VANGUARDIA

A BURO HAPPOLD COMPANY

Dublin Airport North Runway

Review of EIARs & Additional Information - Noise

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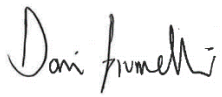
signature	
date	**18th April 2024**

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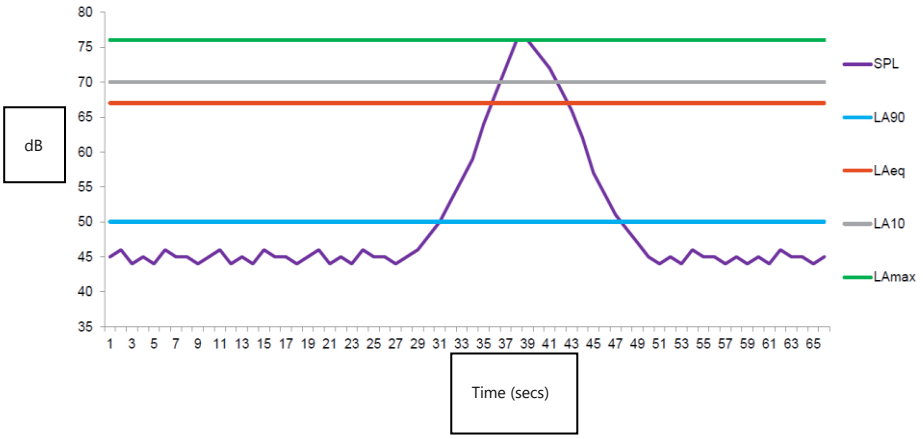
Glossary

Term	Definition
'A' Weighting	"Weighting" networks provide a method of presenting a single figure value representing the range of the audible frequencies designed to reflect how the response of the human ear to noise differs with frequency. The 'A' Frequency Weighting network is most common and is used to represent the response of the human ear to loudness. Measurements made with this frequency weighting will be displayed as dB(A) or dBA. For example, as $L_{Aeq,T}$ $L_{AFmax,T}$ etc. where the A shows the use of 'A' Weighting.
Decibel (dB)	The lowest sound pressure which can be heard by humans is called the hearing threshold, the highest which can be endured is known as the pain threshold. Sound pressure at the pain threshold is a million times greater than that at the hearing threshold e.g. hearing threshold sound pressure is 0.000002 Pascals and the auditory pain threshold is 20 Pascals. To avoid having to consider such a massive range of pressure values sound is measured using decibels with the threshold of hearing at 0 decibels and the threshold of pain at 120 decibels. Because decibel values are added together on a logarithmic scale, the result differs from that on a linear scale. If two equally strong sound sources are added together, the combined sound pressure level does not double but increases by three decibels.
Fast and Slow Time Weightings	The Time Weightings of Fast and Slow are defined by the standards to which the instrument are designed, such as IEC 61672, and they determine the "speed" at which the instrument responds to changing noise levels. For example, an instrument set to Fast will respond quickly to changes in the noise level, whereas an instrument set to Slow will respond more slowly. If the noise level is constant, both instruments will display the same level. Measurements parameters that use these time weightings will show this, for example, as L_{AFmax} which shows that the values are the maximum A-Weighted Fast Time Weighted sound levels.
Equivalent Continuous Sound Level (L_{eq})	$L_{eq,T}$ is the equivalent continuous sound level and represents the hypothetical level of constant sound which would have the same equivalent total energy to the real varying level of sound during a defined period T. $L_{eq,T}$ is often described as the "average" noise level during a noise measurement which although not technically correct, is often the easiest way to think of $L_{eq,T}$, albeit it's an average that tends to be biased towards the highest noise level that occurs during the period T. $L_{eq,T}$ values should be written with a Frequency Weighting, such as dB(A) and also the measurement duration T. For example, $L_{Aeq,8\,hr}$ = 55 dB
$L_{AFmax,T}$	The maximum Sound Level with 'A' Frequency weighting and Fast Time weighting (125 millisecs) during the measurement period T. It can be used to assess the probability of sleep disturbance due to individual noise events.
$L_{ASmax,T}$	The maximum Sound Level with 'A' Frequency weighting and Slow Time weighting (1 sec) during the measurement period T.
L_{den}	Day-evening-night level. It is a descriptor of noise level based on energy equivalent noise level (L_{eq}) over a whole 24 hour day with a penalty of 10 dB(A) for night time noise (23.00-7.00) and an additional penalty of 5 dB(A) for evening noise (i.e. 19.00-23.00).
L_{night}	L_{night}, the A-weighted, L_{eq} (equivalent noise level) over the 8 hour night period of 23:00 to 07:00 hours, also known as the night noise indicator. There is no penalty as it focusses on the 8 hour period of night time.
Sound Exposure level (SEL)	This is an $L_{eq,T}$ normalised to a period of 1 second. It can be used to compare the energy of noise events which have different durations.

	For example, if a noise level of 90 dB lasts for 1 second then the SEL = 90 dB. If the same noise event lasted 10 seconds the SEL would be 100 dBA. If it lasted 20 seconds the SEL would be 103 dBA and so on. SEL can be used to assess the probability of sleep disturbance due to individual noise events and calculate the overall L_{eq} for a period T of a number of events e.g. ATMs, each of different duration shorter than T.
Sound Pressure Level (dB)	Sound pressure level (SPL) is the pressure level of a sound, measured in decibels (dB). It is equal to 20 x the Log_{10} of the ratio of the Root Mean Square (RMS) of sound pressure to the reference of sound pressure (the reference sound pressure in air is 2 x 10-5 N/m2, or 0,00002 Pa). SPL is the base unit used in the measurement of noise metrics by a sound level meter. The microphone measures instantaneous fluctuations in sound pressure level (SPL) every 125 milliseconds (Fast time weighting) or 1 second (Slow time weighting), converts these to a varying electrical signal, and the meter's electronics apply a range of filters and weightings to calculate, display and record the desired range of noise metrics. The figure below shows how measurements of the varying sound pressure level (SPL) of a noise event e.g. an aircraft approaching the microphone to its closest approach and then moving away, can be processed to derive a range of noise metrics each describing the same noise profile differently. 

1 Introduction

Vanguardia Ltd have been commissioned to provide acoustic support to An Bord Pleanála (ABP) in relation to the appeal reference An Bord Pleanála: PL06F.314485 of the Fingal County Council (FCC) Decision F20A/0668 to grant permission to amend and replace two planning conditions, namely conditions no. 3(d) and 5 of the North Runway Planning Permission (FCC: Reg. Ref. No. F04A/1755; ABP Ref. No.: PL06F.217429, 'the North Runway Permission').

The proposed Relevant Action (RA) relates to the night-time use of the runway system at Dublin Airport. It involves the amendment of the operating restriction set out in condition no. 3(d) and the replacement of the operating restriction in condition no. 5 of the North Runway Permission, as well as proposing new noise mitigation measures. Conditions no. 3(d) and 5 came into effect when the operation of the North Runway commenced on 24th August 2022.

The proposed RA, would result in the following changes to how the airport operates:

1. Remove the numerical cap on the number of flights permitted between the hours of 11pm and 7am daily that is due to come into effect in accordance with the North Runway Permission
2. Replace the cap on number of flights at night with an annual night-time noise quota between the hours of 11.30pm and 6am (amended by the FCC decision to apply from 2300 to 0700 hrs).
3. Allow flights to take off from and/or land on the North Runway (Runway 10L 28R) for an additional 2 hours between 2300 hrs to 2400hrs and 0600 hrs to 0700 hrs.

Overall, these changes would allow for an increase in the number of Air Traffic Movements (ATMs) taking off and/or landing at Dublin Airport between 2300 hrs and 0700 hrs over and above the number stipulated in condition no. 5 of the existing North Runway Permission i.e. no more than 65, in accordance with the proposed annual night-time noise quota (The Table 1 of the introduction of the revised EIAR indicates that the study assumes that with the scheme operating the number of ATMs at night would be around 98 and the information regarding the QC system implies around 87 ATMs at night).

The proposed RA does not seek any amendment of conditions of the North Runway Permission governing the general operation of the runway system (i.e., conditions which are not specific to night-time use, namely conditions no. 3 (a), 3(b), 3(c) and 4 of the North Runway Planning Permission) or any amendment of permitted annual passenger capacity of the Terminals at Dublin Airport. Condition no. 3 of the Terminal 2 Planning Permission (Fingal County Council Reg. Ref. No. F04A/1755; ABP Ref. No. PL06F.220670) and condition no. 2 of the Terminal 1 Extension Planning Permission (Fingal County Council Reg. Ref. No. F06A/1843; ABP Ref. No. PL06F.223469) provide that the combined capacity of Terminal 1 and Terminal 2 together shall not exceed 32 million passengers per annum (MPPA).

1.1 Aim of this report

Vanguardia have been instructed to undertake the following:

1. Review the relevant applicant's documents including the methodology used, inputs, outputs and conclusions, with a focus on specific issues raised by parties to the appeal.

2. Review the work undertaken by the Aircraft Noise Competent Authority (ANCA) on the Dublin Airport Case including methodology used, inputs, outputs and conclusions, with a focus on specific issues raised by parties to the appeal,

3. Provide a report of findings detailing the above work with clear recommendation to the reporting inspector regarding the acceptability of the proposal to amend the relevant Conditions attaching to the existing permission for the north runway.

This report constitutes the report of findings described in point 3 above and includes the responses to points 1 and 2.

2 Executive Summary

This review of the revised and supplementary EIARs and associated information regarding the proposal to vary the planning conditions restricting use of the Dublin Airport northern runway at night, submitted in response to the Board's request for further information. Focuses on the effect of noise at night on sleep. As this is the most likely significant adverse effect which occurs much more widely and at lower or similar noise levels than other much less common health effects such as noise induced cardio-vascular disease, hypertension and stroke.

The revised and supplementary EIARs assess the likely significant noise effects of the proposed RA by comparing the noise contours and impact data predicted for a baseline year (2018 for the supplementary EIAR and 2019 for the revised EIAR) with the equivalent information for future years (2025 and 2035) for the permitted scenario i.e. no change from the current operation of the airport, with a proposed scenario with the RA in operation i.e. the Northern Runway in use for flights at night.

The revised and supplementary EIARs focussed on assessment of noise impacts at night based on the L_{night} noise metric. This method averages and accumulates the noise energy from each Air Traffic Movement (ATM) over the whole of the period from 2300 to 0700 hrs (although should the RA be approved; the northern runway will only operate at night between 2300 to 0000 and again from 0600 to 0700 hrs). Consequently, the Board requested submission of an Additional Awakening assessment which evaluates the probability of persons awakening in response to the maximum noise level of each individual ATM i.e. how loud each ATM is.

The long-term trend reported in the revised and supplementary EIARs, and the additional awakenings assessment provided in response to the Board's request for information is that in 2035 fewer people are likely to be highly sleep disturbed or experience an additional awakening over and above normal non-noise induced awakenings at night compared to in 2018 without the RA. But substantially more people will be highly sleep disturbed and/or experience an additional awakening with the proposed RA in place in 2035 compared to the same year under the permitted scenario without the RA. This comes about because although in future a greater proportion of aircraft using the airport will be more modern less noisy types compared to the fleet in 2018, the resulting reduction in noise will be offset by more ATMs in 2025 and 2035 with the proposed RA in operation compared to the permitted scenario with the RA not in use. However, the trends in the shorter term are different. For example, whilst the number of persons highly sleep disturbed falls in 2025 and reduces further by 2035 compared to a baseline of 2018, with the number of persons highly sleep disturbed greater with the RA in either future year, compared to without the scheme. The same is not reported in 2025 for the additional awakenings assessment. Instead, there are marginally fewer additional awakenings reported in 2025 with the proposed RA compared to the permitted scenario without the scheme for the annual and summer averages of the airport's operations and under single mode westerly operations[1]. But for single mode easterly operations in 2025 there are substantially more persons experiencing additional awakening with the RA compared to without.

In general terms, if implemented, the RA will mean some people currently affected by noise from night-time ATMs via the southern runway will experience noise from fewer ATMs using this runway at night; whilst some people currently unaffected or less exposed to noise from night-time ATMs will experience noise from aircraft using the northern runway which is currently prohibited from use at night.

[1] Single mode refers to the direction that aircraft approach or depart the airport into the wind e.g. in westerly single mode aircraft depart the airport to the west and approach from the east, and under easterly mode aircraft approach depart the airport to the east and approach from the west.

The revised and supplementary EIARs propose that the significant adverse noise effects identified will be mitigated by offering noise insulation to those affected and replacing the current cap on the number of ATMs at night with a Quota Count (QC) system based on how noisy ach aircraft is. Quota Count systems are based on aircraft noise certification data measured using a standardised internationally agreed methodology. Each aircraft type is classified and awarded a QC value depending on the amount of noise it generates under controlled certification conditions. The less noisy an aircraft is, the lower its QC value. Aircraft are classified separately for landing and take-off. An overall QC annual budget is developed which allows trading of numbers of aircraft within different QC values e.g. aircraft in a higher QC category can be replaced by a greater number of aircraft in a lower, less noisy category, and *vice versa,* as long as the overall QC fixed annual budget is not breached.

The proposed noise insulation scheme is one of the more generous programmes in Europe in terms of spatial scope and degree of funding offered. However, the qualifying criteria are based on noise metrics averaging intermittent aircraft noise across the whole 8-hour night period, and it is recommended the qualifying criteria are expanded to include an additional clause that reflects how loud an individual ATM by the noisiest aircraft using the airport at night will be.

Furthermore, reliance on the QC system alone to manage noise effects at night is regarded as inadequate as it would permit substantial increases in ATMs for only marginal reductions in how noisy each individual aircraft is. Although this might not lead to any change in the percentage of persons Highly Sleep Disturbed assessed using the L_{night} metric averaging the noise from each ATM over the whole 8-hour night period; it could lead to increases in the number of persons experiencing Additional Awakenings and individuals experiencing more Additional Awakenings[4] evaluated with the L_{max} metric of each ATM i.e. how loud each ATM is. Consequently, it is recommended that if the RA is to go ahead that a cap on ATMs at night is retained. Such caps are in place at Heathrow, Stansted and Gatwick airports where the QC system was developed in the early 1990s and have been updated regularly and recently, with the caps on the numbers of ATMs at night maintained.

Finally, this report suggests amendments to the planning conditions attached to the planning permission granted by Fingal County Council to address the points made above.

[4] An Additional Awakening is a noise induced awakening in addition to the approximately 23 awakenings most people typically experience at night.

3 Documents reviewed.

3.1 Applicant

The original application to FCC for the proposed RA was accompanied by an Environmental Impact Assessment Report (EIAR). In response FCC requested further information in respect of the proposed RA, to be presented in a revised EIAR, which was subsequently submitted in September 2021.

Following the grant of permission by FCC on the 08 Aug 2022 an appeal (ABP-314485-22) was subsequently lodged on 24 Aug 2022 and is now under consideration by An Bord Pleanála (ABP – AKA "the Board").

As part of the consideration of the appeal ABP requested further information from the applicant.

The applicant has responded to the ABP request for further information by providing a supplemental EIAR and other additional information as requested.

The applicant advises that elements of the response to the ABP request for further information have been included in a supplemental EIAR because there have been several changes or evolutions in operations at Dublin Airport since the previous EIAR, or in the baseline environment or legal or policy framework, that could potentially affect the assessment outcomes reported in the September 2021 EIAR. Other elements of the response to the Board's request for further information have been provided in standalone documents e.g. the Additional Awakenings assessment.

The changes that are reflected in the EIAR Supplement are described in Section 1.2 of the document as follows.

1. Actual flightpaths from North Runway upon commencement differing from assumed flightpaths used for modelling/assessment purposes in the 2021 EIAR;

2. Updated air traffic forecast data;

3. Earlier fleet modernisation;

4. The North Runway becoming operational in August 2022; and,

5. Other 'passage of time changes' that include changes to the environmental baseline conditions and changes to relevant aviation, planning and environmental legislation, policy, guidance and best practice.

These changes all have potential to influence the assessment of the potential noise impacts of the proposed RA.

Consequently, Vanguardia have reviewed both the revised EIAR submitted in response to the FCC request for further information and the supplemental EIAR and additional material provided following the ABP request for further information.

3.2 Appellants

As is common for airport development proposals, the proposed RA has provoked concerns regarding the noise impacts.

Multiple appeals have been submitted to ABP by third parties who are typically residents concerned they may be affected by increased aircraft noise where they are already adversely impacted or by the introduction of aircraft noise when they are currently either not impacted or only impacted to a tolerable degree.

Concerns raised in the third-party appeals supplied to Vanguardia by the Board include the following topics:

1. Exceedance of the WHO Guidelines for noise.
2. Changes to flight paths.
3. Cumulative or in-combination impacts.
4. Increased flights at night.
5. The effect of the maximum noise levels of each flight at night.
6. The baseline and assessment years.
7. The effectiveness and boundaries of the proposed noise insulation scheme.
8. Limitations at night in place at other airports.
9. Preferential use of the southern runway at night.
10. Number of flights at night.
11. The 2007 permission for the Northern runway was granted with a ban on its use between 2300 and 0700 hrs.
12. Contradictions between the EIAR and the Noise Action Plan for the airport.
13. Ecological effects of noise on fauna.
14. Loss of the existing ban on ATMs using the northern runway at night.
15. Concerns regarding the proposed Quota Count system.
16. Differences between the numbers Highly Annoyed and Highly Sleep Disturbed in the EIAR and the EPA's report on strategic noise mapping.

This report responds to all these issues.

4 Review of the relevant application documents

The noise aspects of the revised and supplementary EIARs and the additional information provided considered of primary relevance in this review are the effect of noise from aircraft in flight at night.

Whilst there is evidence of aircraft noise at night being associated with health effects such as cardio-vascular disease, stroke and hypertension these have been found at much lower rates with prolonged exposure in large populations e.g. typically around 1 in 100,000 or more persons, and normally begin to occur at noise levels higher than or similar to sleep disturbance which tends to begin at substantially higher rates e.g. 1 in 10 to 20 persons. Consequently, this review focusses on the assessment of aircraft noise related sleep disturbance. Appendix A of this report discusses noise related sleep disturbance.

4.1 Overview of Revised and Supplementary EIARs

The applicant's methodology, inputs, outputs and conclusions of the revised and supplementary EIARs are broadly considered appropriate and relevant. However, as discussed below, there are several areas where analysis further to the revised and supplementary EIARs and additional information has improved the robustness of the reported evaluations.

The approach in the revised and supplementary EIARs to evaluation of noise effects at night focussed on assessment using the L_{night} noise metric. This method averages the noise energy from each Air Traffic Movement (ATM) over the whole of the night period from 2300 to 0700 hrs (although the northern runway will only operate between 2300 to 0000 and again from 0600 to 0700 hrs). Consequently, as part of a wider request for further information the Board asked for an Additional Awakening assessment which evaluates the probability of persons awakening in response to the maximum noise level (L_{Amax}) of each ATM.

The long-term trend reported in the revised and supplementary EIARs and the additional awakenings assessment provided in response to the Board's request for information is that in 2035 fewer people are likely to be highly sleep disturbed or experience an additional awakening over and above normal non-noise induced awakenings at night compared to in 2018 without the RA. But substantially more people will be highly sleep disturbed and/or experience an additional awakening with the proposed RA in place in 2035 compared to the same year under the permitted scenario without the RA. This comes about because although in future a greater proportion of aircraft using the airport will be more modern less noisy types compared to the fleet in 2018[5], the resulting reduction in noise will be offset by more ATMs in 2025 and 2035 with the proposed RA in operation compared to the permitted scenario with the RA not in use.

However, the trend in the shorter term is different. For example, whilst the number of persons highly sleep disturbed falls in 2025 and reduces further by 2035 compared to a baseline of 2018, with the number of persons highly sleep disturbed greater with the RA in either future year, compared to without the scheme. The same is not reported in 2025 for the additional awakenings assessment. Instead, there are marginally fewer additional awakenings reported in 2025 with the proposed RA compared to the permitted scenario without the scheme for the annual and summer averages

[5] See Mott Macdonald report "Dublin Airport Operating Restrictions, Quantification of Impacts on Future Growth Addendum to the Analysis of June 2021 (Report version 1.3.1) September 2023 Addendum v1.0.

of the airport's operations and under single mode westerly operations[6]. But for single mode easterly operations in 2025 there are substantially more persons experiencing additional awakening with the RA compared to without.

In general terms should the RA be permitted some people currently affected by noise from night-time ATMs via the southern runway could experience noise from fewer ATMs at night; whilst some people currently unaffected or less exposed to noise from night-time ATMs via the southern runway will newly experience or be exposed to more noise from aircraft using the northern runway at the beginning and end of the night between 2300 and midnight and 0600 and 0700 hrs respectively.

The revised and supplementary EIARs propose that the significant adverse noise effects identified will be mitigated by offering noise insulation to those affected and replacing the current cap on the number of ATMs at night with a Quota Count (QC) system based on how noisy each type of aircraft is. This is considered insufficient to adequately mitigate significant adverse noise effects on sleep at night and the continuation of an appropriately calibrated cap on the number of ATMs at night as well as the proposed QC system is recommended if the RA goes ahead.

The proposed noise insulation scheme is one of the more generous programmes in Europe in terms of spatial scope and the funding offered. However, the qualifying criteria are based on energy averaging noise metrics, and it is recommended they are expanded to include an additional clause that reflects how loud the noisiest aircraft using the airport at night will be.

Furthermore, reliance on the QC system alone to manage noise effects at night is regarded as inadequate as it would permit substantial increases in ATMs for only marginal reductions in how noisy each aircraft is, which could lead to increases in the number of persons experiencing Additional Awakenings and individuals experiencing more Additional Awakenings. Consequently, it is recommended that if the RA is to go ahead a cap on ATMs at night, based on how the QC scheme is calculated is retained. Such caps are in place at Heathrow, Stansted and Gatwick airports where the QC system was developed in the early 1990s.

4.2 "Average" Noise Levels (L_{night}) & Maximum Noise Levels (L_{Amax})

Appendix B of this report provides information on "average" and maximum noise level metrics.

The WHO 2018[8] review by *Basner et al* showed a significant increase in the probability of additional awakenings due to aircraft noise related to the L_{Amax} noise indicator i.e. the loudest part of an ATM, and an increase in the percentage of persons reporting to be highly sleep disturbed (%HSD) evaluated using the L_{night} noise indicator for night-time i.e. the noise energy of all ATMs aggregated and averaged over an 8-hour night period.

The WHO 2018 review didn't consider any studies after 2014, but the results of more recent studies are generally in line with the findings of the WHO review[9]. Physiologically measured disturbances of sleep quality, represented by an increase of the time to fall asleep and wake time, number of awakenings or increased motility were found for an increase in the exposure represented by higher average night levels or a greater number of (loud) aircraft noise events.

[6] Single mode refers to the direction that aircraft approach or depart the airport into the wind e.g. in westerly single mode aircraft depart the airport to the west and approach from the east, and under easterly mode aircraft approach depart the airport to the east and approach from the west.
[8] Mathias Basner and Sarah McGuire, WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep Int. J. Environ. Res. Public Health 2018, 15, 519; doi:10.3390/ijerph15030519
[9] Smith MG, Cordoza M, Basner M. Environmental Noise and Effects on Sleep: An Update to the WHO Systematic Review and Meta-Analysis. Environ Health Perspectives. 2022 Jul;130(7):76001.

Studies using physiological measurements have confirmed the significant impact of the maximum sound pressure level i.e. L_{Amax} of an ATM, on the probability for awakening reactions.

Studies have shown that noise can affect sleep in terms of short-term immediate effects (e.g., arousal responses, sleep state changes, awakenings, body movements, total wake time, autonomic responses), after-effects (e.g., sleepiness, daytime performance, cognitive function) and long-term effects (e.g., self-reported chronic sleep disturbance; cardiovascular effects such as increased blood pressure, heart attacks). This is summarised in the schematic by *Basner et al* (2018) shown in figure 5 on page 18 of this report.

It is important to realise that two different types of sleep outcomes have been examined. Self-reported subjective sleep disturbance which is linked to metrics which average the noise from all noise events over an 8 hours night period such as L_{night}, and described as being "Highly Sleep Disturbed"; and objective sleep disturbance which uses polysomnography (PSG) to record biophysiological changes that occur during sleep and changes in sleep stages linked to the maximum noise level of individual noise events such as $L_{Amax,}$ and described as "Additional Awakenings".

Reports of self-reported sleep disturbance and objective sleep disturbance can differ as individuals are not always aware of or recall awakenings.

Averaging metrics such as L_{night} may not be best for assessing the impacts of ATMs noise on sleep disturbance, on their own, as these noise events are intermittent rather than continuous, which means that the same L_{night} value can result from differing numbers of events of varying maximum noise level e.g. a smaller number of ATMs louder than a larger number of less noisy ATMs. Consequently, the two types of sleep disturbance should both be considered in an assessment.

The WHO 2018 review comments on the use of energy averaging and maximum noise level metrics to evaluate noise impacts on sleep as follows:

"*Equivalent noise levels are often used in surveys and epidemiologic studies as long-term average exposure metrics, and are therefore also often found in legislative and policy contexts. For example, the Night Noise Guidelines for Europe of the World Health Organization (WHO) define effects of nocturnal noise based on annual average outdoor Lnight ranges [36]. The value of equivalent noise levels in describing the effects of noise on sleep is more limited, as different noise scenarios may calculate to the same equivalent noise level, but differ substantially in their sleep disturbing properties [25]. There is general agreement that the number and acoustical properties of single noise events better reflect the actual degree of nocturnal sleep disturbance in a single night [35]. It is thus questionable whether Lnight can be used as the only indicator for predicting the effects of noise on sleep and the consequences of noise-induced sleep disturbance, or whether supplemental noise indicators are needed [25]*."

It can therefore be concluded that on their own average energy noise levels e.g. L_{night}, are not sufficient predictors for sleep disturbances, and the number of events and maximum level e.g. L_{Amax}, should be taken into account as well.

The revised EIAR and the supplementary EIAR submitted in response to the Board's request for further information primarily evaluated the effect of aviation noise on sleep using only the L_{night} noise metric and the % Highly Sleep Disturbed (%HSD). Consequently, the Board requested further information in the form of an assessment of the likelihood of additional awakening based on the maximum noise level L_{Amax} of each ATM at night.

In response to this request for further information the airport have submitted an Additional Awakenings (AA) assessment. The AA follows the same trend as the assessments in the EIARs using the %HSD based on the L_{night} metric i.e. fewer people are likely to experience an additional awakening in 2025 and 2035 with the RA in operation compared to a baseline in 2018 (Supplementary EIAR) or 2019 (revised EIAR) without the RA. But in the long term substantially

more people are predicted to experience at least on additional awakening per night with the RA in place in 2035 compared to without it. Whereas, in the short term in 2025 there are marginally fewer additional awakenings reported in 2025 with the proposed RA compared to the permitted scenario without the scheme for the annual and summer averages of the airport's operations and under single mode westerly operations. But for single mode easterly operations in 2025 there are substantially more persons experiencing additional awakening with the RA compared to without.

The AA assessment supports retaining a cap on ATMs at night because the L_{night} metric, which is based on the L_{eq} index, is relatively insensitive to changes in numbers of ATMs e.g. if every aircraft is 3 dB marginally less noisy this means there can be twice as many ATMs, for no change in the L_{night} level and therefore no impact on %HSD. Whereas an AA assessment of the same change will probably show that additional awakenings are likely.

Assessing effects and providing mitigation solely based on the aircraft noise averaged over the whole of the night using the L_{night} noise metric is not considered sufficient in this case, especially as the northern runway would only be used for two one-hour periods at critical times at the start and end of the night. By using the L_{night} metric the ATM noise during these times is averaged over the whole night including 6 of the eight hours of the night when the northern runway would not be in use. Consequently, the likelihood of additional awakening based on the L_{Amax} noise levels of each ATM should be considered as well. This view is based on the *Basner et al* study[10] which established the assessment of additional awakenings based on the L_{Amax} of each ATM. The EIARs both solely use the L_{night} metric to assess %HSD for the RA and the energy averaging inherent in this metric implicitly assumes that the effects of aircraft noise on sleep are simultaneously diminished by 50% if no reduction in the number of ATMs is made but each ATM is 3 dBA less noisy; or the effects of aircraft noise on sleep do not change if the ATMs are all 3 dB less noisy but the number of ATMs doubles. The figure below reproduced from the *Basner et al* study demonstrates this is not true.

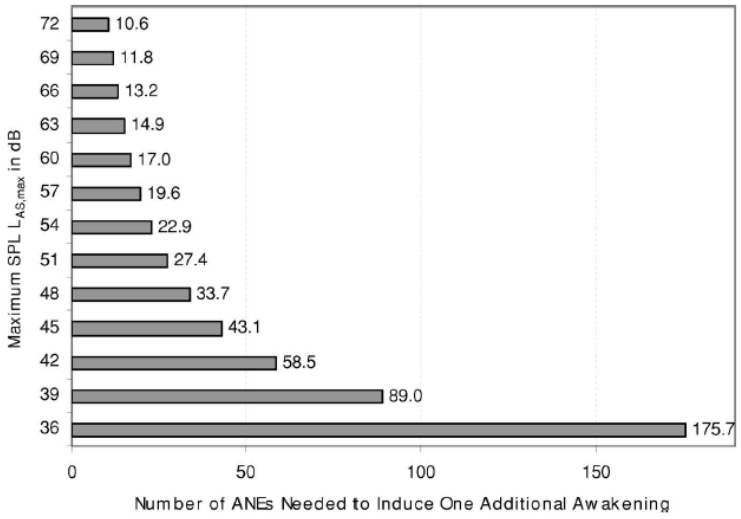


FIG. 4. Number of ANEs needed to induce one additional awakening on average and depending on the maximum SPL. Results are based on the dose-response relationship found in the field study (see Table I).

J. Acoust. Soc. Am., Vol. 119, No. 5, May 2006 Basner *et al.*: Aircraft noise effects on sleep 2777

Figure 1: From Basner M, Samel A and Isermann U, "Aircraft noise effects on sleep: Application of the results of a large polysomnographic field study", Journal of Acoustical Society of America, 119 (5), May 2006.

[10] Basner M, Samel A and Isermann U, "Aircraft noise effects on sleep: Application of the results of a large polysomnographic field study", Journal of Acoustical Society of America, 119 (5), May 2006.

The figure above shows, depending on the L_{Amax} of single ATMs, how many ATMs are needed to induce one additional awakening on average, where independent events were assumed. If the maximum L_{Amax} of single ATMs is reduced by 3 dB from, say, 72 to 69 dB, the permitted number of ATMs inducing one additional awakening may not be doubled but only increased by 11% from 10.6 to 11.8 movements. The allowable change in the number of ATMs following reductions in maximum sound pressure level (SPL) of 3 dB increases continuously from 11% (decrease from 72 to 69 dB) to 97% (decrease from 39 to 36 dB), i.e., the number of ATMs may be nearly doubled only very close to the threshold value of L_{Amax} 33 dB (the lowest level at which any effect can be detected).

A 1992 field study[11] in the UK concluded that actigraphy[12] was a cost effective, useful method of measuring sleep arousals in subjects participating in their own home, and that aircraft noise was a relatively minor cause of such arousals. Actigraphy was able to detect around 90% of awakenings of 10-15 seconds or more and can detect minor arousals, including brief awakenings, some sleep stage changes, and minor body movements. However, it should be noted that all of these characteristics occur naturally during normal sleep. Those subjects who reported awakenings often did not state a cause (26%) and of those who did, aircraft noise was found to be one of the minor causes, with less than one quarter of all subjects attributing this factor, on average about once every five nights. The results of this study suggest that below outdoor event levels of about 80 dB L_{Amax}, Aircraft Noise Events (ANEs) are unlikely to cause any increase in measured sleep disturbance from that which occurs naturally during normal sleep. For those ANEs above this level, the average arousal rate was about 1 in 30. Based on this research Heathrow has a supplementary night noise insulation criterion whereby properties predicted to experience 80 dB L_{Amax} or more at night from the noisiest ATM qualify for noise insulation.

There is more recent research that shows that the probability of an awakening increases as indoor maximum noise levels rise and effects can be detected from an external L_{Amax} of around 48 to 53 dB. The large difference between the awakening threshold in this study and the 1992 UK field study is postulated as being due to the relative insensitivity of the actimetry used in the 1992 UK field study to measure sleeper's movements compared to the sophisticated brain wave monitoring polysomnography used in the more recent research. However, the probability of awakening at around 48 to 53 dB L_{Amax} externally is around 1 in 175 ATMs i.e. more than the number of ATMs likely with both runways operating at Dublin airport at night-time.

Furthermore, the first objective of the German Aerospace Centre's noise protection concept is that on average, based on the L_{Amax} noise level of each ATM, there should be less than one additional awakening induced by aircraft noise, which is clarified elsewhere to mean 'per night".

The CAA report Survey of Noise Attitudes 2014: Aircraft Noise and Sleep Disturbance, Further Analysis CAP 2251 (2022) shows a sharp rise in the proportion of residents surveyed stating that their sleep was highly disturbed which coincides with the objective of less than one additional awakening induced by aircraft noise (Figure 7 from the report showing this is reproduced below).

[11] J.B. Ollerhead et al, Report of a Field Study of Aircraft Noise and Sleep Disturbance: A Study Commissioned by the Civil Aviation Policy Directorate of the Department of Transport from the Department of Safety, Environment and Engineering, Civil Aviation Authority, 1992

[12] Actigraphy is a type of wearable sleep test (often a device worn on the wrist) that tracks your movements to analyse when you are asleep and when you are awake. Actigraphy is generally considered more accurate than a sleep log and less accurate than polysomnography - Marino, M., Li, Y., Rueschman, M. N., Winkelman, J. W., Ellenbogen, J. M., Solet, J. M., Dulin, H., Berkman, L. F., & Buxton, O. M. (2013). Measuring sleep: Accuracy, sensitivity, and specificity of wrist actigraphy compared to polysomnography. Sleep, 36(11), 1747–1755.

Figure 7: Percentage of respondents calculated as highly sleep disturbed as a function of the average summer night additional aircraft noise-induced awakenings (N=1,483)

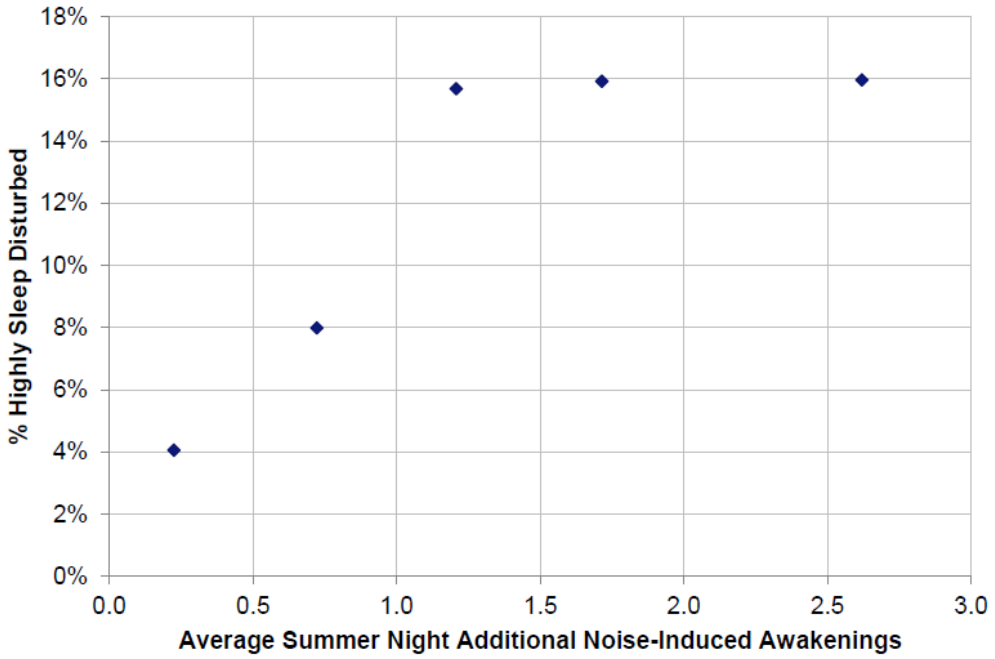


Figure 2: Figure 7 from CAA report Survey of Noise Attitudes 2014: Aircraft Noise and Sleep Disturbance, Further Analysis CAP2251

The recent CAA study also reports that one additional aircraft noise-induced awakening is associated with 10% of respondents being highly sleep disturbed. Two and three additional aircraft noise-induced awakenings per average summer night are associated with 15% and just over 20% of respondents being highly sleep disturbed respectively.

The response to The Board's request for further information includes a note from a sleep specialist which argues that significance criteria in terms of increased awakenings cannot be set because "increased awakenings" is a matter of probabilities. It should be noted that studies assessing %HSD based on self-reported sleep disturbance correlated to the L_{night} averaging noise metric also provide results based on probability of being highly sleep disturbed. Typically, as Odd Ratios (ORs) that represents the probability that an outcome will occur given a particular noise exposure, compared to the odds of the outcome occurring in the absence of that exposure.

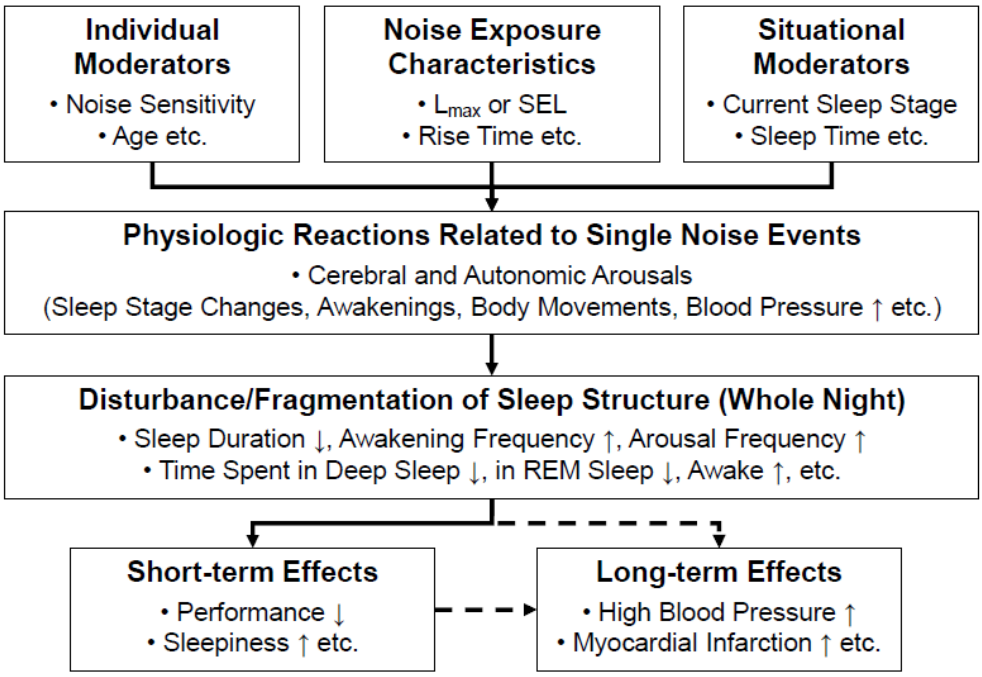
However, the fact that Additional Awakenings are assessed based on probabilities, as is %HSD, has not prevented such assessments featuring in the evaluation of significant effects and adverse effects for multiple recent airport projects. For example, additional awakening assessment have been used in conjunction with evaluation of the %HSD for Manston, Heathrow 3rd runway, Luton, Gatwick and Bristol airports in the last 5 years. Following the Board's request for further information an Additional Awakenings assessment has now been provided and is considered in the review of the assessment of effects in this report.

Moreover, the review[14] supporting the WHO 2018 guidelines has the following commentary:

[14] Mathias Basner and Sarah McGuire, WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep Int. J. Environ. Res. Public Health 2018, 15, 519;

"The auditory system has a watchman function and constantly scans the environment for potential threats. Humans perceive, evaluate and react to environmental sounds even while asleep [23]. At the same sound pressure level, meaningful noise events are therefore more likely to cause arousals from sleep than less meaningful events. During the night, noise can often be described as intermittent (i.e., discrete noise events rather than a constant background noise level). In this case, the effects on sleep are primarily determined by the number and acoustical properties (e.g., maximum SPL, spectral composition) of single noise events (Figure 1). Noise may be accompanied by vibrations (e.g., rail noise), and the combination of noise and vibration induces higher degrees of sleep disturbance than noise alone [24]. Whether or not noise will disturb sleep also depends on situational (e.g., depth of sleep phase [25], background noise level [26]) and individual (e.g., noise sensitivity) moderators [23]. Repeated noise-induced arousals impair sleep quality and recuperation through changes in sleep structure including reduced sleep continuity [27], delayed sleep onset and early awakenings, less deep and REM sleep, and more time spent awake and in superficial sleep stages (Figure 1) [25,28]. Noise may also prevent a subject from falling asleep again after a spontaneous or noise-induced awakening. Deep and REM sleep have been shown to be important for sleep recuperation in general and memory consolidation specifically [10].

Figure 3: Figure 1 from the review supporting the WHO 2018 Guidelines



Consequently, where the noise source is intermittent with periods of significantly lower residual noise in between noise events, such as ATMs to and from an airport, sole reliance on assessment of the percentage Highly Sleep Disturbed (% HSD) using energy averaged metrics such as the L_{night} risks underestimating the impact and a parallel analysis of Additional Awakenings (AA) based on the L_{Amax} of each ATM is necessary to have a fuller appreciation of the scale and scope of likely significant effects.

5 Review of ANCA approach

5.1 Overview of ANCA Approach

The overall ANCA approach is comprehensive, thorough, and broadly agreed.

However, there follows comments on the details of the ANCA approach.

5.1.1 Reliance on L_{night} metric and % Highly Sleep Disturbed (%HSD)

There is no evidence to suggest that ANCA have considered noise effects on sleep beyond the assessment of % Highly Sleep Disturbed based on the L_{night} noise metric, which averages the noise energy for each ATM using the northern runway between 2300 and 0000 and 0600 and 0700 hrs, over the whole 8 hours of the night between 2300 and 0600 hrs. This is not considered as robust an approach as also incorporating an Additional Awakening assessment based on the L_{Amax} of each ATM. An Additional Awakening assessment has now been submitted in response to the Board's request for further information which addresses this gap in information and permits a more thorough evaluation of the likely significant effects of noise associated with ATMs at night because of this RA.

5.1.2 Quota Count

ANCA have undertaken a regulatory decision for the existing cap on the number of ATMs between 2300 and 0700 hrs applied to the initial permission for the Northern Runway to be removed if this RA proceeds, and going forward to rely on a QC system to manage the noise impact of ATMs at night. As described in the next part of this section of this report this is considered to potentially have unintended consequences that could underestimate significant adverse impacts on sleep at night.

5.2 Quota Count

The RA proposes doing away with the existing cap on the total number of ATMs been 2300 and 0700 hrs at night of no more than 65; and replacing this cap with a Quota Count system (QC).

Notwithstanding the existing cap on the number of ATMS at night, the Mott Macdonald report "Dublin Airport Operating Restrictions September 2023 Addendum v1.0 Quantification of Impacts on Future Growth Addendum to the Analysis of June 2021 (Report version 1.3.1) September 2023 Addendum v1.0" in the table on page 6 shows there were 116 ATMs at night in 2019 and 138 ATMs are predicted at night in 2025 if the RA is approved and the current cap is removed.

Table 1 of the introduction of the revised EIAR indicates the study assumed that with the scheme operating the number of ATMs at night would be around 98, and the information regarding the QC system implies around 87 ATMs at night (see later in this section for explanation of how this estimate of numbers of ATMs at night has been derived).

The original application proposed that the QC system would only apply during the hours 2330 to 0600 with a total budget of 7990.

The Quota Count (QC) system originated to regulate night-time noise from ATMs at Heathrow, Gatwick and Stanstead airports in the UK. While the movement limits for each of these airports restricts the total number of aircraft that can take off or land during the night, the QC limit incentivises the use of quieter aircraft to maximise the number of movements that can take place. The QC system at Heathrow, Gatwick and Stanstead gives a choice to airport

operators and airlines between fewer noisy movements or a greater number of less noisy movements, up to a maximum cap on the number of movements.

Most of the world, including Ireland and the rest of EU, and in the UK for the purposes of strategic noise mapping, regard night as being an at least an 8 hour period between 2200 and 0800 hrs. Typically between 2300 and 0700 hrs.

However, to facilitate long haul flights the definition of the night-time period for management of noise at night for airports in the UK has been more flexible e.g. for Heathrow the core hours of 2330 to 0600 hrs are regarded as night-time and 2300 to 2330 and 0600 to 0700 as "shoulder periods". The noisiest aircraft in terms of their QC are excluded the period between 2300 and 0700 hrs and no aircraft of QC 4 or above can operate between 2330 and 0600 hrs. As shown in the image below.

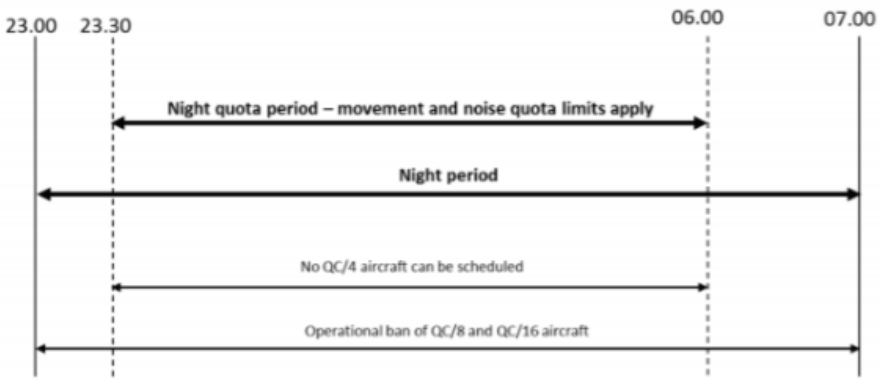


Figure 4: QC time periods at Heathrow.

The use by the UK of a core night period that is shorter than the 2300 to 0700 period normally used elsewhere in the world and for strategic noise mapping in the UK has been criticized, and many continue to object as they see it as underplaying impacts. Arguably this is true as sleep disturbance is more likely in the early and later stages of night when people are in the lighter stages of the sleep cycle which are more susceptible to noise than the deeper stages of sleep. This can cause interruption and extension of the light sleep stages which in turn means that onset of sleep can be delayed or awakening occur early, and for sleep quality to suffer as less time is spent in the deeper stages of sleep when most of the restorative benefits occur.

The ANCA queried the times of operation of the proposed QC regime and the proposal was changed so the QC system would cover the whole of the night period from 2300 to 0700 hrs. This is considered to be a significant improvement in the proposed scheme as it now helps to control how noisy ATMs are over the whole of the night period from 2300 to 0700 rather than only the core period of 2330 to 0600 e.g. it prohibits the noisiest aircraft for the whole of the night rather than just the core period. Because the QC period now extends from 2300 to 0700 hrs the QC budget is substantially larger at 16,260 compared to the original 7990. This is because the greatest numbers of ATMs per hour at night are expected to take place between 2300 and 0000 hrs and 0600 and 0700 hrs[16]. Between 0000 hrs and 0600 hrs there will be ATMs at a reduced number per hour, albeit using the Southern Runway only.

[16] See diurnal ATM profiles in the Mott Macdonald report "Dublin Airport Operating Restrictions September 2023 Addendum v1.0 Quantification of Impacts on Future Growth Addendum to the Analysis of June 2021 (Report version 1.3.1) September 2023 Addendum v1.0." pages 8 & 9.

As described above, a QC system needs to be accompanied by a restriction on the number ATMs. Otherwise, negligible to minor reductions in how noisy aircraft are can be traded against substantial increases in the number of ATMs without the QC budget being exceeded. This produces a nil to negligible change in the %HSD assessed using the L_{night} noise level averaged over the 8 hour period from 2300 to 0700. As this metric assumes that numbers of aircraft and the loudness of aircraft can be interchanged so there is no overall increase in noise energy averaged over the whole of the 8 hours of the night period. Consequently, there is no change in the % Highly Sleep Disturbed. Although the Additional Awakening (AA) assessment of such an increase in numbers of ATMs based on the L_{AMax} of each flight could show a significant adverse effect i.e. an increase in persons likely to suffer at least one additional awakening as a result of the RA compared to if the scheme is not permitted.

The QC system allows each ATM to be individually counted against an overall noise quota (or noise budget) for an airport according to the QC rating ranked using the ICAO noise certification scheme in EPN dB.

Aircraft are classified based on their noise data (adjusted as appropriate) into nine QC categories. The categories are as follows[18]:

Noise Level EPN dB	***Quota Count Value***
More than 101.9	*16*
99 to 101.9	*8*
96 to 98.9	*4*
93 to 95.9	*2*
90 to 92.9	*1*
87 to 89.9	*0.5*
84 to 86.9	*0.25*
81 to 83.9	*0.125*
Less than 80.9	*0*

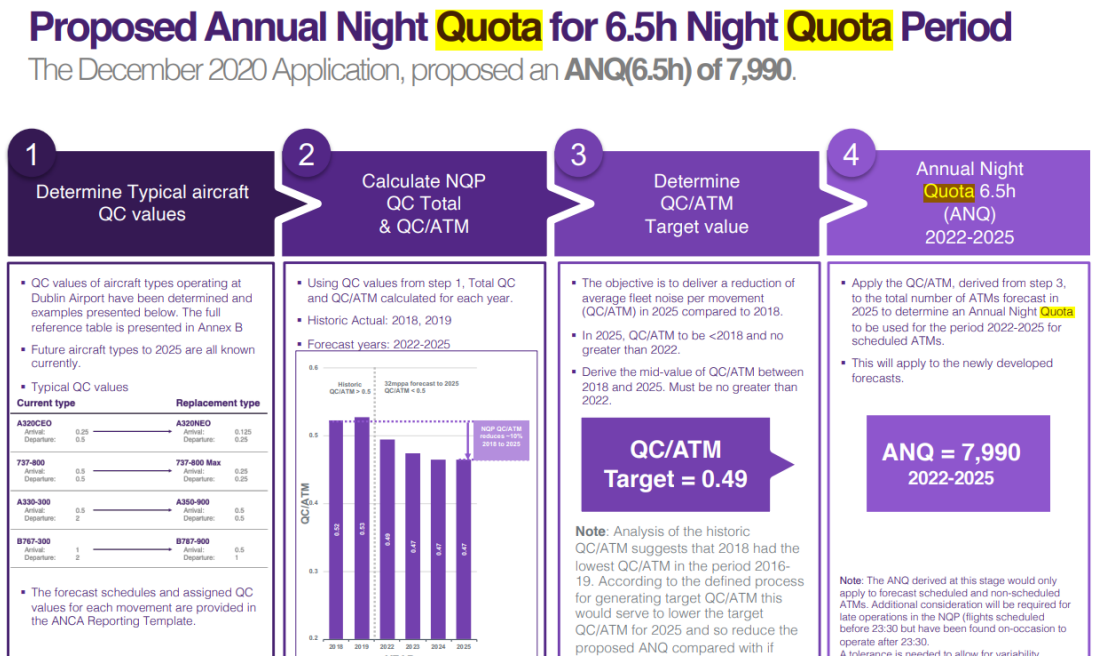
Table 1: QC bandings.

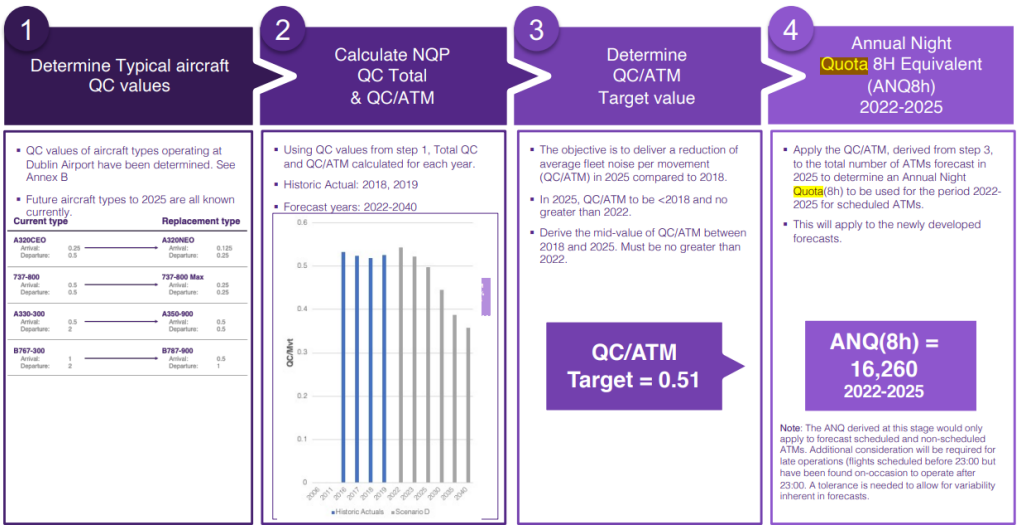
Under the QC system, each aircraft type, including different versions of the same model, is assigned a QC value according to its noise performance, separately for arrival and departure. For example, a business jet, such as a Cessna Citation II, is QC 0 on arrival so there is no restriction on this aircraft. A modern commercial passenger jet, such as an Airbus A320neo, is QC 0.125 on arrival, and an older larger passenger jet such as a Boeing 747-400 is QC2 on arrival. So, a single Boeing 747-400 arrival could be replaced by 16 Airbus A320neo arrivals, as the overall QC value would be the same.

The noise classification in the Quota Count system is based on the noise ranking of each aircraft using the International Civil Aviation Organisation's (ICAOs) noise categorisation method which measures noise using the EPNdB metric in a standardised manner as aircraft approach and depart from an airport and to the side (lateral) of the runway. This is an effective way of ranking how noisy different aircraft are but does not necessarily reflect how noisy aircraft will be at a specific airport. Because planes can be flown differently from the standardised manner in the ICAO test method and the EPNdB is not correlated to population response and cannot be reliably converted to A-weighted noise metrics that are.

[18] See Dublin Airport Development of Proposed Noise Measures. Document: 3870-Development of Proposed Noise Measures Date: September 2021 Version: vF2

As discussed above, the original proposal was for the QC scheme to apply to only between 2330 and 0600 hrs. However, in response to the request from ANCA to extend the QC to the whole of the night from 2300 to 0700 hrs in the document ANCA: Further information request: Appendix A: Dublin Airport Night Quota System Proposal – DRAFT RFI Update, the DAA Calculated an 8h equivalent Annual Noise Quota and the proposed 16,260 NQ budget was introduced, as shown in the extracts below.





A QC budget of 16260 with an average QC to ATM ratio of 0.51 is equivalent to around 87 ATMs per night i.e. a QC budget of 16260 multiplied by a QC/ATM ratio of 0.51 divided by 365 days a year = 87.3 ATMS

Under a QC system the exchange of several aircraft in a QC band for twice as many in the QC band below or even four times as many in the QC band below that, means the overall QC limit is not breached. Consequently, an assessment of potential difference in % Highly Sleep Disturbed would not indicate any change, as the overall energy averaged L_{night} level would not be altered. However, there is a substantial increase in the number of only marginally to moderately less noisy ATMs, which is likely to lead to an increase in Additional Awakenings[19] based on the L_{Amax} of each ATM and the number of ATMs, as this method is more sensitive to changes in the number of intermittent noise events. Consequently, a QC system is best used in conjunction with an overall cap on the number of flights, as for example at Heathrow, Stansted and Gatwick airports.

A difference in noise levels of 3 decibels between QC bands represents a doubling or halving of noise energy. Consequently, a QC system based on 3 decibel bands means it works on the principle that an aircraft classified QC/1 has half the noise energy as an aircraft classified QC/2 and twice the noise energy as aircraft classified QC/0.5 (although the difference in loudness is marginal as most people can only just detect a difference in 3 dB in the noise level of different aircraft). However, this is only approximate as, for example, aircraft rated at 90.1 EPN dB are in the bottom of QC 1 and those rated at 95.9 EPN dB are at the top of QC 2 and would differ by 5.8dB, representing almost a four-fold difference in noise energy that most people would clearly notice, but a difference in QC of only 1. This can lead to an underestimation of the impact, although the aircraft will comply with the QC system as the overall QC "budget" is not breached. A cap on the number of ATMs at night would reduce the risk of this happening.

5.3 Conditions

ANCA recommended a suite of noise conditions should the planning permission be granted. These conditions are considered relevant, necessary, reasonable, precise, and enforceable.

Notwithstanding broad agreement of the conditions, it is recommended that the Board considers supplementing the conditions attached to the FCC permission as follows:

A. Introduce an additional third stand-alone qualifying criterion for noise insulation for all residential properties subject to aircraft noise between 2300 and 0700 hrs of L_{Amax} 80 dB[20] based on the noise footprint of the airport's westerly and easterly single modes of approach and departure (not averaging the modes of operation of the airport over the 92 days of summer) of the noisiest aircraft using the airport at night between 2300 hrs and 0700hrs. (NB this may fall within the proposed noise insulation envelope criteria of >55 dB L_{night} or >50 dB L_{night} and at least a 9 dBA change in L_{night}.)

   Reason – To account for the impact of noise from individual ATMs assessed in terms of the maximum noise level at a receptor during the fly-by.

[19] As part of normal sleep physiology, we have on average around 23 awakenings a night independent of any noise events, extra awakenings due to noise are "*additional*".

[20] The Ollerhead et al 1992 field study in the UK found that below outdoor ATM levels of about 80 dB L_{Amax}, ATMs are not likely to cause any increase in sleep disturbance measured by monitoring people's movements (actimetry) whilst exposed to aircraft noise, from that which occurs naturally during normal sleep. For those ATMs above this level, the average arousal rate was about 1 in 30 aircraft noise events. Based on this research Heathrow has a supplementary night noise insulation criterion whereby properties predicted to experience 80 dB L_{Amax} or more at night from the noisiest ATM qualify for noise insulation. See previous section 4.2 "Average" Noise Levels (L_{night}) & Maximum Noise Levels (L_{Amax}) of this report for more detail.

And

B. Setting a cap on the total number of ATMs at night based on the number of ATMs derived from the calculation of the proposed QC budget of 16260, with a QC to ATM ratio of 0.51 i.e. 87 ATMs.

   Reason – To avoid substantial increases in ATMs being traded against marginal reductions in how noisy aircraft are, leading to increases in Additional Awakenings although the QC budget may not be exceeded.

The above conditions are intended to address the potential impact on sleep of the maximum noise level of individual ATMs, as a parallel measure to the DAA proposal to solely use energy averaging metrics that aggregate the noise from all ATMs, each of which is only for brief periods of around 10 to 30 seconds, and average it over the whole 8 hour period from 2300 to 0700 hrs.

6 Review of appeals

6.1 General

6.1.1 WHO 2018 Noise Guidelines[21]

Concerns are raised in several appeals in relation to the significant effect criteria used in the revised EIAR. These appellants refer to the World Health Organisation (WHO) Night Noise and 2018 noise guidelines which recommended reducing noise levels produced by aircraft to below 45 dB Lden (a 24 hr metric with a 5 and 10 decibel penalty for noise in the evening between 1900 and 2300 at night between 2300 and 0700, respectively), as noise above this level is associated with adverse health effects; and a level of 40 dB L_{night} at night is recommended by the WHO 2018 guidelines. The appellants go on to highlight that Dublin Airport Authority (DAA) have selected 55dB L_{night} at night as the target level above which noise insulation must be provided. The WHO however state that 55dB at night is an interim target level to be used only temporarily in local situations until other mitigation measures are in place. WHO states that vulnerable groups cannot be protected at a noise level of 55dB at night. These guidelines assume that windows are opened at night for a proportion of the year.

RESPONSE

The revised and supplemental EIARs report and evaluate aircraft noise down to the WHO recommendations of 45 dB Lden and 40 dB L_{night} . These typically represents the point at which adverse effect can start to be detected, and significant effects may not occur until higher levels are reached.

For significant adverse effects at night the revised and supplemental EIARs apply a level of 55 dB L_{night} (this represents a steady level of sound over the period 2300 to 0700 that would be equivalent to the overall noise energy of the actual fluctuating level of intermittent aircraft noise during the night) derived from the WHO Night Noise Guideline (NNG) document from 2009. This value has also been applied as an eligibility criterion for insulation schemes at several UK airports including Stanstead (54 dB), Bristol, Manston, Southampton, Leeds Bradford and Luton; and is one of the qualifying criteria for the noise insulation scheme proposed for this RA. In addition to a fixed qualifying threshold of 55dB L_{night} for noise insulation, another criterion for noise insulation designed for locations where there may be a substantial increase in noise at night due to the RA is proposed with a more stringent threshold level of 50 dB L_{night} plus a qualifying requirement that the affected residential property should also experience an increase in L_{night} due to operation of the RA, of 9 dBA or more.

The WHO 2018 Noise Guidelines regarding aircraft noise annoyance have been criticised and claims made of bias in the methodology used to decide which studies were included in the meta-analysis that informed the final recommendations. Alternative researchers have used additional studies to those the WHO working group included and derive recommended noise levels that are markedly higher than the recommendations of the WHO. For example, although the latest research in the UK (2014 and 2021) shows that the general population is more sensitive to aircraft noise nowadays that it was in the 1980s when the previous study underpinning UK policy on aviation noise was undertaken (reflecting a global trend), the identified population reaction ("dose response") is less acute than the 2018 WHO guidelines suggest.

The WHO guidelines regarding sleep disturbance are less contentious and broadly reflect a consensus. However, it is important to understand what effects the guidelines cover as they do not represent thresholds at which most people

[21] Environmental noise guidelines for the European Region – see https://www.who.int/europe/publications/i/item/9789289053563 last viewed 18th April 2024.

will awaken to a fully conscious state, instead they represent thresholds at which effects such as changes in sleep stage may occur (there are 4/5 light to heavy stages in the sleep cycle which typically last 90 minutes, then repeats over the night period, with around 23 awakenings per night on average independent of any noise effects), and effects of noise on brain waves, blood pressure and pulse, and the motility of sleepers can be detected.

However, it is clear the WHO Guidelines do not include consideration of the economic, social and cultural costs of reaching the recommended noise levels. The night-time recommendation of 40 dB L_{night} is particularly stringent and would prohibit virtually any ATMs at Dublin airport at night (or at almost any other airport in Europe). The equivalent WHO recommendations for road and rail noise would also mean virtually all road and rail transport would have to cease at night, and commercial, industrial, recreational and leisure activity at night would be severely curtailed. While the ambition to reduce noise and eliminate associated adverse health and quality of life effects is admirable, policy and decision making needs to be underpinned by the most robust evidence on these effects, including the total cost of action. Constraining flights at the airport to meet the WHO recommendations and the resultant impact on the airport, its employees, businesses that supply the airport, airlines and their staff, travellers, and the regional and national economy, are not considered by the WHO guidelines. This is a primary driver in why no government in Europe or elsewhere in the world has adopted the WHO guideline level of 40 dB L_{night} as a formal limit to control airport activity at night or to mandate that noise insulation is funded or provided by an airport.

A generally accepted effect reflected in the latest WHO guidelines, derived from several studies and research projects, is that the degree of adverse reaction to changes in aircraft noise can be greater when there is a rapid change in the number of ATMs and associated noise e.g. when a new runway or flight path opens, compared to when aircraft noise changes at a much slower rate e.g. gradual increases in ATMs on an existing runway or flight path over several years. This probably why the noise insulation scheme has two qualifying thresholds, one of which at 50 dB L_{night} is below the WHO NNG of 55 dB L_{night} and includes a change criterion of 9 dB.

6.1.2 Flight paths

The issue of flight paths is raised by several of the appellants. Concerns are raised that the flight paths assumed in the initial and revised EIAR do not reflect the reality of how aircraft currently and in future may use the airport if the RA is approved.

However, notwithstanding any discrepancy between assumed and actual flight paths, the overall outcomes of this RA are broadly the same e.g. the sharing of ATMs across two rather than one runway at night means some people get less noise, but others get more noise which will be mitigated by noise insulation, and the numbers in each category are little changed and therefore the decision on the scheme should not be affected.

Nevertheless, the EU directive makes clear that one of the purposes of EIA is to inform the public and facilitate their participation in the decision-making process. It appears some of the people who may be significantly affected by this RA and/or qualify for mitigation i.e. sound insulation, will be different from those identified in the revised EIAR, and from those highlighted in the original study underpinning the decision to approve the northern runway. This is due, at least in part, to the flight paths assumed in the original study, the revised and now the supplementary EIARs being different.

Moreover, the issue of flight paths used for the original and revised EIARs not being the same as those that are used now the northern runway is operational is largely relevant to the daytime operation of the airport between 0700 and 2300 hrs, and therefore is not a factor for the evaluation of this RA which is for the use of the northern runway at night between 2300 and 0700 hrs, which cannot take place under the existing permission.

If this RA is approved, because the southern runway was and has remained in use prior to the northern runway coming into operation, the flight paths for ATMs using the southern runway at night will be the similar to those assumed in the original EIAR for the northern runway, and for the revised and supplementary EIAR for the operation of the northern runway at night under this RA. For example, for most of the time when the airport is operating in westerly mode the flight paths for ATMs from the southern runway both day and night will be in line with the axis of the runway before changing to go on route to destinations once the necessary altitude is achieved.

Flight paths for departures off the northern runway both day and at night will be different from those assumed in the original EIAR for the construction northern runway which assumed flight paths based on the best available predictions at the time. The flight paths will be comparable to those predicted in the revised EIAR published before the northern runway opened as this was based on more recent predictions of flight paths. In reality the flight paths will be as those assumed in the supplementary EIAR as these flight paths are based on the actual operation of the northern runway since it opened in August 2022 i.e. with at least a 15 degree divergence from the runway axis[22] immediately on take-off.

The covering letter accompanying the submission of the supplementary EIAR includes the following comments on flight paths:

"Flightpath changes

During the intervening period, the North Runway has become operational (since August 2022), and we are therefore in a position to update modelling assumptions into the future based on the actual routes flown.

The previous assessments (18th December 2020 & RFI Submission 13th December 2021) were based on route assumptions developed in consultation with the IAA in advance of the North Runway's completion. The updated assessment is based on analysis of radar data of actual routes flown since the most recent change to the published procedures (23rd February 2023). This information is now provided in the attached EIAR Supplement (September 2023)."

6.2 Individual Appeals

There follow reviews of the appeals submitted to the Board as supplied to the author of this report:

6.3 Stephen Smyth and Thomas and Angela Smyth

The Smyth appeal makes several cogent points, for example:

1. The need for evaluation of the noise impacts of individual ATMs at night, not just an appraisal by averaging the noise energy of all flights over the whole of the night period. This has now been provided by DAA in response to the Board's request for further information.

2. The significance of effect criteria – Those used in the EIAR broadly reflect current good practice in the UK, Europe and North America. The concepts of LOAEL and SOAEL quoted in the appeal are from policy in England and Wales, and whilst the aim is to mitigate and minimise adverse effect and avoid significant adverse effects. That does not mean they cannot occur if the planning balance indicates they are not reasonably practicably avoidable.

[22] ICAO Annex 14 Aerodromes – requires for safe separation of aircraft that the departure tracks from parallel runways diverge by at least 15° immediately after take-off.

3. QC system – The appeal correctly identifies that assessing impacts and resulting significant effects at night solely based on the overall noise energy of all the flights averaged over the whole night period is not adequate. Because marginal reductions in how noisy aircraft are can be traded off against increased numbers of still individually noisy ATMs, and this can trigger additional awakenings. This has now been addressed by the additional awakenings assessment required by the board, which supports having in addition to a QC scheme a cap on the number of ATMs at night.

4. Noise Insulation Scheme - much of the criticism raised is about the existing scheme. The proposed noise insulation scheme for this RA is targeted on noise at night and uses qualifying criteria that are in the top half of the best schemes in Europe. The noise insulation scheme would be improved if it included a qualifying threshold based on the approach and departure footprints of the loudest aircraft likely to use the Northern Runway and a threshold of 80 dB L_{AMax} (as per Heathrow, Stanstead and Gatwick). The table below lists examples of various qualifying criteria for airport noise insulation schemes around the world.

Airport	**Qualifying Criteria**
Dublin (Proposed)	L_{night}, 2300 to 0700 = 55 dB or 50 dB + at least a 9 decibel increase compared to without the northern runway in use at night
North America	
Oakland Intl	65 dB(A) CNEL for residential properties
New Orleans	65 dB(A) L_{DN} for residential properties
San Diego	65 dB(A) L_{DN} for residential properties
San Francisco	65 dB(A) CNEL
Los Angeles	65 db(A) CNEL
Seattle/Tacoma	Sound Insulation Program, information on criteria not available
Anchorage Intl	65-69 dB(A) L_{DN} for residential properties
Vancouver	L_{dn} dB(A) 60 for continuous noise and SEL 75 for sporadic noise
Calgary	None. Noise issues tackled through land use control
Europe	
Schipol	58 dB(A) (L_{den}), 49 dB(A) (L_{night})
Amsterdam	63.71 dB(A) L_{den} 54.44 dB(A) L_{night}
Charles de Gaulle	L_{den} 55 dB(A)

Frankfurt	Noise insulation contours of the insulation programme are defined by a combination of L_{Aeq} 55 dB and a max noise level of 6 x 75 dB(A). The target is to avoid noise events that regularly exceed 6 x 52 dB(A) "at the ear of a sleeping person".
Dortmund	Eligibility based on a L_{eq} > 62 dB(A) 24 hour noise contour
Hamburg	Exceedence of L_{eq} 65 dB(A), 55 dB(A) for indoor areas
Madrid	65 dB(A) L_d, (L_{eq} 0700-2300), 55 dB(A) L_N (L_{eq} 2300-0700)
Prague	65 dB(A) L_d, (L_{eq} 0700-2300), 55 dB(A) L_N (L_{eq} 2300-0700)
Oslo	L_{DEN} >60dB outdoor and L_{Amax} > 60dB indoor
Australasia	
Auckland	Existing buildings subject to noise from aircraft operations: AIAL is required to offer acoustic treatment based on Annual Aircraft Noise Contours once existing buildings are within the L_{dn} 60 dBA contour and L_{dn} 65 dBA contour. This includes educational facilities, registered preschools, household units, child centres, hospitals, and rest homes. Offers in the L_{dn} 60 dBA contour are 75% funded by AIAL and in the L_{dn} 65 dBA contour are 100% funded by AIAL.
Sydney	ANEF 30 dB(A) for residences (Australian Noise Exposure Forecast)
Cairns International	None
Thailand	Higher than NEF 40 dB(A) triggers offer of compensation
Macau International	None
Changi International	None. Noise issues tackled through land use control (planning)

Table 2: Examples of noise insulation criteria for other airports internationally

The above list is over 10 years old but indicates that most airports listed above use derivatives of the L_{eq}, which makes direct comparison with Dublin difficult. The three German airports, however, all employ Leq based schemes, with the criteria ranging from 55 to 65 dB(A). It should be noted that in the USA, FAA Sound Insulation Guidelines recommend a criterion of 65 dB(A) DNL, which is regarded as being interchangeable with 65 dB(A) CNEL. An approximate L_{eq} can be derived from DNL by the subtraction of 10 dB. Therefore, it can be seen that the qualification level for most U.S schemes is at the lower i.e. “more generous” end of the range found and similar to what is now proposed for Dublin i.e. approximately $L_{eq,T}$ 55 dB(A). Direct comparison of the DAA

proposals with international standards is difficult because of the difference in noise indices and time periods used. In broad terms, however, the DAA proposals are regarded as being in the more generous part of the range of criteria used internationally; comparing favourably with the most generous schemes worldwide, and towards the least strict end of the range found in the UK.

5. Measured noise levels at the appellants house – These relate to discrepancies between the daytime levels measured since the northern runway opened and those predicted in the original EIAR for the northern runway. Consequently, they have no relevance to the RA under consideration which is for night-time operation of the northern runway. Notwithstanding this, the table on page 17 of the appeal shows a comparison of measured noise levels with those predicted in the original EIAR and the differences range from moderate to major to substantial depending on aircraft type (and probably lateral dispersion across the flight corridor). This difference is likely due to the original EIAR noise modelling not being based on the actual flight paths now being flown after the northern runway has opened. If there are such large differences during the day, it is not difficult to form the view that there could be similar discrepancies between aircraft noise likely to be measured at night and the levels predicted in the original EIAR if the scheme goes ahead. Although the supplementary EIAR recently submitted has remedied this as it is now based on the flight paths in place since the northern runway came into use in August 2022.

6. DAA longitudinal study – The appellant raises as number of discrepancies between a 2018 longitudinal study commissioned by DAA and the predictions in the original EIAR for the northern runway and speculates that changing noise modelling software from the FAA Integrated Noise Model (INM) in 2018 to the FAA's Aviation Environmental Design Tool (AEDT) for the revised EIAR may be the reason. The AEDT incorporates and updates the INM and they both use the same aircraft noise data base. Both the INM and ADET software were and are frequently updated and the noise database is regularly refreshed and added to, so there can be differences between models using the same software at different times. There may be some minor differences in the calculations within the software (both software packages meet the requirements of the internationally agreed standard ECAC.CEAC Doc 29 that specifies the computational requirements for airport noise modelling), but the effect is likely to be nil to negligible on the predicted noise levels based on the same inputs. Instead, the predictions are much more sensitive to the input data, in particular the stage length (distance to next landing) which reflects the mean take-off weight of the aircraft which is largely controlled by fuel load i.e. longer stage length means more fuel carried and therefore more engine thrust is required for take-off and there is slower ascent on departure and therefore more noise for longer at ground level. So, unless the longitudinal study and the EIAR had the same inputs it would be no surprise that there might be some differences in the predicted noise levels between the two studies.

6.4 Appeal of Eugen Dumitras

1. The appellant correctly identifies that the QC system should not be solely relied upon to manage noise impacts at night and that a cap on ATMs at night should be maintained.

2. In addition, the appeal rightly raises the issue of the lack of assessment of additional awakenings in the revised EIAR, which has now been addressed by the DAA submissions in response to the Board's request for further information.

3. The flight paths issue is raised – see comments in response to the Smyth appeal above.

4. The noise insulation scheme offers up to €20,000 to treat bedrooms. This is towards the upper end of the range offered by airports internationally. The funding is specifically to treat bedrooms to mitigate against noise

intrusion at night, and is not for "compensation" e.g. for loss of amenity i.e. having to keep windows closed to mitigate increased noise.

5. The appellant's proposal to increase the area in which assistance with relocation is provided is not supported by any suggestion of what might be the qualifying noise level for such a scheme or description of the size of such an area or how many properties it would cover. It is therefore impossible to carry out a cost benefit analysis to inform the planning balance judgement on such a measure.

6.5 Maurice O'Donnell

This appeal appears to raise the same issues as the Eugen Dumitras appeal. Therefore, the responses given above also apply.

6.6 Tipsy Toes Playschool

The appeal is about noise impacts on the pre-school/nursery during the day arising from the flight paths when the Northern Runway opened being different from those used to assess the application for the Northern Runway. This means the effects are different from what the pre-school/nursery may have anticipated based on the original EIAR. But because the pre-school/nursery does not operate between 2300 and 0700 hrs the appeal is not relevant to the RA considered here, which is for use of the Northern Runway during these times.

6.7 Appeal from Saint Margaret's The Ward Group

6.7.1 PAGE 6 AND 7

Flight paths

"*The St. Margaret's The Ward residents group obtained the "Standard Instrument Departure" (SID) chart for category C & D jet engines as indicated by the IAA. This appears to be the actual flight paths that are being used when the runway opened in August 2022, however these are totally at variance from the planning approved at Reg. Ref. F04A/1755, different to those presented for consultation in 2016 and now different from those presented in the "Relevant Action" Reg Ref F20A/0668. Therefore, all noise contour mapping, all proposed issues associated with the North Runway and all planning documents submitted are incorrect and therefore the appellant argues that the planning process must start again*."

RESPONSE

It is no surprise that there are substantial numbers of complaints about flights now taking off from the western end of the northern runway. This is a consequence of the northern runway opening and being permitted to allow departures in a westerly direction (typically for 70% of the year under prevailing westerly winds) and directly overflying people who had no or very little overflight previously. There is a substantial body of work that shows that when change in noise occurs rapidly i.e. when a new runway opens, the adverse community response to noise is greater i.e. more people are annoyed/disturbed, compared to the response of communities exposed to the same noise levels but under steady state conditions for a number of years.

The figures showing flight tracks in the revised and supplementary EIARs are a simplification of the actual flight paths used in the modelling as they show the centre line of what is in fact a corridor that typically can be 2.5 Km or more

wide, across which individual aircraft tracks will be spread. To account for this in the modelling used for the revised and supplementary EIARs the dispersion of aircraft is along 7 sub-tracks i.e. a centre track and 3 tracks either side, with a proportion of aircraft using the centre track and then progressively lower proportions of the traffic using the outer tracks, as shown in paragraph 13B.3.48 of the revised Environmental Impact Assessment Report Appendix 13B, as reproduced below.

- 28.2% of departures along the centre line;
- 22.2% of departures along each of the two inner Sub Tracks either side of the centre line and offset by a distance of 0.71 standard deviation;
- 10.6% of departures along each of the 2nd pair of Sub Tracks either side of the centre line and offset by a distance of 1.43 standard deviation;
- 3.1% of departures along each of the two outer Sub Tracks either side of the centre line and offset by a distance of 2.14 standard deviations

This means that most aircraft using each flight path will not fly the narrow central line but will be within the much wider overall flight corridor. The dispersion of aircraft across the flight path is determined by the airport's radar tracking records. The revised EIAR Appendix 13 at paragraph 13B.3.49 comments that "*These have been determined from a detailed analysis of radar tracks for operations in 2016 at Dublin. Operations in 2018 have been reviewed and found to follow a similar distribution*."

Flight tracks will vary from day to day based on mode of operation of the airport which is determined by wind direction i.e. easterly or westerly, and with two runways dependent on the mode of operation and whether in mixed or segregated mode. Consequently, there are potentially four different modes of operation of the current baseline with two runways operating e.g.

- Westerly segregated
- Easterly segregated
- Westerly mixed mode
- Easterly mixed mode

The variability in the modes of operation is allowed for in the modelling by taking the average number of movements over the 92 day summer period and the typical fleet mix during this period and distributing them over the flight tracks in proportion to the time the different modes of operation occur over the 92 day summer period e.g. typically westerly modes occur for around 70% of the year and easterly modes for 30% of the year. This results in noise models that represent the average use of flight paths over the 92 day summer period. Day to day the actual flight paths will differ to varying degrees from the "average". However, the dose response data used to evaluate community response to aviation noise is based on the noise over the 92 day summer average of the modes of operation of the airport linked by social studies to population reaction, rather than the noise contours and data for the individual modes of operation of the airport. Social surveys have found that this approach has general been found to provide the reasonable overall correlation with community response[23].

[23]E.g. The SONA 14 study (Survey of noise attitudes 2014: Aircraft, CAP 1506, CAA. 2017) produced evidence indicating that easterly-mode noise exposure for the minority of the time e.g. around 20 to 25 % of the year, correlated best with mean annoyance score (r2=0.95), but westerly-mode noise exposure for the majority of the time i.e. 75 to 80%, was found to have the poorest correlation (r2=0.21). This occurs because respondents were found to be more annoyed by easterly mode noise exposure compared to westerly-mode for a given noise level. Practically, this means that single-mode contours are unsuitable for decision making, but that they may be helpful for portraying exposure and changes to exposure.

The independent review of noise modelling carried out by Noise Consultants Ltd (NCL) out for ANCA (Appendix F Assessment of Aircraft Noise Modelling, Statement in relation to aircraft noise modelling undertaken as part of Application F20A/0668 October 2021) notes the following:

"*NCL is broadly satisfied that the approach taken by the Applicant in modelling its arrival and departure routes is acceptable, however we have made the following observations:*

- *Limited data has been provided to demonstrate how the current situation has been modelled with respect to how the existing departure routes are flown. However, noise contours provided for 2016, 2018 and 2019 appear consistent with the location of flight paths reported in the Airport's Noise Action Plan.*
- *A single dispersion assumption has been used for all scenarios based on analysis that the Applicant undertook in 2016 and reviewed in 2018. It is of course impossible to consider dispersion in future forecast scenario, however NCL notes that the dispersion pattern adopted may not reflect RNAV procedures. This cannot be determined at this point therefore it is highly recommended that from the commencement of North Runway operations that dispersion patterns are remeasured and included in future modelling exercises*."

Because the flight path figures in the revised and supplementary EIAR show a centre line of a corridor up to around 2.5 Km wide, across which aircraft are dispersed and which is replicated in the noise contour modelling, it is no surprise that the images the appellant relies on are not the same. Furthermore, the Standard Instrument Departure (SIDs) figure the appellant relies on is for the use of runway 28R only (departure from the northern runway to the west). It will therefore inherently look different in appearance compared to the other figures the appellant relies on which include arrivals and departures on both runways. In addition, the tracks on the SIDs figure are also centre lines of wider corridors across which aircraft are dispersed, which has been allowed for in the noise modelling. Finally, it is not uncommon that some aircraft may depart from the SIDs.

6.7.2 Noise Insulation

The appellants argue that the current insulation programme for the northern runway which DAA say is complete and in compliance with Planning Reg Ref F04A/1755 is totally incorrect as the wrong set of flight paths have been used to derive the noise contours used to define the scheme boundaries, and people that were formerly excluded from the Noise Insulation Programme are now being exposed to higher noise than previously modelled due to the change in flight paths.

RESPONSE

Please see previous comments about flight tracks.

The current insulation programme for the northern runway only considers daytime noise as the runway cannot be used at night.

The board may wish to note that in relation to this RA the ANCA regulatory decision report in describing condition 4 regarding noise insulation requires annual verification of noise models that will be used to administer the noise insulation scheme against the measurements made using the airport noise monitoring system and to adjust the contours accordingly if appropriate. Consequently, any departure of the predicted noise contours from the reality of the noise conditions once the norther runway is in use at night with the RA in operation will be detected and allowed for.

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6.7.3 PAGE 69

The appellants claim that the revised EIAR shows that 15 out of 35 departures between 06:00 and 07:00 will be on the northern runway, which is contrary to Condition 3(c) which says "Runway 10R shall be preferred for departing aircraft".

RESPONSE

15 departures out of 35 between 0600 and 0700 hrs on runway 28 L does show a preference for Runway 28 R which will have 20 departures, albeit it is not a large difference between the runways.

The appellants state that there are just 2 extra departures between 06:00 – 08:00 and that the DAA want to inflict night-time noise on the populations of Malahide, St Margarets, The Ward and Coolquay for just 2 extra flights from 06:00 – 08:00. It is also worth analysing the number of flights between 23:00 and 24:00 between 2025 Proposed and 2025 Permitted from the tables referred to in this appeal. There would appear to be an additional 10 flights on both runways. However, between 22:00 – 23:00 there are 6 less flights. In summary between 22:00 and 24:00 there are only an additional 4 flights.

RESPONSE

The table reproduced below from the supplementary EIAR shows how the numbers of ATMs at night with the proposed scheme are expected to grow compared to the currently permitted scenario.

Table 3: Table 13:1 from the Chapter 13 revised EIAR[24]

Table 13-1: Assessment Years, Scenarios, PAX and ATMs

Assessment Years and Scenarios	Predicted Annual Passengers (PAX) (millions per annum)	Permitted vs Proposed Difference in PAX (millions)	Air Traffic Movements (ATMs) ('000s per annum)	Typical 'Busy Day' Night-Time ATMs (23:00-07:00)
2025 Permitted	31.8	n/a	227	60
2025 Proposed	32.0	0.2	240	114
2035 Permitted	32.0	n/a	228	60
2035 Proposed	32.0	0.0	240	114

The above table indicates that typically with the RA in operation there are forecast to be an additional 54 ATMs at night in 2025 and 2035 compared to the currently permitted scenarios.

6.7.4 PAGE 75:

The appellants point out the evidence from the Board's consultant, Mr Rupert Thornely-Taylor in his report during the Oral Hearing for the North Runway [10L/28R] in 2007. In his report dated June 4th 2007, on his findings of the Oral Hearing submissions (Microsoft Word - R217429A.DOC (pleanala.ie), Mr Thornely-Taylor recommended the following conditions be applied if permission for the runway was granted:

"The runway hereby permitted shall not be used except in accordance with Option 7b as defined in the Environmental Impact Statement Addendum, Section 16, and accordingly: the runway (10L/28R) shall not be used for take off or landing between the hours of 2300 and 0700; no departures on runway 10L shall take place at any time; except in cases of safety,

[24] The same table is provided as Table 1-1 of Chapter 1: Introduction to the supplementary EIAR.

maintenance considerations, exceptional air traffic conditions, adverse weather, technical faults in air traffic control systems or declared emergencies at other airports."

The appellants state that Mr Thornley-Taylor's recommendation is for no flights on runways 10L/28R (the northern runway) between 23:00 – 07:00 and that no departures take place on runway 10L (the northern runway on easterly operations).

However, Mr Thornely-Taylor makes it very clear that the night-time ban was proposed by the applicant's Counsel, as he states:

"The applicants indicated, through their advocate Mr O'Donnell, that they would implement a planning permission that contained a condition limiting the use of the new runway in accordance with Option 7b, and that this would involve prohibiting the use of runway 10L or 28R for departures during the hours of 2300-0700. He further advised that his statements to the hearing about what the applicants will do are enforceable under Irish planning law."

Mr O'Donnell's advice in his statements to the hearing on what the applicants will do are enforceable under Irish planning law, has consequences for the opening of the North Runway in August 2022, and whether the DAA will adhere to the 65-flight limit.

RESPONSE

Mr Thornely-Taylor did not recommend that the northern runway should not be used at night because of his own analysis; in which he had agreed that the southern runway could continue to operate at night. If there was a fundamental noise-based reason why the northern runway could not operate at night Mr Thornley-Taylor would have stated this, and any such reason would logically have probably applied equally to the southern runway. Instead, he agreed with the applicant's proposal i.e. Mr Thornley-Taylor did not make a positive case that night flights using the northern runway should be banned and that such a ban should remain in perpetuity. In effect, the DAA proposed that the runway should not be used at night under the terms of the application to build the Northern Runway. But, albeit without stating as such, reserved the right to apply for use of the Northern Runway at night at some unstated point in the future e.g. the application for this RA.

Notwithstanding the above, the revised EIAR is clear in Table 13-61: Air Noise (L_{night}) People by Magnitude of effect – 2035 Proposed vs 2035 Permitted that no people were assessed as having a significant beneficial effect, and 4,706 people were assessed as having at least a significant adverse noise effect because of the proposed scheme.

Furthermore, the supplementary EIAR includes updated noise contour areas, dwelling and population counts for the permitted i.e. currently approved operation of the airport, and the proposed RA scenarios with the northern runway in use at night in the years 2018, 2025 and 2035.

In the 83 tables numbered 13C-3 to 13C-86 in the document "13C. Air noise modelling results and figures in the document. A11267_23_RP062_2.0_NR_EIAR_ Appendix_13C_Air_Noise_ Modelling_ Results_Figures". Each table shows a decline in noise contour areas, dwelling and population counts respectively for the permitted currently approved operation of the airport from 2018 to 2025 and further reductions to 2035. This is because under the existing planning permission the numbers of ATMs cannot increase significantly, and aircraft will progressively become less noisy. So, on aggregate the noise contour areas, dwelling and population counts affected by aircraft noise assessed using energy averaging metrics will reduce.

However, the tables referred to above also show that although the 2025 and 2035 proposed scenarios with the RA in operation have reduced predicted noise contour areas, dwelling and population counts compared to the same in 2018, these factors are all greater by a substantial margin when compared to the equivalent scenario without the

proposed RA in place in 2025 and 2035 i.e. with the RA in operation at night there is substantial growth in the numbers of persons significantly adversely effected by noise compared to if the RA is not in operation. This is because whilst new aircraft entering the fleet will progressively get less noisy in future, this is offset by the expected growth in ATMs the RA will facilitate. In effect, the airport is taking the majority, if not all, of the benefit in aircraft becoming progressively less noisy as technology improves and fleets are replenished with the latest less noisy aircraft. This allows growth in numbers of ATMs, but shares with affected local communities little, if any, of the expected reduction in how noisy individual aircraft will be due to on-going and future technological improvements.

6.7.5 Page 100 of - Section 7.8 Summary

The following summary points are examined and commented on.

- Large increase in population affected by noise from Rounds 1-3 of the END (2006 -> 2016) - *Not relevant to this proposal and permitted by existing permission for airport.*
- Population exposed to adverse noise levels increased significantly in 2018 and 2019
    - Lden
        - From 2006 -> 2019, population exposed to >= 55 dB Lden increased from 3100 -> 12400 -> 20300 -> 35476-> 34097
        - WHO recommended safe Lden limit is 45 dB highlighting that 754,135 people exposed to adverse effects of aircraft daytime noise in 2019

Response

The Lden metric is of limited value to the assessment of this RA proposal as it covers the whole 24 hours rather than just night.

L_{night}

- From 2006 -> 2019, population exposed to >= 50 dB Lnight increased from 0 -> 1400 -> 6600 -> 12316 -> 13838
- WHO recommended safe Lnight limit is 40 dB, highlighting that 344,912 people exposed to adverse effects of aircraft night-time noise in 2019.

Response

These increases are permitted under the existing permission. The L_{night} 40 dB noise contour extends into North Dublin where noise from other sources e.g. road traffic, will typically exceed 40 dB L_{night} anyway, this is where most of the 344,912 people exposed above this level live.

Bullet Points (response in italics)

- Differences in 2019 noise figures between this application and those provided in planning application F19A/0449 – *This is probably due to differences in the forecast fleet mix and numbers of ATMs in application F19A/0449 compared to this scheme.*
- 2019 is historical data and differences suggest data cannot be relied upon – *The applicant's justification for using 2019 as a baseline is adequate. It is the last year before the Covid Pandemic dramatically reduced aviation activity, albeit aviation appears to be recovering faster than was expected. Furthermore:*

    a) It is common to use as the baseline for the existing development the year when the levels of ATMs were at the maximum permitted or the full capacity of the airport, even if the actual operation was below the permitted level or capacity.

b) Although 2019 was marginally over the maximum permitted number of ATMs/MPPA the effect in energy averaged noise terms was negligible. For example, there would have had to be more that 25% extra ATMs/MPPA over the permitted number for noise levels to be 1 dBA higher and the actual excess of ATMs/MPPA was less than this.

In addition, the sensitivity testing the Board asked for as part of the request for further information provides information to judge the potential variability of noise effects should the actual future operation of the Northern Runway vary from the core assumptions in the EIAR.

- '2025 Proposed' Lden contours significantly larger than 2016 and '2025 Permitted' contours in terms of size – *Too be expected as there will be more flights at night if the scheme goes ahead i.e. typically 90 ATMS with the scheme in 2025 and 2030 compared to being permitted to have no more than typically 60 ATMs at night in 2016 under the existing permission.*
- 589 submissions to Dublin Airport NAP from members of the public – *Whilst demonstrating public interest the number of submissions does not indicate the relevance or veracity of their content.*
- Historical trail of failure by Fingal County Council to control noise at Dublin Airport – *Subjective opinion with no relevance to this proposal.*
- EPA in their 2020 report state that noise around Dublin Airport has become a significant issue with the DAA logging 1453 noise-related complaints in 2018 – *Airports are noisy, it would be unusual if there were no complaints. It is common to find that airport noise complaint statistics are influenced by a small number of persons who make a substantial proportion of the complaints e.g. see https://www.irishtimes.com/ireland/dublin/2023/02/05/dublin-airport-noise-one-person-files-over-23000-complaints-in-2022/*

  And, an example of the DAA's monthly noise reporting at:https://www.dublinairport.com/docs/default-source/noise-reports/nftms-report-july-2023.pdf
- EPA signals that Policy Objective 65 in Project Ireland 2040 requires to "Promote the pro-active management of noise where it is likely to have significant adverse impacts on health and quality of life and support the aims of the Environmental Noise Regulations through national planning guidance and Noise Action Plans" – *The EIAR recognises significant adverse night-time noise effects and proposes a suite of mitigations to proactively manage the noise impacts.*
- Night-time noise issue identified by Fingal County Council Planning Department when updating their Noise Zones. Neither the Environmental section of Fingal County Council nor ANCA saw it as their role under 2002/49/EC or under EU 598/2014 to mitigate this identified noise problem at Dublin Airport - *Not relevant to this RA.*
- Martin Doherty, DAA's Environmental Manger, publicly acknowledged the noise problem and increased public concern resulting from the 2016 noise data from the 3rd Round of the END at an ICAO conference in May 2019 – *Not relevant to this RA.*
- ANCA were presented with noise data as part of planning application F19A/0449 but failed to progress the noise assessment once the application was withdrawn – *Not relevant to this RA.*

6.7.6 Page 208/209 – Option P11

Would it not be wise to consider P11? In terms of the alternatives to Condition 3(d), Alternative (v) (i.e. runway use pattern P11) is likely to have a negligible effect on protected sites and species, as with aircraft expected to operate as currently (with just the increase in night flights associated with lifting Condition 5) the overall level of noise will

increase very slightly everywhere (i.e. for all of the designated sites within the ZoI). P11 would see an increase of use at night-time on the southern runway but no additional impact from north runway as no night-time flights would be allowed.

RESPONSE

The effect of imposing runway use pattern 11 would be to negate the purpose of granting permission for the RA i.e. it would mean that the prohibition on the use of the northern runway at night would continue.

The appeal does not establish that the changes in noise associated with the RA would cause a significant adverse effect on the fauna in the habitats identified.

The Fingal County Council (FCC) planning report at section 8.3 describes how the submissions by the applicant has demonstrated that significant adverse effects of noise associated with the RA have been screened out of the assessment i.e. observations of bird populations affected by aircraft noise associated with flights to and from Dublin airport show no or very little reaction to aircraft noise and other activities create greater disturbance i.e. walkers, dogs, coast guard helicopters and acquaculture. Section 8.4 of the FCC report describes how the ANCA regulatory decision concludes that in the light of the best scientific information the scheme is not likely to have a significant effect on European Habitats either alone or in combination with other developments.

6.8 SMTW Environmental DAC

- Discrepancies between the EPA's funded report on Environmental Transport Noise and the DAA's statistics. Investigations should be carried out as to how the numbers reported by the DAA for Highly Annoyed and Highly Sleep Disturbed do not match the EPA's report, given the Round 3 END input dataset.
- The Quota Count (QC) System being proposes a noise quota count of zero for aircraft rated at EPN dB up to 81dB. And also, the difference for example that aircraft rated at 91 would result in a QC of 1 however an increase in almost 5 EPN dB would to 95.9EPN dB would only result in a QC of 2.

RESPONSE

The DAA are best placed to explain why there may be differences between the numbers Highly Annoyed and Highly Sleep Disturbed in the EIAR and the EPA's report on strategic noise mapping. Notwithstanding this, the Round 3 END input dataset would have been generated before 2018 and is therefore based on different forecast and actual data on ATMs and fleet mix, and underlying mapping and population distribution. The dataset used for the revised and supplementary EIARs is likely to be different as up to date fleet mix information and ATM numbers and forecasts including the effects of the covid pandemic on influencing these factors, and revised underlying mapping and population distribution data, will have been used.

See earlier comments on the Quota Count which highlight the issue i.e. it can lead to a substantial growth in less noisy but not quiet flights. Whereas the Additional Awakening analysis called for as part of the Board's request for further information is more responsive to the number of noisy ATMs. The QC system should not be relied upon on its own and should be part of a suite of controls including a cap on the total number of ATMs at night.

6.9 Page 62 of Tom Philips and Associates (TPA) response to SMTW appeal para 12.0 Insulation Scheme

This states that Condition 3 of the Regulatory Decision requires a voluntary residential sound insulation grant scheme (RSIGS) to be provided for dwellings exposed to noise levels greater than 55 dB L_{night}. This is a smaller scheme than was proposed within the document submitted with the relevant action application. What is the difference between that originally proposed by the applicant and that now proposed in the RD?

RESPONSE

The TPA response only quotes one of the qualifying criteria for noise insulation i.e. Dwellings forecast to be exposed to "high" night-time noise levels in 2025 – of at least 55 dB L_{night}. However, the proposed scheme has two qualifying thresholds and if either is met properties will be offered noise insulation e.g.

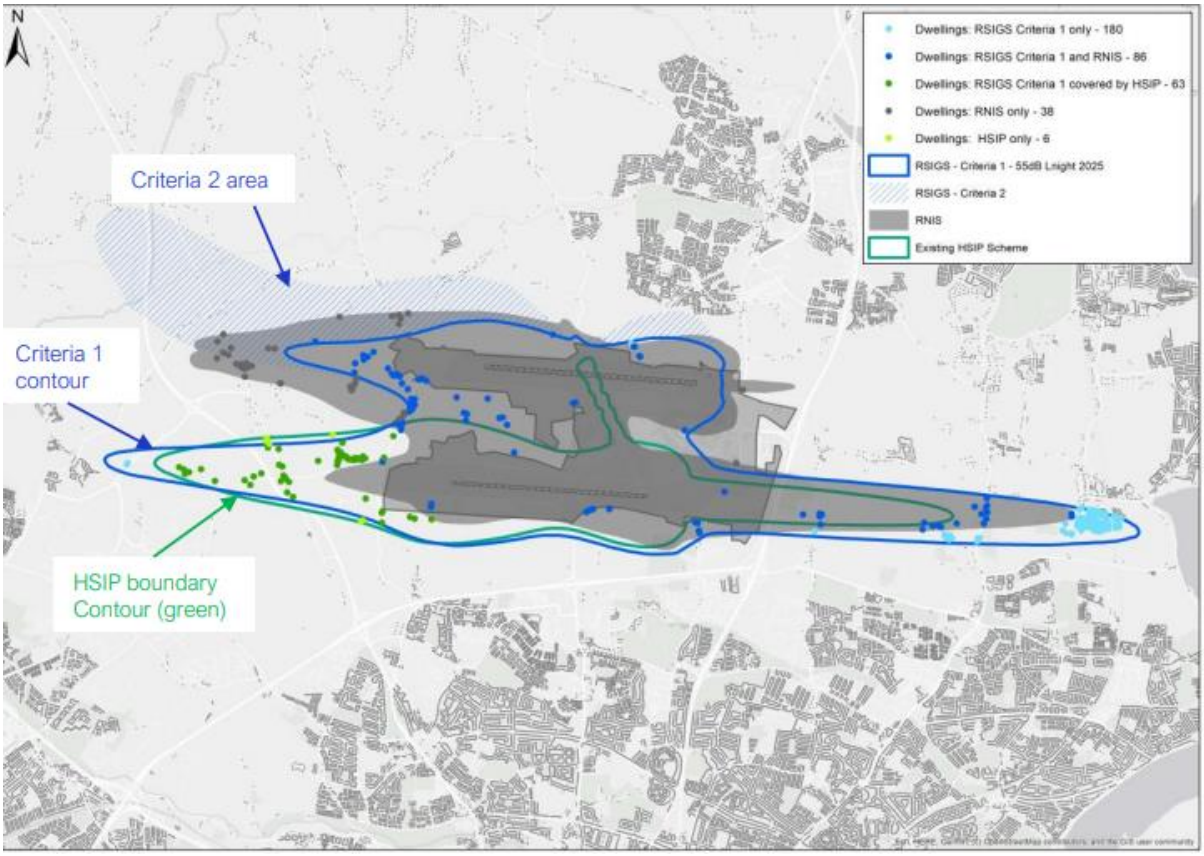
- Criteria 1: Dwellings forecast to be exposed to "high" night-time noise levels in 2025 - at least 55dB L_{night} (dark blue contour line in figure below);

  OR

- Criteria 2: Dwellings with a "very significant" rating arising from forecast noise levels of at least 50dB L_{night} and a change of at least +9dB in the first full year when the Relevant Action comes into operation when compared with the permitted operation in the same equivalent year (area indicated by blue hatch area in the figure below)

Criteria 2 has a 5 dB lower qualifying threshold, with a caveat that this has to be exceeded due to an increase in night-time aircraft noise of at least 9 decibels. Criteria 2 substantial extends the area covered by the proposed RSIGS scheme compared to those properties that are within the Criteria 1 boundary.

The figure below shows where these criteria apply and how they interact with existing RNIS and HSIP schemes that provide noise insulation based on daytime noise criteria. There has been some minor amendment to the scheme but the figure below provides a reasonable indication of how the existing and proposed noise insulations schemes will interrelate.



As the figure above shows there is some overlap between the schemes, but the proposed RSIGS brings substantial numbers of properties that are not currently eligible into the scheme e.g. to the north west of the airport (Blue Hatching) and in Drumnigh to the east of the southern runway (light blue dots - albeit these properties are relatively recently constructed and planning permission should have ensured that they incorporated noise insulation measures in their design and construction as per FCC planning policy). This means the overall area and number of properties covered by the proposed scheme should the RA go ahead are larger than the existing HSIP programme.

6.10 Adrienne McDonnel and Others

This appeal raises issues regarding:

- The WHO guidelines being exceeded and/or not used as criteria for noise insulation.
- Noise surveys producing data indicating the measured levels inside the appellant's dwelling are above WHO Guidelines
- Removal of the cap on ATMs from the northern runway at night.
- The performance of the noise insulation scheme.

RESPONSE

The comments at the start of this section regarding the WHO guidelines apply.

The noise surveys largely relate to daytime noise conditions, but in any case, do not cover the whole 16 hour day or 8 hour hight periods. The surveys are undertaken with windows open. To be effective any noise insulation scheme will rely on windows being kept closed and alternative means of ventilation and control of overheating provided and used.

The appellants comments regarding the proposed removal as part of the RA of the overall cap on ATMs at night are broadly agreed. Although the specific demand that the ban on any flights on the northern runway at night remains in place would render the purpose of granting permission for the RA pointless.

The appeal states that the appellants homes lie in the 69 dB $L_{Aeq,16\ hr}$ day-time noise contour. This means the owners of the properties qualify for the voluntary "buy out" scheme. Such a scheme is provided because retrospectively providing noise insulation to achieve the WHO internal guidelines and alternative means of ventilation and control of overheating other than by opening windows at this noise level and higher may not be practicable. Consequently, if residents wish to opt for noise insulation rather than accept the "buy out" offer the resulting noise levels internally may be higher than the WHO guidelines during the day. Notwithstanding this and relevant to this RA, the internal equivalent and maximum noise levels at night after installation of noise insulation etc. probably will comply with the WHO guidelines as the aircraft noise levels at night will be lower than during the day because there will be fewer ATMs and the noisiest aircraft that can use the airport during the day will be prohibited from flying at night by the QC scheme.

6.11 Angela Lawton

This appeal raises issues regarding the following:

- The WHO guidelines being exceeded and/or not used as criteria for noise insulation.
- Removal of the cap on ATMs from the northern runway at night.
- The ability of the QC scheme to protect residents.

RESPONSE

The comments in responses provided above to other appeals are also relevant to the issues raised by this appeal.

6.12 Brian Murphy

This appeal raises issues regarding the following:

- Flights path diverging from those indicated in documentation for the revised EIAR.

RESPONSE

The comments in responses provided above to other appeals are also relevant to the issues raised by this appeal.

6.13 Connor Kennedy

This appeal raises issues regarding the following:

- The need to retain a cap on the number of ATMs at night.
- Retention of a ban on ATMs using the northern runway between 2300 and 0700 hrs.

RESPONSE

The comments in responses provided above to other appeals are also relevant to the issues raised by this appeal.

6.14 Friends of the Irish Environment

This appeal raises issues regarding the Carbon emission that will result from the RA if approved. Consequently, there are no noise related issues to respond to.

6.15 Niamh Maher

This appeal raises issues regarding the following:

- Day time ATMs using the northern runway not following flight paths the appellant expected.
- Retention of a ban on ATMs using the northern runway between 2300 and 0700 hrs.

RESPONSE

The comments in responses provided above to other appeals are also relevant to the issues raised by this appeal.

6.16 Noel and Breda Deegan

This appeal raises issues regarding the following:

- Retention of a ban on ATMs using the northern runway between 2300 and 0700 hrs.
- Flight paths.
- No apparent link between the QC budget and number of ATMs
- Performance of the noise insulation scheme in reducing noise
- Impacts on pigeons (in a loft) and horses on their property.

RESPONSE

The comments in responses provided above to other appeals, except regarding the impacts on pigeons and horses, are also relevant to the issues raised by this appeal.

The appellant provides no technical analysis or expert opinion from a vet or ecologist supported by acoustic data to support their concerns regarding impacts on pigeons and horses. However, from the supporting information submitted with the appeal it appears that the appellants property is already significantly affected by noise from current operations at the airport, as depending on its location on Kilreesk lane they will be within 1 Km to 1.5 Km of and broadly in line with the western end of the Northern Runway i.e. they are already regularly overflown by noisy aircraft.

6.17 Raymond and Carmel Fox

This appeal raises issues regarding the following:

- Noise from the daytime operation of the northern runway being greater than anticipated.
- The “buy out” scheme is for residential properties only and doesn’t include their transport business.
- Retention of a ban on ATMs using the northern runway between 2300 and 0700 hrs.
- Concerns regarding the QC scheme.

RESPONSE

The comments in responses provided above to other appeals, except regarding the "buy out" scheme, are also relevant to the issues raised by this appeal.

Regarding the "buy out" scheme being for residential properties only, this is typical for any similar scheme the author is aware of. Generally non-residential uses are less sensitive to noise, except for schools, health facilities, places of religious worship and other specific non-residential noise sensitive land uses.

6.18 Terence Murphy

This appeal raises issues regarding the following:

- Impacts of noise from the existing operation of the airport are bad and will worsen if the RA is allowed to go ahead.
- Aircraft are getting less noisy at a slow rate and will still be noisy for the foreseeable future.
- Flight paths in reality being different from those supplied for the evaluation of the 2007 permission.
- The ban on ATMs using the northern runway at night should be maintained.

RESPONSE

The comments in responses provided above to other appeals, except the rate at which aircraft will become less noisy in future, are also relevant to the issues raised by this appeal.

The rate at which aircraft will become less noisy in future has slowed compared to the big reductions from Chapter 2 to Chapter 3 standard between the 1960s and 1980s and lesser reduction with introduction of Chapter 4 and now Chapter 14 standards in the early 2000s and late 2010s respectively. Notwithstanding this the airport's future energy averaged noise contours are predicted to be smaller than the baseline of 2018, albeit they are larger with the RA in operation compared to without it, largely because the future fleet of aircraft using the airport will have a greater proportion of more modern less noisy aircraft than currently.

6.19 Teresa Kavanagh

This appeal raises issues regarding the following:

- Removal of the ban on ATMs using the Northern runway at night
- Replacement of the cap of the number of ATS at night with a QC system.

The comments in responses provided above to other appeals are also relevant to the issues raised by this appeal.

6.20 Trevor Redmond

This appeal raises issues regarding the following:

- Removal of the existing controls on the use of the Northern Runway at night

RESPONSE

The comments in responses provided above to other appeals are also relevant to the issues raised by this appeal.

7 Conclusions

The approach in the revised and supplementary EIARs to assessment of noise effects at night focusses on L_{night} noise metric. This method combines and averages the noise energy from all the ATMs over the whole of the period from 2300 to 0700 hrs (although the northern runway will only operate between 2300 to mid-night and from 0600 to 0700 hrs). Consequently, the Board requested submission of an Additional Awakening assessment which evaluates the probability of persons awakening in response to the maximum noise level of each ATM.

The long-term trend reported in the revised and supplementary EIARs, and the additional awakenings assessment provided in response to the Board's request for information is that in 2035 fewer people are likely to be highly sleep disturbed or experience an additional awakening over and above normal non-noise induced awakenings at night compared to in 2018 without the RA. But substantially more people will be highly sleep disturbed and/or experience an additional awakening with the proposed RA in place in 2035 compared to the same year under the permitted scenario without the RA. This comes about because although in future a greater proportion of aircraft using the airport will be more modern less noisy types compared to the fleet in 2018, the resulting reduction in noise will be offset by more ATMs in 2025 and 2035 with the proposed RA in operation compared to the permitted scenario with the RA not in use. However, the trends in the shorter term are different. For example, whilst the number of persons highly sleep disturbed falls in 2025 and reduces further by 2035 compared to a baseline of 2018, with the number of persons highly sleep disturbed greater with the RA in either future year, compared to without the scheme. The same is not reported in 2025 for the additional awakenings assessment. Instead, there are marginally fewer additional awakenings reported in 2025 with the proposed RA compared to the permitted scenario without the scheme for the annual and summer averages of the airport's operations and under single mode westerly operations[25]. But for single mode easterly operations in 2025 there are substantially more persons experiencing additional awakening with the RA compared to without.

In general terms, if implemented the RA will mean some people currently affected by noise from night-time ATMs via the southern runway will experience noise from fewer ATMs using this runway at night; whilst some people currently unaffected or less exposed to noise from night-time ATMs will experience noise from aircraft using the northern runway which is currently prohibited from use at night.

The revised and supplementary EIARs propose that the significant adverse noise effects identified will be mitigated by offering noise insulation to those affected and replacing the current cap on the number of ATMs at night with a Quota Count (QC) system based on how noisy the aircraft are.

The proposed noise insulation scheme is one of the more generous programmes in Europe in terms of spatial scope and degree of funding offered. However, the qualifying criteria are based on a noise metric which averages intermittent aircraft noise across the whole 8-hour night period, and it is recommended the qualifying criteria are expanded to include a clause that reflects how loud the noisiest ATM using the airport at night will be.

Furthermore, reliance on the QC system alone to manage noise effects at night is regarded as inadequate as it would permit substantial increases in ATMs for only marginal reductions in how noisy each aircraft is, which could lead to increases in the number of persons experiencing Additional Awakenings and some individuals experiencing more Additional Awakenings. Consequently, it is recommended that if the RA is to go ahead that a cap on ATMs at night,

[25] Single mode refers to the direction that aircraft approach or depart the airport into the wind e.g. in westerly single mode aircraft depart the airport to the west and approach from the east, and under easterly mode aircraft approach depart the airport to the east and approach from the west.

based on how the QC scheme is calculated, is retained. Such caps on ATMs are in place at Heathrow, Stansted and Gatwick airports for which the QC system was developed in the early 1990s and which has been updated regularly and recently, with the caps on ATMs maintained.

It is recommended that amendments should be made to the planning conditions attached to the planning permission granted by Fingal County Council to address the points made above.

Appendix A Adverse Effects of Night-time Aircraft Noise

The primary effect of aircraft noise at night is often considered to be adverse impacts on sleep. There is growing evidence that aircraft noise at night can contribute to other health effects such as cardio-vascular disease and hyper-tension (increased blood pressure). But the risks are relatively small and tend to occur at noise levels at or above those at which effects on sleep are detected.

It is therefore worthwhile considering how noise can affect sleep.

The review[26] supporting the WHO 2018 Guidelines comments on the effects and significance of noise induced sleep disturbance as follows:

"Short-term effects of noise-induced sleep disturbance include impaired mood, subjectively and objectively increased daytime sleepiness, and impaired cognitive performance [32,33]. It is hypothesized that noise-induced sleep disturbance contributes to the increased risk of cardiovascular disease if individuals are exposed to relevant noise levels over months and years (dashed lines in Figure 1 (reproduced below). Recent epidemiologic studies indicate that nocturnal noise exposure may be more relevant for the genesis of long-term health outcomes like cardiovascular disease than daytime noise exposure, probably also due to the fact that people more consistently are at home during the night than during the day [34]. Given the many vital biological functions of sleep, and the fact that acutely curtailed or fragmented sleep has immediate consequences for next day alertness and performance, the effects of noise on sleep should not solely be judged based on long-term health consequences. Sleeping satisfies a basic need and is pleasurable if undisturbed and of sufficient length (very much like eating when hungry). Sufficient sleep increases, among others, alertness, mood, productivity, and creativity [2]. Therefore, sleep disturbance (induced by noise or other external or internal factors) needs to be minimized even without clearly established links to long-term health consequences."

Whilst a Consensus Conference Panel of the American Academy of Sleep Medicine and Sleep Research Society reported as follows:

"*Sleep is vital to human health, necessary for life,[1,2] and it serves critical roles in brain functions including neurobehavioral, cognitive and safety-related performance,[3–13] memory consolidation,[14,15] mood regulation,[16,17] nociception[18,19] and clearance of brain metabolites.[20,21] Sleep is also critically involved in systemic physiology, including metabolism,[22–26] appetite regulation,[27,28] immune and hormone function,[29–33] and cardiovascular systems.[34–37] Sleep duration is associated with mortality risk[38–40] and with illnesses ranging from cardiovascular[41] and cerebrovascular[42] disease to obesity,[43] diabetes,[44] cancer,[45,46] and depression.*"[27]

Phrases like "sleep disturbance", "sleep interference" or 'sleep interruption' imply that the noise would fully awaken people who are asleep i.e. they become completely conscious. However, the 'effects' of noise on sleep referred to in the WHO Guidelines and most of the research and wider literature etc. cover many impacts during sleep, not solely being woken up.

To understand the effects of these impacts it is important to recognise that sleep consists of a cycle of alternating stages which during a typical night repeat roughly every 90 minutes. The stages of this cycle can be described as

[26] Basner, M. & McGuire, S. (2018). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep. International Journal of Environmental Research and Public Health, 15(3), 519. doi:10.3390/ijerph15030519.

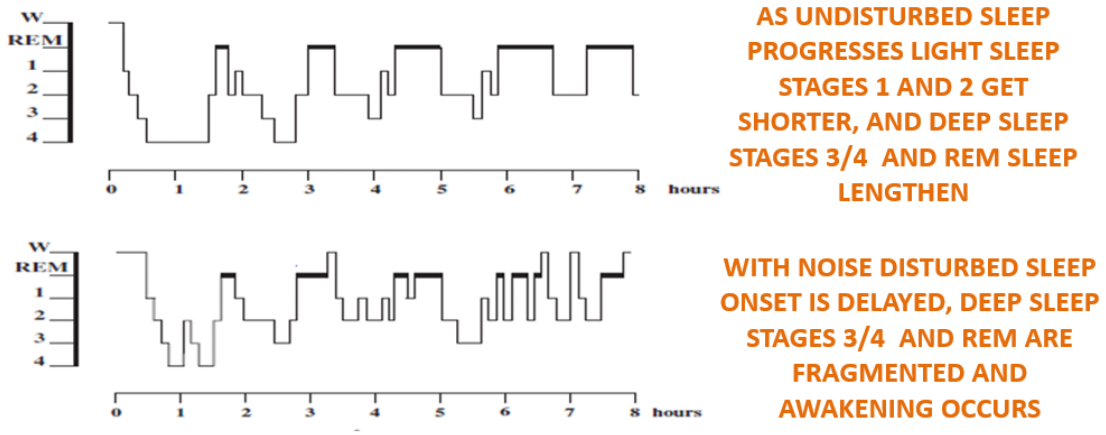
[27] Consensus Conference Panel; Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, etal. 2015. Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society on the recommended amount of sleep for a healthy adult: methodology and discussion. Sleep, Volume 38, Issue 8, August 2015, Pages 1161–1183.

Wake, Stages 1 and 2 of light non-rapid eye movement (NREM) sleep, a Stage 3 of heavy sleep followed by a Stage 4 of rapid eye movement (REM) heavy sleep.

The noise level threshold for awakenings is highest in the stage 3 and REM stages of heavy sleep and is lower in the light sleep stages 1 and 2. The awakening noise threshold also depends on the characteristics of the noise e.g. intermittent noises or rapid on-set noise events have greater impact than continuous noise or slower onset noise events; as well as the connotation of the noise. For example, whispering the sleeper's name can awake the person more easily than a much louder but anonymous noise. Similarly, the noise of an alarm or warning will awaken a sleeper more easily than a noise of similar level without any meaning. Furthermore, the rapid onset of noise from a train passing close by at high speed is more likely to cause awakening compared to the slower onset of noise of an aircraft approaching from a distance to its closest approach before moving away, although the overall and maximum noise energy of each event may be similar.

Noise effects sleep by increasing arousal levels leading to a redistribution of time spent in the different stages of sleep, with typically an increase in the duration of the awake, and light sleep stages 1 and 2 as these are more easily disturbed by noise; and a reduction of time in the heavy sleep stages 3 and 4 and the REM parts of the cycle which are more tolerant of noise. As shown in the figure below.

Figure 5: Fragmentation of sleep stages due to noise.



From - Alain Muzet, Environmental noise, sleep and health, Sleep Medicine Reviews (2007) 11, 135–142

Such sleep fragmentation has been shown to affect, among other effects, waking psychomotor function, next day performance, memory, creativity, risk – taking behaviour, mood, signal detection performance, daytime fatigue and tiredness and to increase accident risks.

Classification and determination of sleep states is best achieved using a polysomnograph (a multi-channel electronic device which records brainwave, heart, muscle and breathing data). An important general finding of sleep research is that the noise levels at which impacts occur in laboratory-based studies are lower, often by a substantial degree, than those found in field studies. This is thought to be due to the unfamiliar nature of laboratory conditions compared to the circumstances in a test subject's own bedroom to which they have adapted/habituated too over time. Consequently, field sleep studies in the subject's home are regarded as more reliable means of testing the effects of noise on sleep than laboratory-based experiments. Until relatively recently polysomnographs were large, complex and cumbersome items of equipment best used in controlled laboratory conditions rather than in a bedroom at home. However, modern sleep studies benefit from the availability of smaller and more convenient polysomnographs better

suited to use in field studies than previous generations of equipment. Even so, there are currently only a small number of suitable polysomnography based field studies on the effects of noise on sleep. Consequently, other studies using different means of appraising noise effects on sleep also need to be considered e.g. motility and self-recording and reporting.

It is important to recognise that typically many awakening events are unrelated to noise and that normally the average person is subject to several spontaneous awakenings per night independent of any effects of noise. For example, the WHO Community Noise Guidelines at section 3.4 advises that "*It is estimated that 80-90% of the reported cases of sleep disturbance in noisy environments are for reasons other than noise originating outdoors. For example, sanitary needs; indoor noises from other occupants; worries; illness; and climate (e.g. Reyner & Horne 1995)*".

It is also important to understand what the word 'awakening' means. When the word is used colloquially, most regard it as meaning being fully awake to the degree that they can recall having been awakened the following morning. Some noise and sleep research has focussed on this type of awakening by requiring the subject to press a button to record their awakening (this is called a 'behavioural awakening'). However, the scientific meaning of the term awakening covers a wider range of responses, many of which do not involve awareness or recollection of being conscious. To understand the results of the research of the effects of noise on sleep it is therefore important to be able to distinguish between various kinds of awakening, for example:

- Behavioural awakening - equivalent to the everyday understanding of conscious 'awakening', when the subject is usually aware of being conscious at the time and can often recall being "awake" the next day;
- Physiological awakening -defined by changes sleep stages measured by a polysomnograph or an EEG, which the subject may not be aware of at the time or recall the next day, and.
- The onset and degree of "motility" i.e. body movements which the subject may not be aware of at the time or recall the next day – typically measured using wrist watch like actimeters.

The above shows that at a physiological level sleep disturbance due to noise can occur, although behavioural awakening may not result. In other words, there are noise impacts on sleep that can be measured by examining changes in EEG patterns or a person's motility, but the person would not necessarily be aware of these impacts which may not have adverse or significant adverse pathological effects. Therefore, care should be taken to not ascribe significance to impacts on sleep detectable at a physiological level, that may occur or appear to occur as a result of noise impacts, as they may not reflect significant pathological effects or even the impact of noise (because they are part of normal sleep).

Where research is in terms of physiological awakenings measured using polysomnography or an EEG typically only around 1 in 12 awakenings is of sufficient duration to become a behavioural awakening.

Notwithstanding there can be a number of arousals from sleep on average that are independent of noise effects, there is evidence "*noise-induced awakenings* [i.e. additional awakenings] *may come at a greater biological cost for recuperation than spontaneous awakenings that are part of the physiologic sleep process*."[28]

[28] Mathias Basner and Sarah McGuire, WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep Int. J. Environ. Res. Public Health 2018, 15, 519; doi:10.3390/ijerph15030519

Appendix B Noise Metrics

The sound level at any location is rarely constant from one moment to the next, second to second, minute to minute, hour to hour, one 24 hour period to the next, week to week, month to month, seasonally and annually etc. Consequently, the science of acoustics has developed a range of single figure noise metrics to try and represent these constantly changing circumstances.

The ideal noise metric for assessment of aviation noise would have at least the following attributes:

- The maximum instantaneous noise level of the ATM;
- The duration the noise of the ATM is audible at a location;
- The degree to which the ATM noise exceeds the ambient noise;
- How often ATM noise occurs;
- Correlate well with the different impacts of the aviation noise e.g. annoyance and sleep disturbance.
- Be easily measured;
- Be capable of modelling/prediction;
- Be readily understood by non-specialists.

Unfortunately, no single noise index has yet been developed that can meet all the above requirements. Instead, three broad categories of noise metric exist, as follows:

Category 1: Single event indexes:

Measurements taken to describe the noise occurring during one noise event, such as an aircraft over-flight ATM. Typically, these are based on the highest instantaneous noise level measured during the noise event e.g. L_{Amax} or represent the total noise energy of the noise event normalised from the overall duration of the event down to 1 second e.g. SEL; as shown in the figures below.

Figure 1: Graphical representation of L_{max}

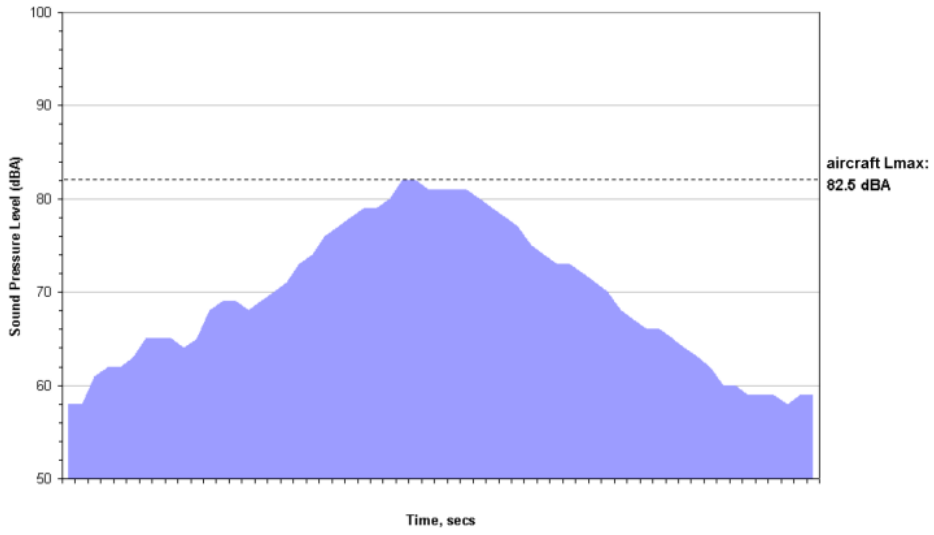


Figure 6: Graphical representation of LAmax of an aircraft overflight – from CAA ERCD Report 0904 Metrics for Aircraft Noise

Figure 2: Graphical representation of SEL

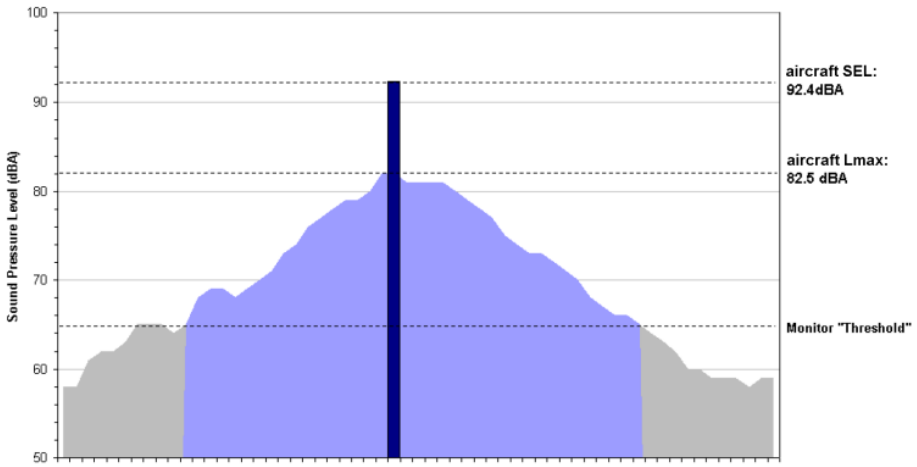


Figure 7: Graphical representation of the SEL of an aircraft overflight – from CAA ERCD Report 0904 Metrics for Aircraft Noise

Category 2: Exposure indexes:

Used to provide a description of the type of noise exposure experienced over a stated period. Typically, these are a level of constant steady sound over a defined period, T, that would have the same noise energy as the actual varying noise level during the same period and are based on the number of noise events and the noise energy of each noise event averaged over the defined period T; e.g. Continuous Equivalent Noise Level $L_{Aeq,T}$, as shown in the figure below:

Figure 3: Graphical representation of L_{eq}

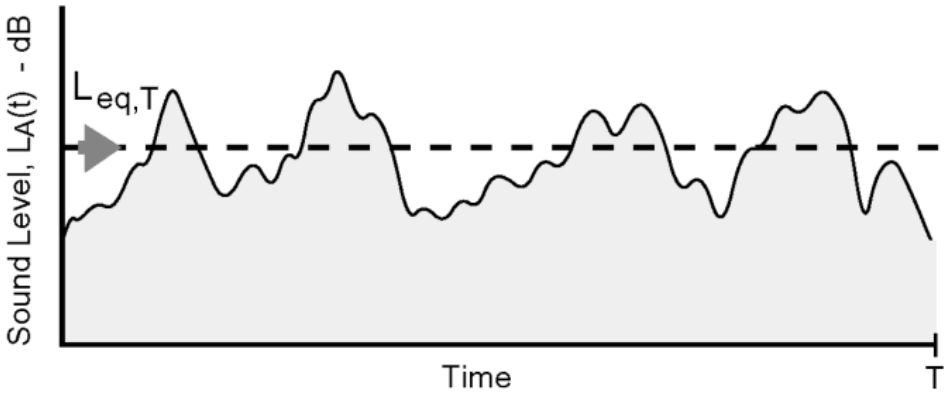


Figure 8: Graphical representation of the $L_{Aeq,T}$ of an aircraft overflight – from ERCD Report 0904 Metrics for Aircraft Noise

Category 3: Supplementary indexes: Measurements often used in conjunction with the above, to provide a more meaningful depiction of the potential impact of noise exposure e.g. N60 or N65 which are the number of ATMs that exceed an L_{Amax} of 60 or 65 dB respectively within a defined period.

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