019).

Some movements are exempt from the QC and movement counts, including (NATS, 2019);

- Emergencies, where there is an immediate danger to life or health, whether human or animal.
- Widespread and Prolonged Air Traffic Disruption.
- Delays as a Result of Disruption leading to Serious Hardship and Congestion at the Airfield or Terminal.

The NATS publication also includes a list of aircraft types and their noise classification according to arrival or departure.

Table 5: Aircraft noise classification and their associated quota count from NATS's September 2019 publication (NATS, 2019). As these classifications are regularly updated, please refer to NATS for the latest version.

Noise Classification	Quota Count
Below 81 EPNdB	0
81 - 83.9 EPNdB	1.25
84 - 86.9 EPNdB	0.25
87 - 89.9 EPNdB	0.5
90 - 92.9 EPNdB	1
93 - 95.9 EPNdB	2
96 - 98.9 EPNdB	4
99 - 101.9 EPNdB	8
Greater than 101.9 EPNdB	16

Table 5 Aircraft noise classification and their associated quota count from NATS's September 2019 publication (NATS, 2019). As these classifications are regularly updated, please refer to NATS for the latest version.

Annex C

Airports that have more than 50,000 movements per year and/or whose noise affects an agglomeration, an urban area with more than 100,000 people, are required to produce a noise action plan and noise maps. This is following the Environmental Noise Directive (END), Directive 2002/49/EC (Official Journal of the European Communities, 2002), which has been transposed into law for the UK's nations.

A list of the UK airports that are currently required to produce noise action plans is given in Table 6 below. This table also indicates a link to the current noise action plan.

The full list of agglomerations affected by aviation noise in England is published by Defra (Defra, 2019), as is the list of airports in England which are required to produce the next round of noise action plans (Defra, 2017). It should be noted that there is considerable inconsistency across the aviation industry in terms of how '50,000 movements per year' is defined. Our future work on developing best practice guidance will consider how this can be improved.

The Scottish Government lists the agglomerations and airports for which a noise action plan must be produced on their website, along with the links to the current noise action plans.

The Northern Ireland Government publish the noise action plans for the airports which quality under the END guidance on their website, along with interactive noise maps.

No airport in Wales is currently required to produce a NAP.

This annex has been updated since initial publication, including the removal of a number of airports from Table 6 below.

Table 6: Which UK airports are required to produce noise action plans (NAPs), with links to the NAPs, where available.

Airport	Total ATMs (2019)	NAP link
Aberdeen	78,209	Link
Belfast City	34,625	Link
Birmingham	102,515	Link

Airport	Total ATMs (2019)	NAP link
Bournemouth	4,973	Link
Bristol	62,556	Link
Cambridge	-	-
Dundee	1,212	Link
East Midlands	56,219	Link
Edinburgh	127,335	Link
Gatwick	282,896	Link
George Best Belfast City	34,625	Link
Glasgow	79,276	Link
Heathrow	479,811	Link
Leeds Bradford	29,746	Link
Liverpool John Lennon	34,976	Link
London City	80,931	Link
Luton	112,745	Link
Manchester	195,926	Link

Airport	Total ATMs (2019)	NAP link
Newcastle	40,169	Link
Southampton	32,529	Link
Southend	19,162	Link
Stansted	183,566	Link
Wycombe Air Park	-	Link

Table 6 List of airports which are required to produce a noise action plan. The total number of air transport movements from the CAA's 2019 data is given, where available. A link to the airport's latest noise action plan is given, where available. This information was correct as of August 2020.

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