Bickerdike
Allen
Partners
Architecture
Acoustics
Technology

DUBLIN AIRPORT

AIRCRAFT NOISE METHODOLOGY REPORT

Prepared for:

daa plc
Old Central Terminal Building
Dublin Airport
Co Dublin
Ireland

A11267_16_RP016_3.0
31 March 2020

Bickerdike Allen Partners LLP is an integrated practice of Architects, Acousticians, and Construction Technologists, celebrating over 50 years of continuous practice.

Architects: Design and project management services which cover all stages of design, from feasibility and planning through to construction on site and completion.

Acoustic Consultants: Expertise in planning and noise, the control of noise and vibration and the sound insulation and acoustic treatment of buildings.

Construction Technology Consultants: Expertise in building cladding, technical appraisals and defect investigation and provision of construction expert witness services.

REVISION HISTORY

Revision	Details
1.0	Working Draft issued for client comment.
2.0	Draft issued for client comment.
3.0	Final document for issue.

Bickerdike Allen Partners
Architecture
Acoustics
Technology

Contents

Page No.

Figures:

1.0 INTRODUCTION

Dublin Airport (daa plc) have submitted an application to Fingal County Council (FCC) for planning permission at Dublin Airport (re: F19A/0449) which proposes a change of use to provide for an increased combined capacity for all passenger buildings from 32 million passengers per annum to to 35 million passengers per annum (mppa). The application has been referred by FCC to the Aircraft Noise Competent Authority (ANCA) as the designated competent authority for the purposes of assessing this application with respect to Regulation (EU) No 598/2014.

On 19th February 2020 ANCA requested further information to enable it to consider the proposal. daa plc have requested additional time to provide this information. In order for ANCA to properly consider daa's request for additional time, ANCA have requested the following preliminary and methodological information be provided by 31 March 2020:

- Noise Modelling Methodology Report

Section 2.0 of this report sets out the methodology and the assumptions used in the prediction of airborne aircraft noise levels and the production of noise contours. Due to recent events concerning the COVID-19 pandemic there is currently uncertainty around the timeframe over which activity at the airport might grow from 32mppa to 35mppa, therefore the methodology allows for the possibility of assessing the effects of the change based on the current airport layout or the airport layout once the new North Runway, which is currently under construction, is operational.

Appendix 1 includes a glossary of acoustic and aviation terminology.

- Population and Demographic Methodology Report

Section 3.0 of this report sets out the methodology used to assess the number of people and dwellings within the contours, as well as noise sensitive community buildings such as schools and hospitals.

- Exposure and Effects Methodology Report

Section 4.0 of this report sets out the methodology proposed to assess the noise effects of the application. Appendix 2 gives details of the derivation of the assessment criteria and the relevant legislation, policy, technical guidelines.

- A sample of the Noise Modelling, Population and Demographic Information and Exposure and Effects information

Section 5.0 of this report presents a summary of the aircraft movements in 2019 and the areas of the 2019 noise contours and the numbers of people and dwellings they contain, representing the current noise exposure.

2.0 NOISE MODELLING METHODOLOGY

The noise modelling methodology utilises the Federal Aviation Authority Aviation Environmental Design Tool (AEDT) version 2d SP2, which is compliant with *ECAC.CEAC Doc 29 4th Edition Report on Standard Method of Computing Noise Contours around Civil Airports* and with *EU Commission Directive 2015/996 Establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council*.

The Aviation Environmental Design Tool (AEDT) software evaluates aircraft noise in the vicinity of airports using flight track information, aircraft fleet mix, aircraft profiles and terrain. AEDT is used to produce noise exposure contours as well as predict noise levels at specific user-defined sites. For Dublin Airport it is being used with:

- physical details of the airport, both current and future,
- the topography of the surrounding area,
- the aircraft movements themselves,
- the routes flown by the aircraft movements,
- the procedures used by the aircraft movements,
- dwellings, population and community building data.

This information is described in the following sections. The associated validation exercise against measured information is described in Section 2.7.

Figure DR002 defines the study area.

2.1 AEDT Study

The AEDT default weather settings for Dublin Airport and all-soft ground lateral attenuation are being used, and the directivity effects of aircraft bank angle are being allowed for in accordance with EU 2015/996.

Terrain data has been acquired for the study area. This was provided by emapsite in the form of a Digital Terrain Model dataset and has been incorporated within the noise model.

2.2 Airport Layout

The current airfield layout including runways and taxiways is shown on the AIP Ireland Aerodrome Chart ICAO (EIDW AD 2.24-1, dated 28 March 2019). This information is being used with a construction drawing for the North Runway to set up the Dublin Airport runways in the model.

2.3 Aircraft Movements

The AEDT software includes noise information for many common aircraft types, but it does not include every aircraft type. Therefore, the actual and forecast aircraft types need to be mapped to aircraft types in the AEDT software. For most aircraft, substitutions are proposed by the AEDT software or the ANP database[1] where a similar alternative aircraft type is used to model the actual type. For larger aircraft this generally does not involve a change but for the smaller aircraft, and in particular the general aviation aircraft, some substitutions occur. Where the AEDT and ANP databases have no guidance, an aircraft type is being assigned based on the aircraft size and engine details.

This is in accordance with EU 2015/996 which states that "The ANP database provided in Appendix I covers most existing aircraft types. For aircraft types or variants for which data are not currently listed, they can best be represented by data for other, normally similar, aircraft that are listed."

Helicopters are being excluded from this assessment as they perform less than 1% of the aircraft movements at Dublin Airport and therefore do not materially contribute to the noise contours. Helicopters have historically been excluded from contours produced for Dublin Airport.

This is in accordance with EU 2015/996 which states "Where noise generating activities associated with airport operations do not contribute materially to the overall population exposure to aircraft noise and associated noise contours, they may be excluded. These activities include: helicopters, taxiing, engine testing and use of auxiliary power-units."

[1] Aircraft Noise and Performance Database, https://www.aircraftnoisemodel.org

2.4 Runway Usage

2.4.1 Current Airport Layout

The runway usage for past years has been obtained from the individual aircraft movement data for the relevant year. A summary of the overall runway split for the 2019 annual period is given in Table 1 below.

Runway	Arrivals	Departures
10	23.3%	24.1%
28	72.2%	71.4%
16	3.8%	2.4%
34	0.6%	2.1%

Table 1: 2019 Annual Runway Usage

For forecast contours produced based on the current runway layout the modelled runway usage is being based on the 10 year average (2011-2019) runway usage, which is shown in Table 2 below.

Runway	Arrivals	Departures
10	25.5%	25.8%
28	69.7%	69.2%
16	3.9%	2.6%
34	0.8%	2.4%

Table 2: 2011-2019 Average Annual Runway Usage

2.4.2 North Runway Airport Layout

Once the North Runway is built the cross runway (16/34) will continue to be used, however only for essential use (e.g. when there are strong crosswinds) as stated in Condition 4 of the parent permission. Specifically for the purposes of noise modelling the future use is assumed to be 1% of aircraft movements, with the remaining 99% of movements on the two main runways. 0.75% of aircraft movements are forecast to use Runway 16 with the remaining 0.25% on Runway 34. The expected future runway usage over a given year is summarised in Table 3 below, based on the average runway usage over the last 10 years and allowing for the expected reduction in cross runway usage.

Runway	Arrivals	Departures
10L/10R	29.0%	29.0%
28L/28R	70.0%	70.0%
16	0.75%	0.75%
34	0.25%	0.25%

Table 3: Future Runway Usage

Once the North Runway is constructed and operational Dublin Airport will operate during the daytime (07:00 – 23:00) in accordance with Conditions 3a-3c per the mode of operation Option 7b, as detailed in the Environmental Impact Statement Addendum, Section 16 as received by the planning authority on the 9th day of August, 2005. This provides that:

(a) the parallel runways (10R-28L and 10L-28R) shall be used in preference to the cross runway, 16-34,

(b) when winds are westerly, Runway 28L shall be preferred for arriving aircraft. Either Runway 28L or 28R shall be used for departing aircraft as determined by air traffic control,

(c) when winds are easterly, either Runway 10L or 10R as determined by air traffic control shall be preferred for arriving aircraft. Runway 10R shall be preferred for departing aircraft, and

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

In practice it is expected that, unless capacity requires mixed mode, the runways will operate in segregated mode during the day with arrivals using either Runway 10L or Runway 28L and departures using either Runway 10R or Runway 28R depending on wind direction.

The few movements by Code F aircraft are an exception to this, as they will always use the North Runway. It is also proposed that departures by Category A & B aircraft heading south during westerly operations will use the South Runway, and those heading north during easterly operations will use the North Runway.

A method of determining mixed mode runway usage on the main runways (North and South) for modelling purposes has been developed. The modelled runway usage has been determined on an hourly basis.

Most of the time the runways will operate in segregated mode, i.e. one runway for all arrivals, the other for all departures. However, there will be occasions during peak hours when runways will need to operate in mixed mode, i.e. both runways used simultaneously for arrivals and departures. The change from segregated to mixed mode and back to segregated mode will be determined by ATC and once changed to a particular mode the airport is likely to operate in that mode for at least two hours.

Activity switches from segregated mode to mixed mode where activity is such that any of the three following single runway capacity limits are exceeded:

1. More than 35 arrivals in one hour.
2. More than 44 departures in one hour.
3. More than 48 movements (combined arrivals and departures) on one runway in one hour.

In mixed mode, where each individual runway handles both arrivals and departures, departures will operate using the compass departure principle. This means that if a departure is using a route that turns to the north then the North Runway will be used, and conversely if it is using a route that turns to the south, the South Runway will be used.

For westerly operations when in mixed mode as few arrivals as possible will use 28R, while not exceeding the single runway capacity limit of 48 combined arrivals and departures on runway 28L. For easterly operations when in mixed mode as few arrivals as possible will use 10R, while not exceeding the single runway capacity limit of 48 combined arrivals and departures on runway 10L.

When using the North Runway most aircraft will not use the full length on departure, and instead join the runway from the 1st intermediate taxiway. The exception are Code E and Code F aircraft, which will typically use the full runway length. All departures on the existing South Runway will use the full runway length.

During the night-time period (23:00 – 07:00) for scenarios based on what is currently permitted the South Runway is the preferred runway.

2.5 Flight Routes

2.5.1 Flight Routes – Current Airport Layout

For the cross runway straight arrival routes have been used with a set of modelled departure routes for Category A&B and Category C&D aircraft, which have been developed based on the published SIDs.

For the main runway arriving aircraft have been modelled as using a continuous descent approach with a glide slope of 3 degrees. Based on an analysis of radar data in 2018, approaching aircraft are generally lined up with the extended centreline of the runway at least 17km from the runway threshold. Consequently the main runway approach routes have been modelled as straight out to this point. Before this point arrivals are modelled using 7 routes which cover the broad swathe of directions that the arriving aircraft approach from. The modelled current arrival routes are shown in pink on Figure DR033.

For departures on the current main runway (10/28), that will be known as 10R/28L in the future, the current routes used vary with aircraft type and destination.

<u>Category A & B Aircraft – Departures</u>

The IAA have stipulated that Category A & B aircraft, which are predominantly turboprops such as the ATR 72, are not required to remain within the existing environmental corridors to the same extent as the larger jet aircraft types. They therefore commonly turn off the extended runway centreline to the north or south shortly after the end of the runway. A review of radar tracks for recent activity has resulted in a set of routes for these aircraft types shown in red on Figure DR033.

<u>Category C & D Aircraft – Departures</u>

Currently the airport has a total of 11 Standard Instrument Departure (SID) routes for westerly operations and 10 for easterly operations, although in both cases a number are initially the same before separating some distance from the airport. As the point at which they separate is distant from Dublin Airport, the aircraft will have attained sufficient height to not cause significant noise disturbance on the ground by this point. Given this similarity, for noise modelling purposes a set of seven initial departure routes have been created from the western end and four initial departure routes from the eastern end.

For departures during periods of easterly operations the INKUR and SUROX routes initially follow the ROTEV route until well beyond the extent of the noise contours, therefore all movements that head north west after their initial turn have been assigned to ROTEV, along with the movements that head north. Additionally the PELIG route is initially the same as the NEPOD route, therefore both PELIG and NEPOD movements have been assigned to NEPOD.

For Category C & D aircraft, which are jet engined aircraft, these routes have been supplemented for departures to the west by routes that turn earlier, although not as early as Category A & B aircraft routes. This assumption originally arose from a detailed study of radar data from 2010, which found that many of the larger aircraft on runway 28 actually performed their initial turn earlier than described by the SIDs. This is because after reaching an altitude of 3000 ft, they are vectored off by ATC. Two additional 'Early Turn' routes were therefore created for each route with initial turns to the north, south, or east, i.e. the ROTEV, NEPOD, LIFFY and DEXEN routes. Traffic has been distributed equally between the three turning points, the two early turns and the SID, for each route. Recent radar data has been reviewed and these assumptions are still considered to be appropriate for current activity at Dublin Airport.

The modelled current Category C & D routes are shown in blue on Figure DR033.

This approach is in accordance with EU 2015/996 which states that "The backbone track defines the centre of the swathe of tracks followed by aircraft using a particular routeing. For the purposes of aircraft noise modelling it is defined either (i) by prescriptive operational data such as the instructions given to pilots in AIPs, or (ii) by statistical analysis of radar data as explained in Section 2.7.9 — when this is available and appropriate to the needs of the modelling study."

2.5.2 Flight Routes – North Runway Airport Layout

Due to the expected reduction in the use of the cross runway in the future, the noise contours do not reach the point where aircraft turn off the extended runway centreline. Straight arrival and departure routes have therefore been used for the cross runway.

Aircraft have been modelled as approaching along a glide slope of 3 degrees. Arrival routes for the existing South Runway have been modelled the same as the current routes. Arrival routes have been created for the North Runway which broadly replicate those for the South Runway. The modelled arrival routes based on the future North Runway airport layout are shown on Figures DR034 and DR035.

<u>Category A & B Aircraft – Departures</u>

Once the North Runway is in use Category A & B aircraft will continue to turn off the extended runway centreline shortly after the end of the runway, however they will not be allowed to turn across the other runway. A new set of departure routes has therefore been developed for Category A & B aircraft. From the southern runway this replicates the current routes, but with no turns to the north. For the North Runway the routes have been designed to replicate the current routes to a large extent but with no turns to the south as shown in Figures DR034 and DR035.

Category C & D Aircraft – Departures

For Category C & D aircraft a number of the modelled routes have been used to represent more than one of the SIDs, so combining the traffic on some of the SIDs onto a single modelled route. The departure routes to the west are supplemented by early turn routes, similar to the current routes.

In order to achieve a safe minimum separation between flights from the two main runways, when both are in operation, departure routes have been used which include a course divergence of at least 15°. This means that the departure routes from the two main runways differ in course (head in different directions) by at least 15°.

A set of departure routes from the North Runway has been developed, taking into account the resulting noise. The result is routes with an early turn to the north. When heading east all of the routes turn 15° at 1.06nm from the end of the runway. When heading to the west the routes to DEXEN, INKUR, NEPOD, PELIG and SUROX turn 30°, while those to ABBEY and ROTEV turn 75°, all at 1.18nm from the end of the runway.

The departures on the South Runway continue along the extended runway centreline before turning.

The modelled current Category C & D routes are shown in blue on Figures DR034 and DR035.

This approach is in accordance with EU 2015/996 which states that "In many cases is not possible to model flight paths on the basis of radar data — because the necessary resources are not available or because the scenario is a future one for which there are no relevant radar data. In the absence of radar data, or when its use is inappropriate, it is necessary to estimate the flight paths on the basis of operational guidance material".

2.5.3 Dispersion

Aircraft on departure are allocated a route to follow. In practice, this route is not followed precisely by all aircraft allocated to this route. The actual pattern of departing aircraft is dispersed about the route's centreline. The degree of dispersion is normally a function of the distance travelled by an aircraft along the route after take-off and also on the form of the route.

When considering many departures, it is commonly found that the spread of aircraft approximates to a "normal distribution" pattern, the shape or spread of which will vary with distance along the route. A simplified mathematical model can be adopted to represent a normal distribution of events, based on standard deviations. *ECAC.CEAC Doc 29 4th Edition Report on Standard Method of Computing Noise Contours around Civil Airports* advises the use of seven "dispersed" tracks associated with each departure route, these comprise the Centreline of each route and the three Sub Tracks either side.

The allocation of movements adopted in this case to each track is as follows: -

- 28.2% of departures along the Centreline;
- 22.2% of departures along each of the two inner Sub Tracks either side of the Centreline 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 Centreline 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 Centreline and offset by a distance of 2.14 standard deviations.

This dispersion model has been applied with a departure offset profile, which comprises the standard deviations of the magnitude of the dispersion for lengths of straight and curved track. 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.

This approach complies with *EU 2015/996* which advises that "it is normal practice to represent flight path swathes by a small number of laterally displaced 'subtracks' ".

2.5.4 Route Usage

The actual aircraft movement logs for years that have already occurred provide destination airports for each departure movement. This has been combined with an assessment that has been carried out of which departure route is used for each destination which utilise the direction it is from Dublin.

The forecasts for future years generally include departure route information for each movement, which has been used. Where departure route information is not available, a departure route has been assigned based on the destination airport.

2.6 Flight Profiles

2.6.1 Custom Flight Profiles

For the most common aircraft, based on information provided by the airlines and daa and noise data from the NMTs (noise monitoring terminals), custom “USER” profiles have been created that more closely replicate the procedures used by aircraft departing from Dublin Airport.

The standard arrival profiles for many of the aircraft in the AEDT database include level sections. An analysis of radar data found these do not occur at Dublin, therefore 3 degree continuous descent approach profiles have been created for all aircraft types.

The AEDT departure profiles for many of the aircraft in the AEDT database finish at 10,000ft. To allow predictions over the whole of the study area these profiles have been extended to 30,000 ft or for certain propeller aircraft the maximum altitude AEDT calculates to be achievable for the particular aircraft type.

This approach is in line with EU 2015/996 which advises that “Caution must be exercised before adopting default procedural steps provided in the ANP database (customarily assumed when actual procedures are not known). These are standardised procedures that are widely followed but which may or may not be used by operators in particular cases. … When modelling actual scenarios, improved accuracy can be achieved by using radar data to supplement or replace this nominal information. Flight profiles can be determined from radar data in a similar way to the lateral backbone tracks”.

2.6.2 Stage Lengths

For departure movements the AEDT software offers a number of flight profiles for most aircraft types, and in particular for the larger aircraft types. These relate to different departure weights which are greatly affected by the length of the flight, and consequently the fuel load. In the AEDT software this is referred to as the stage length and is in increments of 500 nm up to 1,500nm and then in increments of 1,000nm. The AEDT software assumes all aircraft take off with a full passenger load irrespective of stage length. As the stage length increases the aircraft has to depart with greater fuel and so its flight profile is slightly lower than when a shorter stage length is flown.

For some of the aircraft types, their small size results in only one stage length being available. For the remainder a stage length was chosen based on the distance to the destination airport.

This approach complies with *EU 2015/996* which states that “Vertical dispersion is usually represented satisfactorily by accounting for the effects of varying aircraft weights on the vertical profiles.”

2.7 AEDT Validation

Results from the Dublin Airport Noise and Track Keeping (NTK) system have been used for noise validation purposes. Specifically, the results from Noise Monitoring Terminals (NMTs) 1, 2 and 20 between January and December 2018 have been used.

The noise levels from the monitors are automatically correlated with aircraft movements using the radar track keeping system and the average determined by aircraft type and operation. A number of parameters are measured by the system, for this validation the Sound Exposure Level (SEL) of the individual aircraft movements has been used.

To take into account the measured levels the AEDT software has been used to predict the level at the NMT locations using the recommended AEDT aircraft type. This has been compared to the measured averages for the aircraft types when separately arriving and departing. Where the differences between the measured and predicted results were found to be significant then adjustments were made to the modelling to minimise the differences.

Seventeen aircraft have had modifications made to their arrival and departure noise assumptions. The modifications are detailed in Table 4 below.

Aircraft Type	Arrivals		Departures		
	AEDT Type	Adjustment (dB)	AEDT Type	Profile	Adjustment (dB)
A306	A300-622R	-3.1	A300-622R	30KFT	+0.6
A319	A319-131	-1.4	A319-131	30KFT	+0.9
A320	A320-211	-0.7	A320-211	USER	-1.3
A320neo	A320-211	-2.0	A320-211	USER	-3.2
A321	A321-232	-0.4	A321-232	USER	-0.5
A332	A330-301	-1.3	A330-301	30KFT	-1.1
A333	A330-301	-1.1	A330-301	30KFT	-0.8
ATR72	SD330	+1.5	SD330	STANDARD[2]	+0.1
B734	737400	+0.4	737400	30KFT	-0.1
B738	737800	-2.7	737800	USER	-1.2
B738MAX	7878max	-3.0	7378max	USER	-1.5
B752	757RR	-0.4	757RR	30KFT	-2.3
B772	777200	+0.2	777200	30KFT	+1.5
B773	777300	-0.8	777300	30KFT	-2.4
B787	7878R	-0.3	7878R	30KFT	+0.1
E190	EMB190	-0.8	EMB190	30KFT	+0.5
RJ85	BAE146	-3.3	BAE146	STANDARD[2]	-1.6
DH4[1]	SD330	0	DHC6	STANDARD[2]	0

[1] The DH4 type was not validated due to insufficient results. The modelled AEDT types are based on BAP's experience of this aircraft at other airports where it operates more frequently, as the default AEDT suggested type of DHC830 typically leads to significant under-prediction of noise levels.

[2] Maximum altitude limited to AEDT calculated max for the AEDT type.

Table 4: Modifications to AEDT Default Assumptions

These modifications achieve a better correlation between predicted and measured noise at the airport. Generally resulting in differences between predicted and measured levels of less than 1 dB at each of the three NMTs. This is in line with EU 2015/996, which requires that "All input values affecting the emission level of a source, including the position of the source, shall be determined with at least the accuracy corresponding to an uncertainty of ± 2dB(A) in the emission level of the source".

2.7.1 Performance of Modernised Aircraft Types

The degree of expected improvement in noise levels for the recently introduced and future aircraft types in the forecasts which are not contained within the AEDT model are given below in Table 5 for arrivals and departures. The expected improvement in noise levels is based on a comparison with either the current generation aircraft that is being directly replaced, or the most similar aircraft type available in AEDT.

The expected changes in noise levels are based on the differences in average certification noise levels between the current and modernised aircraft types from the *EASA Approved Noise Levels database*[2] where available. For aircraft whose certification noise levels are not available the assumptions have been based on the assumptions used by the ERCD for the Airports Commission (2014)[3].

Current Aircraft Type	Modernised Aircraft Type	Expected Change in Noise Levels between Current and Modernised Aircraft Types (dB)	
		Arrival	Departure
737700	Bombardier CS300	-3.4	-4.3
Airbus A321	Airbus A321neo	-2.4	-5.4
Airbus A321	Airbus A321LR[1]	-2.4	-5.4
Airbus A330-300	Airbus A330-900neo	-1.1	-4.8
Airbus A330-300	Airbus A350-900	-3.0	-7.5
Boeing 777-300	Boeing 777X[2]	-0.8	-3.8
Embraer E190	Embraer E190-E2	-1.9	-6.2

[1] Based on A321neo certification noise levels
[2] Based on ERCD assumptions

Table 5: Expected Change in Noise Levels between Current and Modernised Aircraft Types

[2] https://www.easa.europa.eu/easa-and-you/environment/easa-certification-noise-levels
[3] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/389579/noise_methodology_addendum.pdf

3.0 POPULATION AND DEMOGRAPHICS ASSESSMENT METHODOLOGY

3.1 Dwelling and Population Data

Dwelling data has been acquired by daa from GeoDirectory for 2019 Q2, which was the latest available dataset when the assessment work began.

An assessment of not yet built dwellings, which have already been granted planning permission, has been carried out. This has utilised information on permitted developments provided by Tom Phillips and Associates which has been compared to the data from GeoDirectory, as a number of the developments are progressing on site. This resulted in a separate permitted dwellings database.

Population data has been estimated using the average dwelling occupancy by small area. This has been obtained for 2016 based on Census data from the Central Statistics Office[4]. It has then been determined into which of the small areas each of the dwellings falls, based upon which they have been assigned the average dwelling occupancy for the area. This approach is in line with that used for the last round of European Noise Mapping.

An assessment of zoned land has also been included as part of the permitted developments. This identified a number of areas which are designated for residential use. Some of these already contain existing or permitted dwellings and so are included in those datasets. The remaining areas have been assumed to have future developments with an average density of 35 dwellings per hectare and 3 people per dwelling.

3.2 Community Buildings

Noise sensitive community buildings have been identified through a manual review of the GeoDirectory data. For the purposes of this assessment noise sensitive education buildings include nurseries, schools, colleges and universities, but not day-care or creches. Noise sensitive healthcare buildings include healthcare facilities where people may have an overnight stay such as hospitals or nursing homes, but not GP surgeries or dentists.

[4] http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=EP008

4.0 EXPOSURE AND EFFECTS ASSESSMENT METHODOLOGY

4.1 Sensitive Receptors

This section details the methodology to be used for assessing the noise effects resulting from any proposed changes and includes an outline of some of the key legislation and guidance that has informed the methodology. Full details of all relevant legislation, policy, technical guidelines and the assessment criteria are given in Appendix 2.

The assessment will primarily consider a comparison between 'future with development' and 'future without development' scenarios. This is considered to represent a reasonable worst case assessment. Although comparisons between the future with development and the baseline situation will also be made.

The following will be considered as potential receptors of high sensitivity for this assessment:

- Dwellings;
- Schools;
- Healthcare facilities;
- Places of worship; and
- Quiet areas, as set out in the Dublin Agglomeration Noise Action Plan[5].

These noise sensitive receptors are consistent with those recommended for consideration by the UK Government[6] to the Civil Aviation Authority, for example, when assessing the noise impact from any airspace change. Other potential receptors exist with lower sensitivity to noise, for example offices and hotels. These are likely to be less numerous than the high sensitivity receptors. It would be expected that the changes in noise level due to the proposed development will be similar and therefore the magnitude of any effects would be less significant than for the high sensitivity receptors.

---

[5] Dublin City Council, Fingal County Council, South Dublin County Council, Rathdown County Council. (2019). Dublin Agglomeration Environmental Noise Action Plan December 2019 – November 2023
[6] Department for Transport. (2017). UK Air Navigation Guidance 2017, [online]. Available at: https://www.gov.uk/government/publications/uk-air-navigation-guidance-2017 [Checked 23/04/2019].

4.2 Guidance and Legislation

4.2.1 Overview

There are various noise metrics available for the assessment of the impacts of air noise. These are described in detail in Appendix 2. The choice of metric used here includes those that have been used previously to rate air noise around Dublin Airport, as used currently in the UK and also those used around Europe for strategic noise mapping purposes and in noise action plans. Whilst other metrics have been considered in this assessment, emphasis will be placed on the UK noise metrics, i.e. $L_{Aeq,16h}$ for daytime noise and $L_{Aeq,8h}$ for night-time noise, for the reasons given below. Detailed consideration has however also been given to the L_{den} and L_{night} metrics, which have been developed and used in Europe as measures to rate the health impacts of noise. They are based around the $L_{Aeq,T}$ unit. They are therefore included in this assessment as primary metrics, alongside $L_{Aeq,16h}$ and $L_{Aeq,8h}$.

4.2.2 Primary Air Noise Assessment Metrics - Residential

As used previously for the assessment of air noise around Dublin Airport, for example in relation to the North Runway Change to Permitted Operations consultation and 2016 noise contour work for the sound insulation scheme, noise contours will be prepared in terms of the established UK noise metrics for air noise, the $L_{Aeq,16h}$ metric for the daytime (07:00-23:00) period and the $L_{Aeq,8h}$ metric for the night-time (23:00-07:00) period. These periods relate to an average summer day. Summer in this instance is defined as the 92-day period between 16 June and 15 September inclusive.

The $L_{Aeq,16h}$ metric has been used for many years and is still used today in the UK as the basis for assessing the impact of aircraft noise on the community. A recent study[7] confirmed that $L_{Aeq,16h}$ is still considered to be the most appropriate metric for assessing daytime air noise.

The 2006 Local Area Plan (LAP) promoted the concept of the Inner and Outer Airport Noise Zones utilised in the Fingal Development Plan. The LAP recently underwent a variation and new noise zones were created for the 2020 version[8], although they remain based on the daytime and night-time noise contours for the airport.

[7] Civil Aviation Authority (2017). Survey of noise attitudes 2014: Aircraft, CAP 1506.
[8] Fingal County Council. (2020) Dublin Airport Local Area Plan 2020. [online]. Available at: https://www.fingal.ie/dublin-airport-local-area-plan-2020

Night-time aircraft noise can be assessed in a number of different ways. The most common method is to rate night noise in terms of noise exposure, using the $L_{Aeq,8h}$ metric. This metric has previously been used for the assessment of air noise around Dublin Airport and is used in the UK to describe aircraft noise at night for airport planning purposes. Another common method is to assess the noise of individual aircraft, in terms of SEL or L_{Amax}. The assessment will not consider the impacts of typical individual aircraft, as the types of aircraft using Dublin Airport are not expected to significantly change as part of the proposed development. Therefore, the impacts of a typical individual aircraft are considered to be broadly the same. In practice, future modernisation will lead to the replacement of some aircraft in the fleet mix including the common types operating now, such as the Boeing 737-800 with the quieter Boeing 737 MAX 8.

Under Council Directive 2002/49/EC relating to the assessment and management of environmental noise ('the European Noise Directive'), all member states of the European Union have been required to produce noise maps and noise action plans for major agglomerations. In Ireland, this requirement has been achieved by way of the Environmental Noise Regulations 2006. One of the key noise metrics used for this purpose is L_{den}. This is a metric that considers an average annual day of aircraft traffic (although it can be applied equally to either rail or road traffic) over a 24-hour period, providing greater emphasis, by way of adding noise penalties of 5 dB and 10 dB to noise levels arising during the evening (19:00-23:00) and night (23:00-07:00) respectively. This metric is explained in detail in Appendix 2.

For major airports that operate at night, there is a general relationship between L_{den} and $L_{Aeq,16h}$ such that the L_{den} values are approximately 2 dB higher, e.g. a value of 63 dB $L_{Aeq,16h}$ broadly equates to 65 dB L_{den}. In practice, this relationship might vary as it will depend on the relative levels of activity at Dublin Airport during the day, evening and night, and during the summer relative to the rest of the year.

From information set out in Appendix 2, the following general criteria may be adopted for rating noise exposure levels at night in terms of the primary indicators.

In the absence of specific national guidance in Ireland, UK guidance has been considered accordingly, in particular the Aviation Policy Framework (APF[9]) and their response to the UK Air Space Change Consultation[10]. Based on UK Government guidance, and, the following contour bands are considered relevant in terms of assessing daytime air noise:

- 51 dB $L_{Aeq,16h}$ which the UK Government recognises as a threshold below which there are no observed adverse impacts from air noise; i.e. imperceptible/negligible impact.
- 54 dB $L_{Aeq,16h}$ which currently provides an indication of the onset of significant community annoyance in the UK.
- 63 dB $L_{Aeq,16h}$ which denotes the level at which the UK Government recommends that sound insulation is provided. It is also the level which currently defines the Inner Airport Noise Zone in the Fingal Development Plan.; i.e. significant impact.
- 69 dB $L_{Aeq,16h}$ which denotes the level at which UK Government guidance is for consideration to be given by airports to assist in the costs of re-locating people from exposed dwellings, or, under certain circumstances, to offer to purchase such dwellings; i.e. profound impact.

The following contour bands are considered relevant in terms of assessing night-time air noise:

- 45 dB $L_{Aeq,8h}$ which the UK Government recognises as a threshold below which there are no observed adverse impacts from air noise;
- 55 dB $L_{Aeq,8h}$ which denotes the onset of sleep disturbance and is adopted here as a threshold for significant impacts. This is derived from the internal levels of 30 dB $L_{Aeq,8h}$ given in the 1999 WHO guidance and an assumption of closed windows. Further discussion of this threshold is given in Appendix 2.

---

[9] Department for Transport (2013). Aviation Policy Framework. [online]. Available at: https://www.gov.uk/government/publications/aviation-policy-framework [Checked 04/03/2019].

[10] Department for Transport (2017). Consultation Response on UK Airspace Policy: A framework for balanced decisions on the design and use of airspace. [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/653801/consultation-response-on-uk-airspace-policy-web-version.pdf [Checked 04/03/2018].

4.2.3 Air Noise Assessment Metrics – Non- Residential

Noise criteria for non-residential receptors are given in Table 6. These levels represent the threshold for potentially significant impacts. Their derivation is given in Appendix 2.

Receptor	**External noise level threshold**
Schools	55 dB $L_{Aeq,30m}$ (day)
Places of worship	As per residential buildings
Healthcare facilities	55 dB $L_{Aeq,1h}$ (day) / 50 dB $L_{Aeq,1h}$ (night)
Quiet areas	55 dB L_{den} / 45 dB L_{night}

Table 6: Air noise impact criteria – non-residential

4.2.4 Supplementary Air Noise Assessment Metrics

The primary air noise assessment metrics generally rely on extensive surveying of attitudes to aircraft noise resulting in a dose-response relationship linking levels of community annoyance to the metric, such as L_{Aeq}. Supplementary noise metrics on the other hand, while having no clearly recognised correlation with community annoyance, can be useful in reflecting how aircraft noise is experienced in the locality around an airport.

To understand the noise levels that an individual will experience when an aircraft event occurs, consideration has also been given to the N65 and N60 indices. These are a measure of how many times a given L_{Amax} level is exceeded in the assessed time period. It is common to assess daytime operations using N65 and night-time operations using N60. These metrics are discussed in more detail in Appendix 2. There is no conventionally accepted method of assessing impacts arising from these supplementary metrics but they provide an alternative means of describing how the noise climate, and particularly the number of events of a given noise level, might vary between scenarios. These metrics will be assessed for residential receptors only.

4.3 Impact Assessment Methodology

4.3.1 Overview

The air noise impacts will be assessed in terms of absolute noise levels. Both the absolute noise levels and the change in noise level due to the proposed development are then taken into account to determine whether there are any significant effects due to the operation of the proposed development. This section sets out the criteria adopted and how these have been combined to produce an effect rating.

4.3.2 Absolute Criteria

On the basis of the guidance discussed in Section 4.2 and Appendix 2, the absolute noise values used to assess the impacts of aircraft noise at residential receptors are given in Table 7. For non-residential receptors, the values given in Table 6 are taken to be a significant impact.

Subjective Description of Impact	Summer Day, dB $L_{Aeq,16h}$	Annual L_{den}, dB L_{den}	Summer Night, dB $L_{Aeq,8h}$ / Annual L_{night}, dB L_{night}
Imperceptible/Negligible	51	-	45
Not significant	54	55	48
Slight	57	60	51
Moderate	60	-	54
Significant	63	65	55
Very Significant	66	-	60
Profound	69	70	63

Table 7: Air noise impact criteria (absolute) – residential

4.3.3 Relative Criteria

In addition to the absolute noise level, the relative change in noise level between operational scenarios is used to assess the air noise effect. A potential impact rating for a change in level is given in Table 8.

A semantic scale of this type, following the format of examples given in the Institute of Environmental Management and Assessment guidelines[11], has been applied in previous air noise assessments and accepted in Public Inquiries for airport developments in the UK and Ireland, for example the application for the North Runway at Dublin Airport, at the London City Airport Inquiry in relation to the City Airport Development Programme (Reference: 13/01228/FUL) and Public Inquiries into the second runway at Manchester Airport[12] and the conversion of RAF Finningley to become Robin Hood Airport[13].

Change in noise level, dB(A)	Subjective impression	Potential impact classification
0 to 2	Imperceptible change	Imperceptible/Negligible
2 to 3	Barely perceptible change	Not significant
3 to 6	Perceptible change	Moderate
6 to 9	Up to a halving or a doubling of loudness	Significant
>9	Equal to or more than a halving or doubling of loudness	Very significant

Table 8: Air noise impact criteria (relative)

4.3.4 Overall Criteria

The magnitude of an effect from changing between one scenario and another (e.g. without and with the proposed development) will be established by considering both the absolute noise level after the change and the relative change in noise level that occurs at a given receptor.

The effect of a change in noise level tends to increase with the absolute level of noise experienced at a receptor. If, for example, the daytime noise level at a dwelling were to change from 40 dB to 45 dB $L_{Aeq,16h}$, the overall effect for the occupants would be less than if the daytime noise level were to increase by the same amount from 60 dB to 65 dB $L_{Aeq,16h}$.

---

[11] Institute of Environmental Management & Assessment. (2014). Guidelines for Environmental Noise Impact Assessment, [online]. Available at: http://programmeofficers.co.uk/Preston/CoreDocuments/LCC393.pdf [Checked 23/04/2019]

[12] Manchester Airport : Second Runway: 15 January 1997 : Decision Letter.

[13] Robin Hood Airport (ex. Finningley) : 3 April 2003 : Decision Letter.

There is no clearly accepted method of how to rate the magnitude of the effect of a change in the absolute air noise level and the associated change in noise level. Some guidance however has been provided in the UK's National Planning Practice Guidance (NPPG)[14] which states:

"In cases where existing noise sensitive locations already experience high noise levels, a development that is expected to cause even a small increase in the overall noise may result in a significant adverse effect occurring even though little or no change in behaviour would be likely to occur."

Table 9 shows how the primary air noise metrics are interpreted into magnitude of effect. This is based on the information presented in this assessment and professional judgement.

[14] Defra. (2014). National Planning Policy Guidance, Planning Practice Guidance, Noise, [Online] Available at: https://www.gov.uk/guidance/noise--2 [Checked 01/03/2019].

Receptor Type	Noise Level	Magnitude of effect				
		Very Low	Low	Medium	High	Very High
Residential, Day (07:00-23:00)	$51 \leq L_{Aeq,16h} < 63$	0-2	2-3	3-6	6-9	>9
	$L_{Aeq,16h} \geq 63$	0-1	1-2	2-4	4-7	>7
Residential, Night (23:00-07:00)	$45 \leq L_{Aeq,8h} < 55$ $45 \leq L_{night} < 55$	0-2	2-3	3-6	6-9	>9
	$L_{Aeq,8h} \geq 55$ $L_{night} \geq 55$	0-1	1-2	2-4	4-7	>7
Residential, 24h	$55 \leq L_{den} < 65$	0-2	2-3	3-6	6-9	>9
	$L_{den} \geq 65$	0-1	1-2	2-4	4-7	>7
Schools	$L_{Aeq,30min} \geq 55$	0-2	2-3	3-6	6-9	>9
Places of worship, Day (07:00-23:00)	$L_{Aeq,16h} \geq 63$	0-1	1-2	2-4	4-7	>7
Places of worship, Night (07:00-23:00)	$L_{Aeq,8h} \geq 55$	0-1	1-2	2-4	4-7	>7
Healthcare facilities, Day (07:00-23:00)	$L_{Aeq,1h} \geq 55$	0-1	1-2	2-4	4-7	>7
Healthcare facilities, Night (07:00-23:00)	$L_{Aeq,1h} \geq 50$	0-1	1-2	2-4	4-7	>7
Quiet areas, Day (07:00-23:00)	$L_{den} \geq 55$	0-1	1-2	2-4	4-7	>7
Quiet areas, Night (07:00-23:00)	$L_{night} \geq 45$	0-1	1-2	2-4	4-7	>7

Table 9: Summary of magnitude of effect – air noise

A potential significant effect (adverse or beneficial) would be considered to arise if in Table 9 the magnitude of the effect was rated as medium or higher. Whether a significant effect then arises would depend on context, such as the number of noise sensitive receptors affected and how often it occurs.

5.0 SAMPLE OF THE NOISE MODELLING, POPULATION AND DEMOGRAPHIC INFORMATION AND EXPOSURE AND EFFECTS INFORMATION

In response to ANCA's request for a sample of the noise modelling, population and demographic information and exposure and effects information, this section presents the baseline aircraft noise exposure which has been determined based on the actual aircraft movements in 2019. Summer day and night and annual L_{den} and L_{night} contours have been produced. The areas of these contours, the number of people and dwellings they contain both including and excluding permitted developments and the number of community buildings within the noise contours has been determined and are presented in this section. All areas have been rounded to 1 decimal place, and all population and dwelling counts have been rounded to the nearest 100.

While these permitted developments do not exist in 2019, dwelling and population counts including permitted developments have been provided to assist in comparison with future scenarios.

5.1 Aircraft Movements

5.1.1 Summer

A summary of the actual aircraft movements in Summer 2019 by the key aircraft types is given below in Table 10.

Aircraft Type	2019 Summer Movements	
	Daytime	Night Time
Airbus A306	77	77
Airbus A319	1,163	119
Airbus A320	13,948	2,688
Airbus A320neo	378	1
Airbus A321	1,888	389
Airbus A321neo	227	55
Airbus A330	2,842	575
Airbus A330neo	0	0
Airbus A350	59	45
ATR 72	4,625	290
BAe 146/Avro RJ	1,484	67
Boeing 737-400	228	144
Boeing 737-700	336	2
Boeing 737-800	21,208	3,917
Boeing 737 MAX	0	0
Boeing 757	924	136
Boeing 767	745	188
Boeing 777	567	279
Boeing 777X	0	0
Boeing 787	1,186	254
Bombardier CS300	306	0
Bombardier Dash 8	792	0
Embraer E190/E195	1,310	119
Embraer E190-E2	4	0
Other	3,866	100
Helicopters (not modelled for noise)	242	6
Military (not modelled for noise)	11	1
Total	**58,416**	**9,452**

Table 10: Summary of 2019 Summer Movements by Key Aircraft Types

5.1.2 Annual

A summary of the actual aircraft movements in the calendar year of 2019 by the key aircraft types is given below in Table 11.

Aircraft Type	2019 Annual Movements	
	Daytime	Night Time
Airbus A306	397	313
Airbus A319	3,219	324
Airbus A320	39,661	5,674
Airbus A320neo	737	11
Airbus A321	4,890	799
Airbus A321neo	362	80
Airbus A330	6,880	1,513
Airbus A330neo	0	0
Airbus A350	184	132
ATR 72	12,972	834
BAe 146/Avro RJ	4,022	169
Boeing 737-400	590	406
Boeing 737-700	984	69
Boeing 737-800	58,740	9,670
Boeing 737 MAX	257	103
Boeing 757	2,353	471
Boeing 767	1,945	498
Boeing 777	1,605	865
Boeing 777X	0	0
Boeing 787	2,207	691
Bombardier CS300	734	0
Bombardier Dash 8	2,249	5
Embraer E190/E195	4,008	243
Embraer E190-E2	4	0
Other	10,490	425
Helicopters (not modelled for noise)	689	21
Military (not modelled for noise)	17	1
Total	**160,196**	**23,317**

Table 11: Summary of 2019 Annual Movements by Key Aircraft Types

5.2 Noise Contour Results

5.2.1 Summer Day

The areas of the 2019 summer day contours and the numbers of dwellings and people they contain including and excluding permitted developments are shown in Table 12. The number of community buildings withing the contours are shown in Table 13.

2019 Summer Day Contour					
Contour Value, $L_{Aeq,16h}$	Area, km^2	Excluding Permitted Developments		Including Permitted Developments	
		Dwellings	Population	Dwellings	Population
≥ 51 dB	114.3	17,800	53,300	24,900	75,000
≥ 54 dB	69.9	8,200	24,600	13,400	40,500
≥ 57 dB	39.8	3,100	9,700	6,700	20,900
≥ 60 dB	21.3	700	2,200	2,700	8,400
≥ 63 dB	11.4	100	300	100	300
≥ 66 dB	6.1	100	100	100	100
≥ 69 dB	3.3	0	0	0	0
≥ 72 dB	1.9	0	0	0	0

Table 12: Areas, dwelling and population counts - 2019 Summer Day contours

2019 Summer Day Contour			
Contour Value, $L_{Aeq,16h}$	Education Facilities	Healthcare Facilities	Places of Worship
≥ 51 dB	16	2	6
≥ 54 dB	8	2	5
≥ 57 dB	2	1	3
≥ 60 dB	1	1	2
≥ 63 dB	1	0	0
≥ 66 dB	0	0	0
≥ 69 dB	0	0	0
≥ 72 dB	0	0	0

Table 13: Community Buildings - 2019 Summer Day contours

5.2.2 Summer Night

The areas of the 2019 summer night contours and the numbers of dwellings and people they contain including and excluding permitted developments are shown in Table 14. The number of community buildings withing the contours are shown in Table 15.

2019 Summer Night Contour					
Contour Value, $L_{Aeq,8h}$	Area, km^2	Excluding Permitted Developments		Including Permitted Developments	
		Dwellings	Population	Dwellings	Population
≥ 45 dB	140.1	28,100	86,000	35,500	108,600
≥ 48 dB	84.8	9,500	28,300	15,500	46,800
≥ 51 dB	50.8	3,900	12,300	7,900	24,800
≥ 54 dB	27.8	1,200	3,200	4,500	13,800
≥ 57 dB	14.4	200	600	200	800
≥ 60 dB	7.6	100	200	100	200
≥ 63 dB	4.1	0	0	0	0
≥ 66 dB	2.3	0	0	0	0
≥ 69 dB	1.3	0	0	0	0
≥ 72 dB	0.8	0	0	0	0

Table 14: Areas, dwelling and population counts - 2019 (Current) Summer Night contours

2019 Summer Night Contour			
Contour Value, $L_{Aeq,8h}$	Education Facilities	Healthcare Facilities	Places of Worship
≥ 45 dB	20	3	10
≥ 48 dB	9	2	6
≥ 51 dB	4	1	3
≥ 54 dB	2	1	2
≥ 57 dB	1	1	1
≥ 60 dB	0	0	0
≥ 63 dB	0	0	0
≥ 66 dB	0	0	0
≥ 69 dB	0	0	0

Table 15: Community Buildings - 2019 Summer Night contours

5.2.3 Annual L_{den}

The areas of the 2019 annual L_{den} contours and the numbers of dwellings and people they contain including and excluding permitted developments are shown in Table 16. The number of community buildings withing the contours are shown in Table 17.

2019 Annual L_{den} Contour					
Contour Value, L_{den}	Area, km^2	Excluding Permitted Developments		Including Permitted Developments	
		Dwellings	Population	Dwellings	Population
≥ 45 dB	745.7	304,600	847,100	316,200	883,600
≥ 50 dB	218.7	119,900	339,700	130,800	374,000
≥ 55 dB	88.3	26,000	73,700	33,400	96,300
≥ 60 dB	35.6	6,500	17,600	11,300	32,500
≥ 65 dB	12.2	1,100	2,700	3,900	11,800
≥ 70 dB	4.4	0	0	0	0
≥ 75 dB	1.7	0	0	0	0

Table 16: Areas, dwelling and population counts – 2019 Annual L_{den} contours

2019 Annual L_{den} Contour			
Contour Value, L_{den}	Education Facilities	Healthcare Facilities	Places of Worship
≥ 45 dB	510	57	215
≥ 50 dB	179	11	65
≥ 55 dB	25	3	15
≥ 60 dB	6	2	4
≥ 65 dB	1	1	2
≥ 70 dB	0	0	0
≥ 75 dB	0	0	0

Table 17: Community Buildings - 2019 Annual L_{den} contours

5.2.4 Annual L_{night}

The areas of the 2019 annual L_{night} contours and the numbers of dwellings and people they contain including and excluding permitted developments are shown in Table 18. The number of community buildings withing the contours are shown in Table 19.

2019 Annual L_{night} Contour					
Contour Value, L_{night}	Area, km²	Excluding Permitted Developments		Including Permitted Developments	
		Dwellings	Population	Dwellings	Population
≥ 45 dB	122.2	11,900	33,800	19,100	55,900
≥ 50 dB	52.3	3,500	10,000	7,500	22,600
≥ 55 dB	18.6	500	1,300	1,300	3,900
≥ 60 dB	6.4	0	0	0	0
≥ 65 dB	2.5	0	0	0	0
≥ 70 dB	1.0	0	0	0	0

Table 18: Areas, dwelling and population counts - 2019 Annual L_{night} contours

2019 Annual L_{night} Contour			
Contour Value, L_{night}	Education Facilities	Healthcare Facilities	Places of Worship
≥ 45 dB	15	2	7
≥ 50 dB	3	1	3
≥ 55 dB	1	1	2
≥ 60 dB	0	0	0
≥ 65 dB	0	0	0
≥ 70 dB	0	0	0

Table 19: Community Buildings - 2019 Annual L_{night} contours

6.0 SUMMARY

As requested by ANCA, the methodology that will be used for predicting aircraft noise levels using the Aviation Environmental Design Tool, in relation to Dublin Airport's application to increase its current annual passenger limit, has been described.

Further, the details of the methodology that will be used to derive population and dwelling statistics have also been provided.

The methodology that will be used for the assessment of any noise effects arising from the application has been set out, with full details of its derivation and relevant legislation, policy, technical guidelines provided in Appendix 2.

Finally, a sample of the noise modelling, population and demographic information and exposure and effects information has been provided in the form of the current aircraft noise exposure, which has been determined based on the actual aircraft movements in 2019. The data provided includes aircraft movements, contour areas, and the numbers of dwellings, people and community buildings within them.

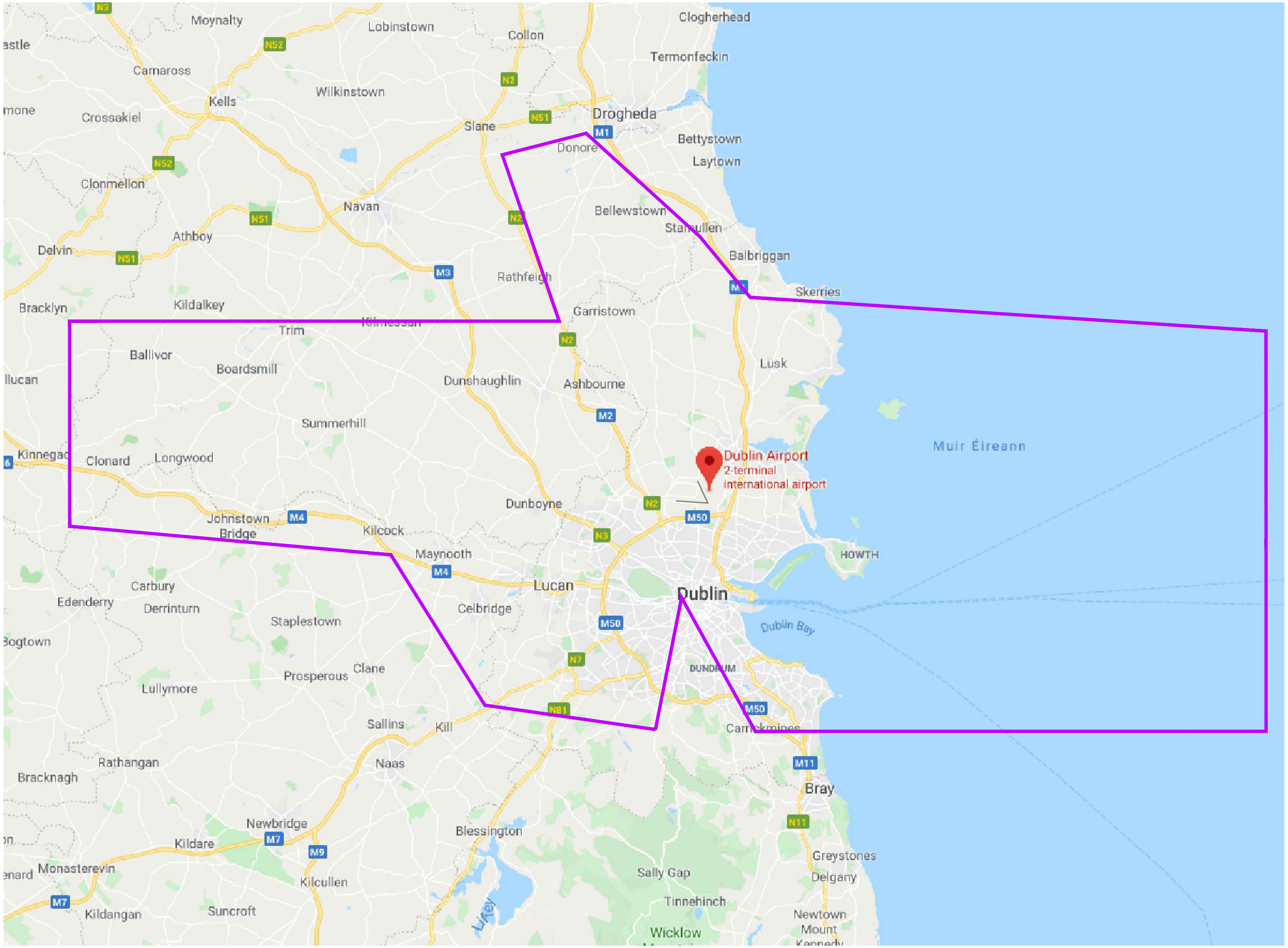
As such it is considered that this report reasonably responds to all items listed in ANCA's request dated 19th February 2020.

Duncan Rogers	**David Charles**
for Bickerdike Allen Partners LLP	**Partner**

Map data ©2019 Google.

LEGEND:

Air Noise Study Area



Rev	Date	Description	Initials

REVISIONS

Bickerdike Allen Partners
Architecture
Acoustics
Technology

121 Salusbury Road, London, NW6 6RG
Email: mail@bickerdikeallen.com
www.bickerdikeallen.com
T: 0207 625 4411
F: 0207 625 0250

Dublin Airport
Change to Permitted Operations

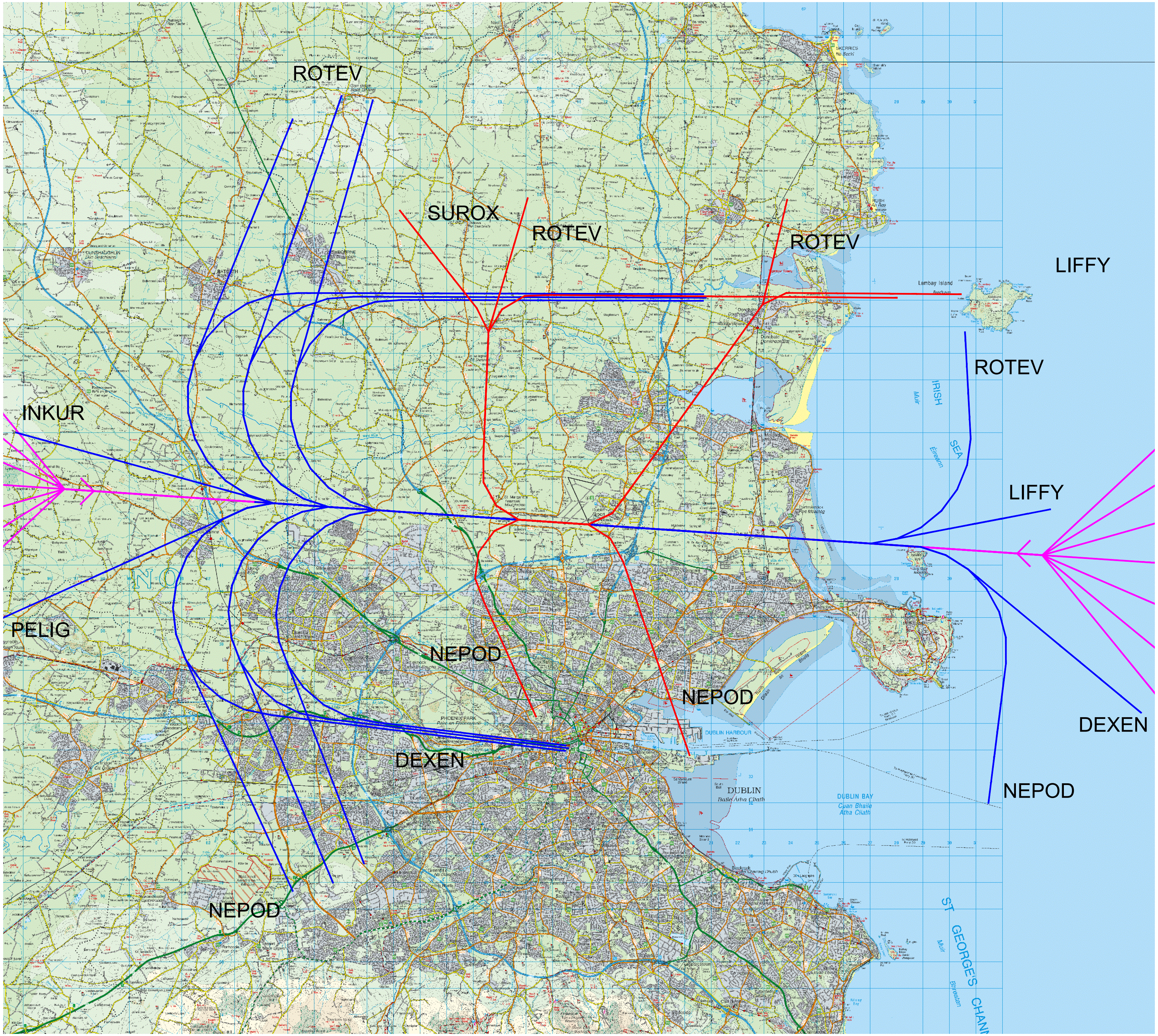
Air Noise Study Area

DRAWN: NW　　CHECKED: DC

DATE: November 2019　　SCALE: 1:500000@A4

FIGURE No:

A11267_12_DR002_2.0



LEGEND:

- Category A&B Aircraft Departure Route Centrelines
- Category C&D Aircraft Departure Route Centrelines
- Arrival Routes

Rev	Date	Description	Initials

REVISIONS

Bickerdike Allen Partners
Architecture Acoustics Technology

121 Salusbury Road, London, NW6 6RG
Email: mail@bickerdikeallen.com
www.bickerdikeallen.com
T: 0207 625 4411
F: 0207 625 0250

Dublin Airport
Change to Permitted Operations

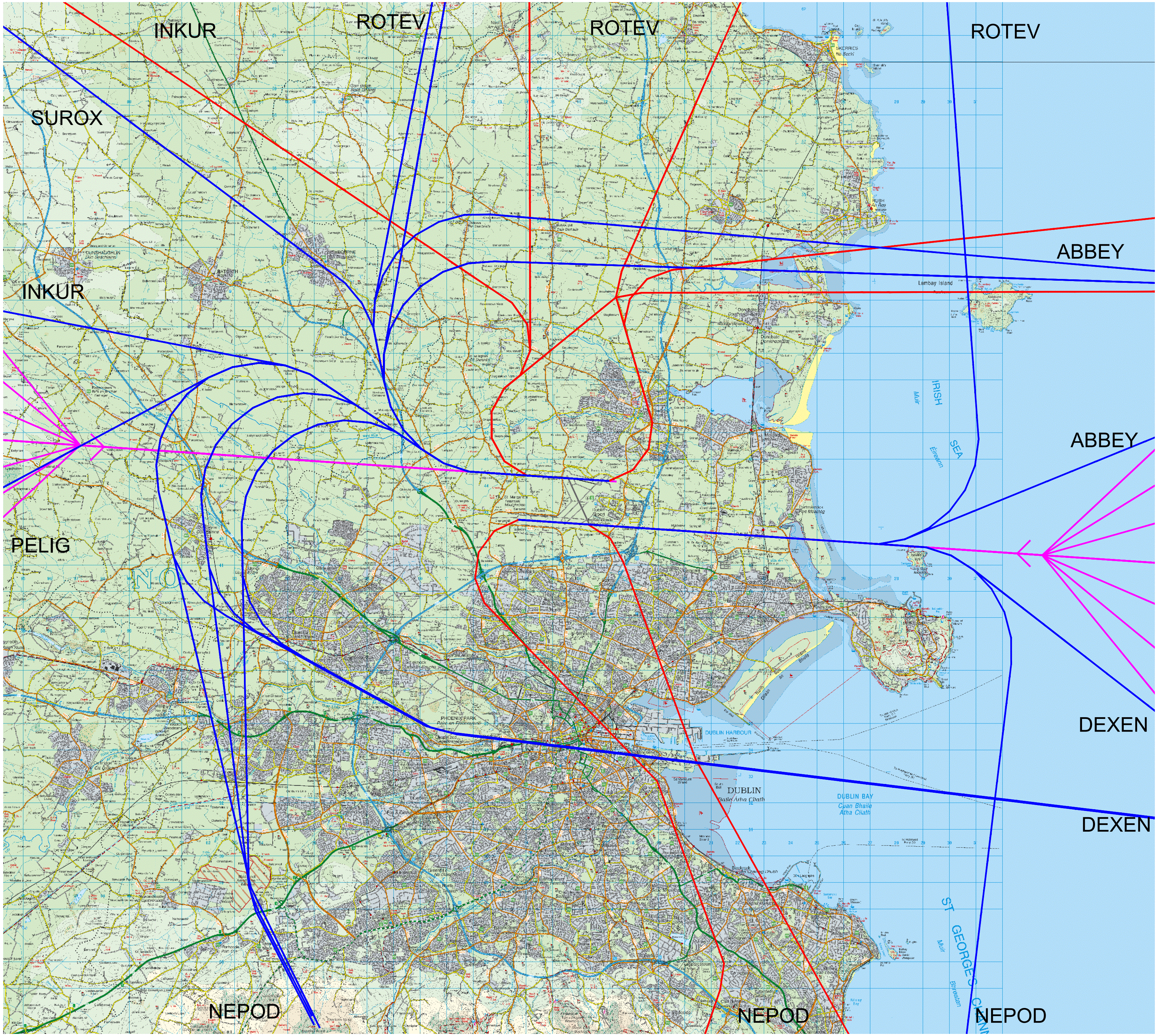
Main Runway Modelled Routes
Current

DRAWN: NW
CHECKED: DC

DATE: November 2019
SCALE: 1:200000@A4

FIGURE No:

A11267_01_DR033_2.0



LEGEND:

Category A&B Aircraft Departure Route Centrelines

Category C&D Aircraft Departure Route Centrelines

Arrival Routes

Rev	Date	Description	Initials

REVISIONS

Bickerdike Allen Partners
Architecture
Acoustics
Technology

121 Salusbury Road, London, NW6 6RG
Email: mail@bickerdikeallen.com
www.bickerdikeallen.com
T: 0207 625 4411
F: 0207 625 0250

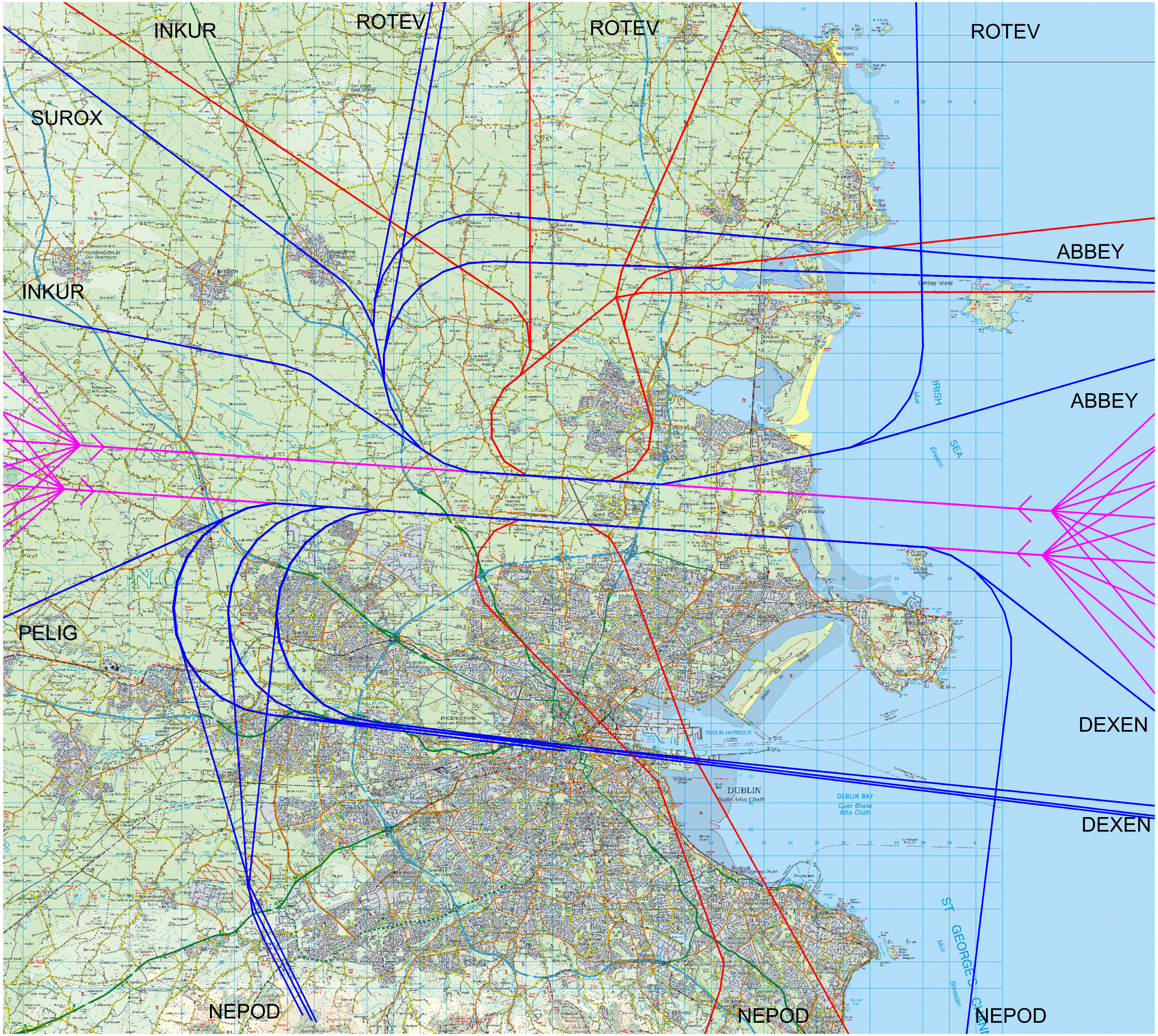
Dublin Airport
Change to Permitted Operations

Main Runway Modelled Routes
Future Segregated Mode

DRAWN: NW
CHECKED: DC

DATE: November 2019
SCALE: 1:200000@A4

FIGURE No:
A11267_01_DR034_2.0



LEGEND:

- Category A&B Aircraft Departure Route Centrelines
- Category C&D Aircraft Departure Route Centrelines
- Arrival Routes

Rev	Date	Description	Initials

REVISIONS

Bickerdike Allen Partners
Architecture
Acoustics
Technology

121 Salusbury Road, London, NW6 6RG
Email: mail@bickerdikeallen.com
www.bickerdikeallen.com
T: 0207 625 4411
F: 0207 625 0250

Dublin Airport
Change to Permitted Operations

Main Runway Modelled Routes
Future Mixed Mode

DRAWN: NW CHECKED: DC

DATE: November 2019 SCALE: 1:200000@A4

FIGURE No: A11267_01_DR035_2.0

APPENDIX 1

GLOSSARY OF ACOUSTIC AND AVIATION TERMINOLOGY

Sound

This is a physical vibration in the air, propagating away from a source, whether heard or not.

The Decibel, dB

The unit used to describe the magnitude of sound is the decibel (dB) and the quantity measured is the sound pressure level. The decibel scale is logarithmic and it ascribes equal values to proportional changes in sound pressure, which is a characteristic of the ear. Use of a logarithmic scale has the added advantage that it compresses the very wide range of sound pressures to which the ear may typically be exposed to a more manageable range of numbers. The threshold of hearing occurs at approximately 0 dB (which corresponds to a reference sound pressure of 2×10^{-5} Pascals) and the threshold of pain is around 120 dB.

The sound energy radiated by a source can also be expressed in decibels. The sound power is a measure of the total sound energy radiated by a source per second, in watts. The sound power level, L_w is expressed in decibels, referenced to 10^{-12} watts.

Frequency, Hz

Frequency is analogous to musical pitch. It depends upon the rate of vibration of the air molecules that transmit the sound and is measure as the number of cycles per second or Hertz (Hz). The human ear is sensitive to sound in the range 20 Hz to 20,000 Hz (20 kHz). For acoustic engineering purposes, the frequency range is normally divided up into discrete bands. The most commonly used bands are octave bands, in which the upper limiting frequency for any band is twice the lower limiting frequency, and one-third octave bands, in which each octave band is divided into three. The bands are described by their centre frequency value and the ranges which are typically used for building acoustics purposes are 63 Hz to 4 kHz (octave bands) and 100 Hz to 3150 Hz (one-third octave bands).

A-weighting

The sensitivity of the ear is frequency dependent. Sound level meters are fitted with a weighting network which approximates to this response and allows sound levels to be expressed as an overall single figure value, in dB(A).

Sound Transmission in the Open Air

Most sources of sound can be characterised as a single point in space. The sound energy radiated is proportional to the surface area of a sphere centred on the point. The area of a sphere is proportional to the square of the radius, so the sound energy is inversely proportional to the square of the radius. This is the inverse square law. In decibel terms, every time the distance from a point source is doubled, the sound pressure level is reduced by 6 dB.

Road traffic noise is a notable exception to this rule, as it approximates to a line source, which is represented by the line of the road. The sound energy radiated is inversely proportional to the area of a cylinder centred on the line. In decibel terms, every time the distance from a line source is doubled, the sound pressure level is reduced by 3 dB.

Factors Affecting Sound Transmission in the Open Air

Reflection

When sound waves encounter a hard surface, such as concrete, brickwork, glass, timber or plasterboard, it is reflected from it. As a result, the sound pressure level measured immediately in front of a building façade is approximately 3 dB higher than it would be in the absence of the façade.

Screening and Diffraction

If a solid screen is introduced between a source and receiver, interrupting the sound path, a reduction in sound level is experienced. This reduction is limited, however, by diffraction of the sound energy at the edges of the screen. Screens can provide valuable noise attenuation, however. For example, a timber boarded fence built next to a motorway can reduce noise levels on the land beyond, typically by around 10 dB(A). The best results are obtained when a screen is situated close to the source or close to the receiver.

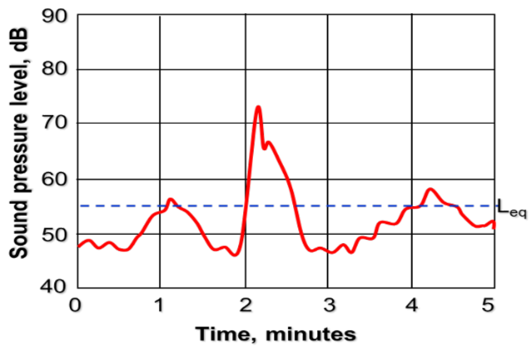
Meteorological Effects

Temperature and wind gradients affect noise transmission, especially over large distances. The wind effects range from increasing the level by typically 2 dB downwind, to reducing it by typically 10 dB upwind – or even more in extreme conditions. Temperature and wind gradients are variable and difficult to predict.

Environmental Noise Descriptors

Where noise levels vary with time, it is necessary to express the results of a measurement over a period of time in statistical terms. Some commonly used descriptors follow.

Statistical Term	Description
$L_{Aeq,T}$	The most widely applicable unit is the equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$). It is an energy average and is defined as the level of a notional sound which (over a defined period of time, T) would deliver the same A-weighted sound energy as the actual fluctuating sound. This is shown in the graph below:



L_{den} The day-evening-night noise indicator in decibels (dB) defined by the following formula:

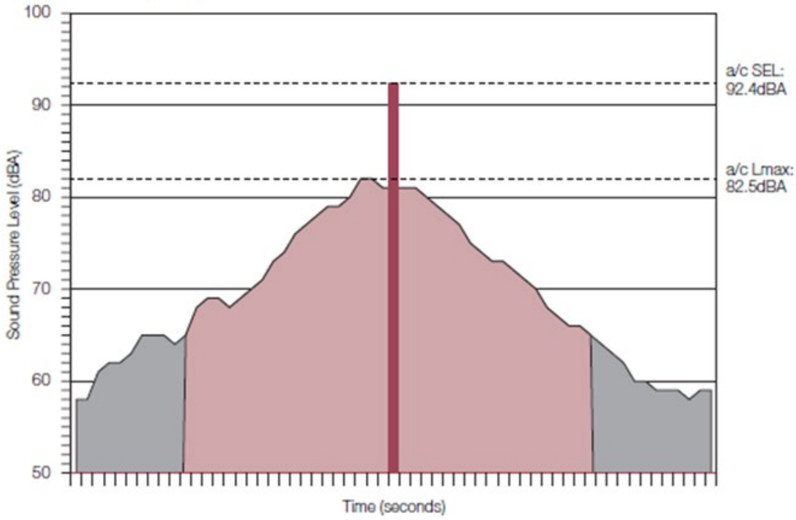
$$L_{den} = 10 \times \log\left(\frac{12 \times 10^{\frac{L_{day}}{10}} + 4 \times 10^{\frac{L_{evening}+5}{10}} + 8 \times 10^{\frac{L_{night}+10}{10}}}{24}\right)$$

in which:

L_{day} is the A-weighted long-term average sound level for the daytime period (07:00-19:00)
$L_{evening}$ is the A-weighted long-term average sound for the evening period (19:00-23:00)
L_{night} is the A-weighted long-term average sound level for the night time period (23:00-07:00)

Sound Exposure Level (SEL)	An SEL is a measure the total noise from an aircraft movement. The SEL noise level for an aircraft movement is the sum of all the noise energy for the event expressed as an average noise level for 1 second. This is shown in the graph below:

Figure 3.1: Aircraft time history, showing maximum level L_{Amax} and associated Sound Exposure Level (SEL)[41]



Source: CAA data

Aviation Terms

Air Transport Movements

Air transport movements are landings or take-offs of aircraft engaged on the transport of passengers, cargo or mail on commercial terms. All scheduled movements, including those operated empty, loaded charter and air taxi movements are included.

NPR

Noise preferential route – departure flight ground tracks to be followed by aircraft to minimise noise disturbance on the surrounding population.

Dispersion

Due to the effect of the wind, aircraft speed, and pilot choice differing aircraft tracks about the nominal track are flown; this is known as dispersion around a nominal track.

Start of Roll

The position on a runway where aircraft commence their take-off runs.

Threshold

The beginning of that portion of the runway usable for landing.

Nominal Tracks

Using recognised international design techniques, tracks across the ground can be delineated for departing and arriving aircraft. These tracks are nominal because they can be influenced by the wind, ATC instructions, the accuracy of navigational systems and the flight characteristics of individual aircraft. In UK it is usual to permit a 1500m swathe to be established about the nominal track for the purposes of assessing whether an aircraft has stayed on track.

APPENDIX 2

RELEVANT LEGISLATION, POLICY, TECHNICAL GUIDELINES AND ASSESSMENT CRITERIA

This appendix considers the legislation, policy and technical guidelines relevant to the assessment of air noise, defined as the operational noise associated with flights arriving and departure from Dublin Airport. The appendix then sets out the criteria that will be used as part of the assessment.

INTERNATIONAL REGULATION

The International Civil Aviation Organisation (ICAO) is the inter-governmental body that oversees the worldwide civil aviation industry. ICAO has adopted a set of principles and guidance[15], constituting the 'balanced approach' to aircraft noise management, which encourages ICAO member states to address the following points:

- Mitigate aviation noise through selection at a local level the optimum combination of four key measures;
    - Reducing noise at source (from use of quieter aircraft);
    - Making best use of land (plan and manage the land surrounding airports);
    - Introducing operational noise abatement procedures (by using specific runways, routes or procedures);
    - Imposing noise-related operating restrictions (such as a night time operating ban or phasing out of noisier aircraft);
- Select the most cost-effective range of measures; and
- Not introduce noise-related operating restrictions unless the authority is in a position, on the basis of studies and consultations, to determine whether a noise problem exists and having determined that an operating restriction is a cost-effective way of dealing with the problem.

ICAO has also set a number of standards for aircraft noise certification which are contained in Volume 1 of Annex 16 to the *Convention on International Civil Aviation*[16]. This document sets maximum acceptable noise levels for different aircraft during take-off and landing, categorised for subsonic jet aeroplanes as Chapter 2, 3, 4 and 14.

Chapter 2 aircraft have been prevented from operating within the EU since 2002, unless they are granted specific exemption, and therefore the vast majority of aircraft fall within Chapter 3, 4 and 14 parameters. These aircraft are quieter than Chapter 2 aircraft.

---

[15] ICAO (2006) Doc 9829 AN/451, Guidance on the Balanced Approach to Aircraft Noise Management 2nd Edition. ICAO.
[16] ICAO (2017), Annex 16 to the Convention on International Civil Aviation, Volume 1 8th Edition. ICAO.

Chapter 4 standards have applied to all new aircraft manufactured since 2006. These aircraft must meet a standard of being cumulatively 10 dB quieter than Chapter 3 aircraft.

Chapter 14 was adopted by the ICAO in 2014. This represents an increase in stringency of 7 dB compared with Chapter 4 and applies to new aircraft submitted for certification after 31st December 2017.

EUROPEAN REGULATION

EU Regulation 598-2014

The European Commission introduced *EU Regulation 598-2014*[17] in 2016 to account for developments in the aviation world. This repeals 2002/30/EC[18] which set out procedures and rules for the introduction of noise related operating restrictions to the busiest of the European airports. This previous regime for managing airport noise placed the responsibility with the airport operator. The entry into force in 2016 of *EU Regulation 598/2014* represents a shift in responsibility from the airport operator to a separate, independent statutory entity or competent authority to oversee the delivery of the new, more prescriptive approach to airport noise management. Fingal County Council is considered to be best placed to perform this regulatory role in Ireland.

There are seven key elements of the new regulatory regime which are:

- Designation of a separate, independent statutory entity as the Competent Authority;
- Appropriate collaborative working arrangements;
- Robust consultation requirements;
- Adhere to the ICAO Balanced Approach;
- Compliance with Environmental Impact Assessment (EIA), Habitats & Birds, and the Environmental Noise Directives;
- Establishment of an appropriate, robust appeal mechanism, and
- Ongoing monitoring and enforcement activities.

---

[17] European Commission (2014). Regulation (EU) No 598/2014 of the European Parliament and of the Council of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC, [online]. Available at: https://publications.europa.eu/en/publication-detail/-/publication/b6947ca7-f1f6-11e3-8cd4-01aa75ed71a1/language-en [Checked 21/08/2018].

[18] European Commission (2002), Directive 2002/30/EC Directive of the European Parliament and the Council of 26th March 2002 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports [online]. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0030&from=EN [Checked 21/11/2018].

These new arrangements have been given statutory effect by way of a Statutory Instrument, the Aircraft Noise (Dublin Airport) Regulation Act 2019.

Environmental Noise Directive 2002/49/EC 2002

The *Environmental Noise Directive* (END)[19] concerning the assessment and management of environmental noise from transport, came into effect in June 2002. Its aim was to define a common approach across the European Union with the intention of avoiding, preventing or reducing on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise. This involves:

- Informing the public about environmental noise and its effects;
- Preparation of strategic noise maps for large urban areas ('agglomerations'), major roads, major railways and major airports as defined in the END; and
- Preparation of action plans based on the results of the noise mapping exercise.

This process is carried out every 5 years. The strategic noise maps were last produced in 2017 (based on 2016 activity) and are presented in the Dublin Airport's Noise Action Plan[20] (2019-2023).

IRISH REGULATION AND POLICY

S.I. No. 140/2006 - Environmental Noise Regulations 2006

The Environmental Noise Regulations 2006 are a transposition of EC/2002/49/EC and came into force on 3rd April 2006.

A "major airport" (having more than 50,000 movements per annum) is required to produce noise maps on a rolling (5 year) basis. The maps are used in "developing co-ordinated and cost-effective action plans to reduce noise" and are presented in terms of L_{den} and L_{night} indices. Regulations also require relevant airports to undertake an action planning process.

Dublin Airport is the only airport in Ireland that qualifies as a "major airport".

[19] European Commission (2002). Directive 2002/49/EC Directive of the European Parliament and of the Council of 25th June 2002 relating to the assessment and management of environmental noise, [online]. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0049&from=EN [Checked 21/08/2018].
[20] Noise Action Plan for Dublin Airport 2019 – 2023, Final, Published 19th December 2019

Dublin Airport Noise Action Plan 2019-2023

This document[20] was consulted on in late 2018 and published in 2019. It sets out the results of the latest strategic noise mapping exercise for Dublin Airport and sets out the noise management strategy.

A number of operational and management mitigation measures are currently in place at Dublin Airport which are set out in the Action Plan and summarised below:

- Preferential runway usage to minimise aircraft overflying noise-sensitive areas
- Noise preferential routes and environmental noise corridors are used to minimise disruption by routing aircraft away from built up areas, where possible
- Continuous Descent Approach (CDA) is utilised which minimises noise from arriving aircraft
- ICAO Noise Abatement Departure Procedures (NADP) are followed which minimise noise from departing aircraft
- Reverse thrust, sometimes used to aid deceleration of landing aircraft on the runway, should not be used at night unless required for safety reasons
- A Noise and Flight Track Monitoring System (NFTMS) is in place which monitors the noise level of aircraft and checks that they are following the prescribed routes. A report is prepared twice a year detailing the monitoring results.
- A Home Sound Insulation Programme (HSIP) is available for residential dwellings located within the daytime 2016 63 dB $L_{Aeq,16h}$ contour. This voluntary scheme provides for the supply and insulation of a full noise insulation package such as glazing and loft insulation.

A National Aviation Policy for Ireland[21], 2015

This document states that Ireland will implement a “Balance Approach” to noise management at Irish airports in accordance with EU Regulation 598. It shares the responsibility for aircraft noise reduction between Dublin Airport, the Irish Aviation Authority (IAA), and the airlines.

The policy proposes to promote Dublin Airport as a secondary hub to open up new routes to the Unites States and compete directly with UK and European airports.

---

[21] Department for Transport, Tourism and Sport (2015). A National Aviation Policy For Ireland, [online]. Available at: http://www.dttas.ie/sites/default/files/publications/aviation/english/national-aviation-policy-ireland/national-aviation-policy-ireland.pdf [Checked 19/03/2019]

Project Ireland 2040 – National Planning Framework (NPF)[22]

This is a high-level strategic plan to guide development and investment over the coming years. The framework (2018-2027) supports the implementation of the National Aviation Policy. It has ten National Strategic Outcomes, including 'High-Quality International Connectivity' which specifies the development of the approved additional runway and terminal facilities at Dublin Airport.

It also has a stated objective of developing national planning guidance relating to environmental noise.

LOCAL REGULATION AND POLICY

Regional Spatial & Economic Strategy for the Eastern and Midland Region[23] 2019-2031

The Regional Spatial & Economic Strategy (RSES) is a strategic plan which will support the implementation of national government policies such as the NPF and also set out the framework for local economic development and spatial planning. These replace the Regional Planning Guidelines.

The RSES states the following in relation to the noise effect of Dublin Airport:

Section 8.5 International Conectivity:

"Consideration of continued growth of the Airport has to include the environmental considerations, airplanes are a significant emitter of Green House Gas and noise both of which have to be mitigated."

Policy Objective RPO 8.17:

"Support the National Aviation Policy for Ireland and the growth of movements and passengers at Dublin Airport to include its status as a secondary hub airport. In particular, support the provision of a second runway, improved terminal facilities and other infrastructure."

Policy Objective RPO 8.19:

"Spatial planning policies in the vicinity of the airport shall protect the operation of Dublin Airport in respect to its growth and the safe navigation of aircraft from non-compatible land

---

[22] Government of Ireland (2018). Project Ireland 2040 National Planning Framework, [online]. Available at: https://www.gov.ie/en/campaigns/09022006-project-ireland-2040/#documents [Checked 19/03/2019].
[23] Eastern and Midland Regional Assembly. Regional Spatial & Economic Strategy, [online]. Available at: https://emra.ie/final-rses/ [Checked 26/03/2019].

uses. Policies shall recognise and reflect the airport noise zones associated with Dublin Airport. Within the Inner Airport Noise Zone, provision of new residential and/or other noise sensitive development shall be actively resisted. Within the Outer Noise Zone, provision of new residential and/or other noise sensitive development shall be strictly controlled and require appropriate levels of noise insulation in all cases."

Dublin City Development plan 2016-2022 Written Statement – Volume 1[24]

This document makes reference to the planning noise zones around Dublin Airport in stating:

"There are DCC lands located within Dublin Airport's Outer Noise Zone. The Dublin Airport Authority (DAA), (www.dublinairport.com) have produced Noise Contour Maps detailing these areas. These contours relate to the protection/prevention of noise sensitive uses within the noise zones."

Fingal Development Plan 2017-2023[25]

This document is the current development plan for Fingal.

With regard to Dublin Airport, the 2017-2023 Plan states in Section 6.7:

"*Dublin Airport is of strategic importance to national social and economic policy. Strong growth is forecast in air services and passenger traffic within the lifetime of the Development Plan, a significant proportion of which will be catered for at Dublin Airport.*

The development Plan was varied on the 9th December 2019 to give effect the to new noise zones developed as part of the preparation of teh Dublin Airport LAP 2020, the provision of specific noise related policy concerning noise from aircraft road and rail and the removal of the Red Approach Area at the end of the airport's runways.

[24] Dublin City Council (2016). Dublin City Development Plan 2016-22 Written Statement, [online]. Available at: https://dublincitydevelopmentplan.ie/downloads/Written%20Statement%20Volume%201.pdf [Checked 19/03/2019].
[25] Fingal County Council. (2017). Fingal Development Plan 2017 – 2023. [online]. Available at: http://www.fingal.ie/planning-and-buildings/development-plans-and-consultations/fingaldevelopmentplan2017-2023/ [Checked 19/02/2018].

In respect of Noise, the new variation provides for 4 noise zones at the airport, Zones A-D. The plan notes that:

'Three noise zones are shown in the Development Plan maps, Zones B and C within which the Council will continue to restrict inappropriate development, and Zone A within which new provisions for residential development and other noise sensitive uses will be actively resisted. An additional assessment zone, Zone D is also proposed to identify any larger residential developments in the vicinity of the flight paths serving the Airport in order to promote appropriate land use and to identify encroachment.

Table 7.2 presents the four aircraft noise zones and the associated objective of each zone along with an indication of the potential noise exposure from operations at Dublin Airport. The zones are based on potential noise exposure levels due to the airport using either the new northern or existing southern runway for arrivals or departures.

The noise zoning system has been developed with the overarching objective to balance the potential impact of aircraft noise from the Airport on both external and internal noise amenity.This allows larger development which may be brought forward in the vicinity of the Airport's flight paths to be identified and considered as part of the planning process. The focus of the noise zones is to ensure compatibility ofresidential development and ensuring compatibility with pertinent standards and guidance in relation to planning and noise, namely:

- *NationalPlanning Framework 2040, DHPLG, February 2018;*
- *ProPG: Planning & Noise –New ResidentialDevelopment, May 2017;*
- *British Standard BS8233:2014 'Guidance on sound insulation and noise reduction for buildings'; and*
- *ICAO guidance on Land-use Planning and Management in Annex 16, Volume I, Part IV and in the ICAO Doc 9184, Airport Planning Manual, Part 2 —Land Use and Environmental Control.*

Where development includes other non-residential noise sensitive receptors, alternative design guidance will need to be considered by the developer. Non-residential buildings and uses which are viewed as being noise sensitive within the functional area of FCC include hospitals, residential care facilities and schools.'

Table 7.2 form the Variation to the Development Plan is as follows:

Table 7.2 Aircraft Noise Zones		
Zone	**Indication of Potential Noise Exposure during Airport Operations**	**Objective**
D	≥ 50 and < 54 dB $L_{Aeq,\ 16hr}$ and ≥ 40 and < 48 dB L_{night}	**To identify noise sensitive developments which could potentially be affected by aircraft noise and to identify any larger residential developments in the vicinity of the flight paths serving the Airport in order to promote appropriate land use andto identify encroachment.** *All noise sensitive development within this zone is likely to be acceptable from a noise perspective. An associated application would not normally be refused on noise grounds, however where the development is residential-led and comprises non-residential noise sensitive uses, or comprises 50 residential units or more, it may be necessary for the applicant to demonstrate that a good acoustic design has been followed.* *Applicants are **advised** to seek expert advice.*
C	≥ 54 and < 63 dB $L_{Aeq,\ 16hr}$ and ≥ 48 and < 55 dB L_{night}	**To manage noise sensitive development in areas where aircraft noise may give rise to annoyance and sleep disturbance, and to ensure, where appropriate, noise insulation is incorporated within the development** *Noise sensitive development in this zone is less suitable from a noise perspective than in Zone D. A noise assessment **must** be undertaken in order to demonstrate good acoustic design has been followed.* *The noise assessment must demonstrate that relevant internal noise guidelines will be met. This **may** require noise insulation measures.* *An external amenity area noise assessment **must** be undertaken where external amenity space is intrinsic to the development's design. This assessment should make specific consideration of the acoustic environment within those spaces as required so that they can be enjoyed as intended. Ideally, noise levels in external amenity spaces should be designed to achieve the lowest practicable noise levels.* *Applicants are **strongly advised** to seek expert advice.*

B	≥ 54 and < 63 dB $L_{Aeq, 16hr}$ and ≥ 55 dB L_{night}	**To manage noise sensitive development in areas where aircraft noise may give rise to annoyance and sleep disturbance, and to ensure noise insulation is incorporated within the development.** *Noise sensitive development in this zone is less suitable from a noise perspective than in Zone C. A noise assessment* ***must*** *be undertaken in order to demonstrate good acoustic design has been followed.* *Appropriate well-designed noise insulation measures* ***must*** *be incorporated into the development in order to meet relevant internal noise guidelines.* *An external amenity area noise assessment* ***must*** *be undertaken where external amenity space is intrinsic to the developments design. This assessment should make specific consideration of the acoustic environment within those spaces as required so that they can be enjoyed as intended. Ideally, noise levels in external amenity spaces should be designed to achieve the lowest practicable noise levels.* *Applicants* ***must*** *seek expert advice.*
A	≥ 63 dB $L_{Aeq, 16hr}$ and/or ≥ 55 dB L_{night}	**To resist new provision for residential development and other noise sensitive uses.** *All noise sensitive developments within this zone may potentially be exposed to high levels of aircraft noise, which may be harmful to health or otherwise unacceptable. The provision of new noise sensitive developments will be resisted.*

Notes:

- ‘Good Acoustic Design’ means following the principles of assessment and design as described in ProPG: Planning & Noise – New Residential Development, May 2017;
- Internal and External Amenity and the design of noise insulation measures should follow the guidance provided in British Standard BS8233:2014 ‘Guidance on sound insulation and noise reduction for buildings’

Dublin Airport Local Area Plan, 2020[26]

The 2020 Local Area Plan (LAP) dedicates an entire Section (section 9.1) to noise. In this section it notes the following:

"The Dublin Airport LAP is a land use plan for the purposes of effective land-use planning and safeguarding the use of the Airport. Noise zones relating to Dublin Airport have been in place for many years to aid land use planning. Since the publication of previous noise zones in 2005, and over the last decade, further evidence has emerged that has updated understanding of how aircraft noise can affect health and quality of life. With the north runway set to become operational in 2022, updated information is available relating to aircraft noise performance and flight paths. For these reasons, it was considered appropriate to update the noise zones for Dublin Airport to allow for more effective land use planning for development within airport noise zones.

The updated noise zones are set out in Fig. 9.1. Dublin Airport Noise Zones and policies relating to development in Noise Zones are set out in Variation No. 1 to the Fingal Development Plan 2017 - 2023."

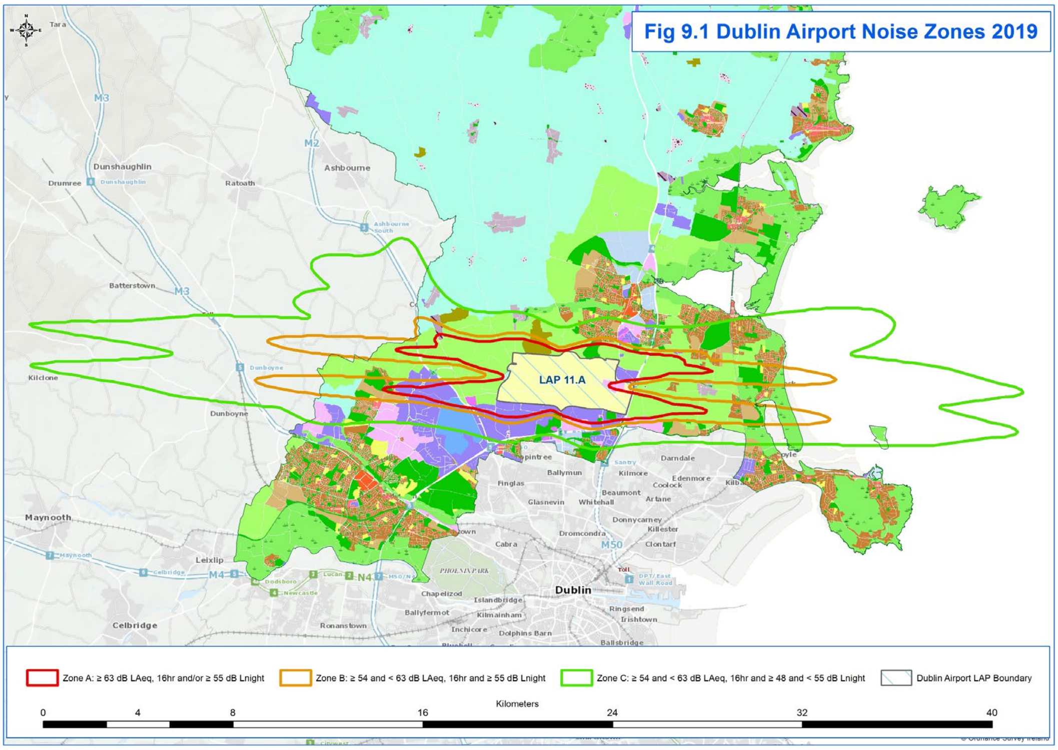


Fig 9.1 Dublin Airport Noise Zones 2019

---

[26] Fingal County Council (2020). Dublin Airport Local Area Plan, [online]. Available at: https://www.fingal.ie/sites/default/files/2020-01/dublin-airport-lap-2020.pdf [Checked 26/03/2020].

RELEVANT UK REGULATION AND POLICY

Relevant UK regulation and policy is set out below. These supplement the internal, national and local regulations and policies set out above and provide consistency with approach taken for past applications at Dublin Airport.

National Planning Policy Framework (NPPF)[27] 2018

The *National Planning Policy Framework* (NPPF) originally published 27th March 2012 and updated in July 2018, sets out the UK Government's planning policies for England and how these are expected to be applied. It is designed to make the planning system less complex and more accessible, to protect the environment and to promote sustainable growth.

The UK Government's current planning policy concerning noise is embodied in the NPPF (and more specifically the *Noise Policy Statement for England* or NPSE[28]). The aim of planning policies and decisions with respect to noise is addressed in paragraph 180 of the NPPF:

"*Planning policies and decisions should also ensure that new development is appropriate for its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development. In doing so they should:*

- *Mitigate and reduce to a minimum potential adverse impacts resulting from noise from new development – and avoid noise from giving rise to significant adverse impacts on health and quality of life; and*
- *Identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason;"*

The above policy refers to "significant adverse impacts" and "other adverse impacts" which are not defined numerically although reference is made to further research being underway in this regard in NPSE[28]. That research has not yet resulted in clarification on numerical levels.

[27] Ministry of Housing, Communities and Local Government (2018). National Planning Policy Framework, [online]. Available at: https://www.gov.uk/government/publications/national-planning-policy-framework--2 [Checked 21/11/2018].

Noise Policy Statement for England (NPSE)[28] 2010

The *Noise Policy Statement for England* (NPSE) provides the framework for noise management decisions to be made that ensure noise levels do not place an unacceptable burden on society.

The stated aims of the *Noise Policy Statement for England* are to:

- Avoid significant adverse impacts on health and quality of life from environmental, neighbour and neighbourhood noise within the context of UK Government policy on sustainable development;
- Mitigate and minimise adverse impacts on health and quality of life from environmental, neighbour and neighbourhood noise within the context of UK Government policy on sustainable development, and
- Where possible, contribute to the improvement of health and quality of life through the effective management and control of environmental, neighbour and neighbourhood noise within the context of UK Government policy on sustainable development.

The NPSE introduces the concepts of NOEL (No Observed Effect Level), LOAEL (Lowest Observed Adverse Effect Level) and SOAEL (Significant Observed Adverse Effect Level). The definition of these is as follows:

- NOEL – No observed effect level. This is the level below which no effect can be detected;
- LOAEL – Lowest observed adverse effect level. This is the level above which adverse effects on health and quality of life can be detected, and
- SOAEL – Significant observed adverse effect level. This is the level above which significant adverse effects on health and quality of life occur.

Further guidance on how planning authorities should take account of the acoustic environment and the mitigation strategies which should be applied in relation to the above terms is provided in the *National Planning Practice Guidance* (NPPG)[29] which was published in March 2014.

---

[28] Defra (2010). Noise Policy Statement for England, [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69533/pb13750-noise-policy.pdf [Checked 10/04/2018].
[29] Defra (2014). National Planning Policy Guidance, Planning Practice Guidance, Noise, [online] Available at: https://www.gov.uk/guidance/noise--2 [Checked 21/08/2018].

The advice is that noise above the SOAEL should be avoided using appropriate mitigation while taking into account the guiding principles of sustainable development.

Where noise is between LOAEL and SOAEL, the advice is to take all reasonable steps to mitigate and minimise adverse effects on health and quality of life while also taking into account the guiding principles of sustainable development. Noise in this category is described as an observed adverse effect which is noticeable and intrusive.

NPSE states that it is not possible to give a single objective noise-based measure that defines a SOAEL that is applicable to all sources of noise for all situations. It acknowledges that the SOAEL is likely to be different for different noise sources, for different receptors and at different times. It also acknowledges that further research is required to increase our understanding of what may constitute a significant adverse impact on health and quality of life from noise. However, it states that not having specific SOAEL values in the NPSE provides the necessary policy flexibility until further evidence and suitable guidance is available.

Where any adverse noise effects are predicted, these are identified and if these cannot be avoided, mitigation measures are recommended to ensure no significant residual effects on health and quality of life arise. This approach is considered consistent with the principal aims of the NPSE. It is important to note that findings against the LOAEL and SOAEL are measures of the effect of noise on health and quality of life, and not environmental impact assessment findings.

As well as assisting with the interpretation of the NPSE, the *Planning Practice Guidance*[29] provides a web-based resource in support of the NPPF. The *Planning Practice Guidance* states (Noise, paragraph 3) that local planning authorities should take account of the acoustic environment and in doing so consider:

"*whether or not a significant adverse effect is occurring or likely to occur,*

whether or not an adverse effect is occurring or likely to occur, and

whether or not a good standard of amenity can be achieved."

The guidance advises on how planning can manage potential noise impacts in new development and provides a series of guidelines that are in line with the NPPF and the *Noise Policy Statement for England*. Paragraph 5 provides guidance on how to recognise when noise could be a concern. It advises that as noise increases beyond the lowest observed level noise it can start to cause small changes in behaviour and attitude, for example, having to turn up the volume on the television or needing to speak more loudly to be heard. It states that where noise could have an adverse effect consideration needs to be given to mitigating and minimising those effects (taking account of the economic and social benefits being derived from the activity causing the noise).

The guidance includes a table that summarises the noise exposure hierarchy based on the likely average response. This is reproduced in Table 20**.**

Perception	Examples of Outcomes	Increasing Effect Level	Action
Not noticeable	No Effect	No Observed Effect	No specific measures required
	Noise can be heard, but does not cause any change in behaviour or attitude. Can slightly affect the acoustic character of the area but not such that there is a perceived change in the quality of life.	No Observed Adverse Effect	No specific measures required
		Lowest Observed Adverse Effect Level	
Noticeable and Intrusive	Noise can be heard and causes small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a perceived change in the quality of life.	Observed Adverse Effect	Mitigate and reduce to a minimum
		Significant Observed Adverse Effect Level	
Noticeable and disruptive	The noise causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.	Significant Observed Adverse Effect	Avoid
Noticeable and very disruptive	Extensive and regular changes in behaviour and/or an inability to mitigate effect of noise leading to psychological stress or physiological effects, e.g. regular sleep deprivation/awakening; loss of appetite, significant, medically definable harm, e.g. auditory and non-auditory	Unaccept-able Adverse Effect	Prevent

Table 20: Noise exposure hierarchy based on the likely average response

The guidance advises that above the significant observed adverse effect level boundary, the planning process should be used to avoid this effect occurring, by use of appropriate mitigation such as by altering the design and layout. Such decisions must be made taking account of the economic and social benefit of the activity causing the noise, but it is undesirable for such exposure to be caused.

At the highest extreme, noise exposure would cause extensive and sustained changes in behaviour without an ability to mitigate the effect of noise. The impacts on health and quality of life are such that regardless of the benefits of the activity causing the noise, this situation should be prevented from occurring.

UK Aviation Policy Framework[30] 2013

The *Aviation Policy Framework* (APF) was published in March 2013 by the Department for Transport (DfT). The APF defines the UK Government's objectives and policies on the impacts of aviation in the UK.

On managing aviation's environmental impacts, and specifically noise, it states in paragraph 3.12 that the UK Government's overall objective on noise is to "*Limit and where possible reduce the number of people in the UK significantly affected by aircraft noise*".

It goes on in paragraph 3.13 to state that "*This is consistent with the Government's Noise Policy, as set out in the Noise Policy Statement for England (NPSE) which aims to avoid significant adverse impact on health and quality of life.*"

Guidance is provided on the noise metric used to rate airborne noise in paragraph 3.13 where it states '*To provide historic continuity, the Government will continue to ensure that noise exposure maps are produced for the noise-designated airports on an annual basis providing results down to a level of 57 dB $L_{Aeq,16hour}$'*.

The noise index is described in a footnote as "*the A-weighted average sound level over the 16 hour period of 07:00-23:00. This is based on an average summer day when producing noise contour maps at the designated airports*."

In paragraph 3.17 the interpretation of the contour is given as "*We will continue to treat the 57 dB $L_{Aeq,16h}$ contour as an average level of day time aircraft noise marking the approximate onset of significant community annoyance. However, this does not mean that all people within this contour will experience significant adverse effects from aircraft noise. Nor does it mean that no-one outside of this contour will consider themselves annoyed by aircraft noise*."

[30] Department for Transport (2013). Aviation Policy Framework. [online]. Available at: https://www.gov.uk/government/publications/aviation-policy-framework [Checked 19/03/2018].

Under the heading "Noise insulation and compensation" the APF states that:

"*The Government continues to expect airport operators to offer households exposed to levels of noise of 69 dB $L_{Aeq,16h}$ or more, assistance with the cost of moving.*

The Government also expects airport operators to offer acoustic insulation to noise sensitive buildings, such as schools and hospitals, exposed to levels of noise of 63 dB $L_{Aeq,16h}$ or more. Where acoustic insulation cannot provide an appropriate or cost-effective solution, alternative mitigation measures should be offered."

With regard to airport development it continues:

"*Where airport operators are considering developments which result in an increase in noise, they should review their compensation schemes to ensure that they offer appropriate compensation to those potentially affected. As a minimum, the Government would expect airport operators to offer financial assistance towards acoustic insulation to residential properties which experience an increase in noise of 3dB or more which leaves them exposed to levels of noise of 63 dB LAeq,16h or more."*

Survey of Noise Attitudes 2014[31] (published in 2017)

The Civil Aviation Authority *Survey of Noise Attitudes 2014* (or SoNA 2014) includes the results of a survey to noise attitudes to civil aircraft. It is the most recent study of its kind in the UK.

SoNA 2014 compared reported mean annoyance scores against average summer-day noise exposure defined using $L_{Aeq,16h}$, L_{den}, N70 and N65. Mean annoyance score correlated well with average summer day noise exposure, $L_{Aeq,16h}$. No evidence was found to suggest any of the other indicators correlated better with annoyance than $L_{Aeq,16h}$.

The survey has resulted in the 54 dB $L_{Aeq,16h}$ becoming acknowledged to correspond to the onset of significant community annoyance rather than 57 dB $L_{Aeq,16h}$ which was based on the *UK Aircraft Noise Index Study*[32] (or ANIS) from 1985.

[31] Civil Aviation Authority (2017). Survey of noise attitudes 2014: Aircraft, CAP 1506, [online]. Available at: https://publicapps.caa.co.uk/docs/33/CAP%201506%20FEB17.pdf [Checked 30/08/2018].
[32] Brooker et al (1985). United Kingdom Aircraft Noise Study: Main Report, DR Report 8402, Civil Aviation Authority Directorate of Operational Research and Analysis for Department of Transport. London: Civil Aviation Authority.

UK Airspace Policy: A framework for balanced decisions on the design and use of airspace 2017 consultation[33]

Although the APF[30] remains the current national aviation policy document, in 2017 the Department for Transport reported on the outcome of consultations regarding changes to UK airspace (Consultation Response on UK Airspace Policy: A framework for balanced decisions on the design and use of airspace) which included a review of criteria and metrics for assessing aircraft noise. This states in paragraph 9: "*The Government's current aviation policy is set out in the Aviation Policy Framework (APF). The policies set out within this document provide an update to some of the policies on aviation noise contained within the APF, and should be viewed as the current government policy. The government also intends to develop aviation noise policy further through the Aviation Strategy consultation process. As part of the Aviation Strategy consultation on sustainable growth planned for 2018 the Government intends to consider the roles, structures and powers that currently exist and what, if any, new ones will be necessary to bring about the network wide, co-ordinated and complex changes needed for airspace modernisation*".

Based on this report, the UK Government will implement a range of proposals of which the key points are:

- The creation of an Independent Commission on Civil Aviation Noise (ICCAN) as an advisory non-departmental public body;
- The removal of the 3 dB minimum change requirement for financial assistance towards acoustic insulation to residential properties in the 63 dB $L_{Aeq,16h}$ level or above;
- A level of 54 dB $L_{Aeq,16h}$ is now acknowledged to correspond to the onset of significant community annoyance and replaces the 57 dB $L_{Aeq,16h}$ level in the APF,
- Some adverse effects of annoyance can now be seen to occur down to 51 dB $L_{Aeq,16h}$. LOAEL of 51 dB $L_{Aeq,16h}$ and 45 dB L_{night}, for daytime and night-time noise respectively, are to be used in assessing and comparing noise impacts of airspace changes (N.B. Following consultation with the CAA, the UK Government consider it appropriate to use 45 dB $L_{Aeq,8h}$ as the LOAEL for air space change assessment, for consistency with daytime noise).

[33] Department for Transport (2017). Consultation Response on UK Airspace Policy: A framework for balanced decisions on the design and use of airspace. [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/653801/consultation-response-on-uk-airspace-policy-web-version.pdf [Checked 7/09/2018].

As part of this consultation the Department for Transport published their draft *Air navigation guidance on airspace and noise management and environmental objectives*[34]. This proposes that rather than limiting the number of people exposed to any level of aircraft noise, the number of people experiencing significant adverse effects should be limited. For the purposes of assessing and comparing the noise impacts of airspace changes, a LOAEL of 51dB L_{Aeq} for daytime noise and 45dB L_{night} for night time noise is proposed.

Aviation 2050: The future of UK aviation[35]

This consultation paper lays out the UK Government's vision for future UK aviation strategy. On the topic of noise they state the following:

"3.72 The government believes all major airports should establish and maintain community funds, to invest in these sufficiently so that they are able to make a difference in the communities impacted and the raise the profile of these funds. The levels of investment should be proportionate to the growth at the airport. Community funds are complementary measures to ensure communities get a fair deal and do not substitute for noise reduction. The government proposes to:

- **produce guidance on minimum standards for community funds**

3.115 The proposed new measures are:

- **setting a new objective to limit, and where possible, reduce total adverse effects on health and quality of life from aviation noise**. This brings national aviation policy in line with airspace policy updated in 2017
- **developing a new national indicator to track the long term performance of the sector in reducing noise**. This could be defined either as a noise quota or a total contour area based on the largest airports.

[34] Department for Transport (2017). Air navigation guidance on airspace and noise management and environmental objectives. [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/587669/air-navigation-guidance-on-airspace-and-noise-management-and-environmental-objectives.pdf [Checked 30/08/2018].
[35] Department for Transport (2018). Aviation 2050 The future of UK aviation, [online]. Available at: https://www.gov.uk/government/consultations/aviation-2050-the-future-of-uk-aviation [Checked 19/03/2019].

- **routinely setting noise caps as part of planning approvals (for increase in passengers or flights)**. The aim is to balance noise and growth and to provide future certainty over noise levels to communities. It is important that caps are subject to periodic review to ensure they remain relevant and continue to strike a fair balance by taking account of actual growth and the introduction of new aircraft technology. It is equally important that there are appropriate compliance mechanisms in case such caps are breached and the government wants to explore mechanisms by which airports could 'pay for' additional growth by means of local compensation as an alternative to the current sanctions available.
- **requiring all major airports to set out a plan which commits to future noise reduction, and to review this periodically**. This would only apply to airports which do not have a noise cap approved through the planning system and would provide similar certainty to communities on future noise levels. The government wants to see better noise monitoring and a mechanism to enforce these targets as for noise caps. The noise action planning process could potentially be developed to provide the bases for such reviews, backed up by additional powers as necessary for either central or local government or the CAA.

3.121 The government is also:

- **proposing new measures to improve noise insulation schemes for existing properties, particularly where noise exposure may increase in the short term or to mitigate against sleep disturbance**

3.122 Such schemes, while imposing costs on the industry, are an important element in giving impacted communities a fair deal. The government therefore proposes the following noise insulation measures:

- **to extend the noise insulation policy threshold beyond the current 63 dB $L_{Aeq,16h}$ contour to 60 dB $L_{Aeq,16h}$**
- **to require all airports to review the effectiveness of existing schemes. This should include how effective the insulation is and whether other factors (such as ventilation) need to be considered, and also whether levels of contributions are affecting take-up**
- **the government or ICCAN to issue new guidance to airports on best practice for noise insulation schemes, to improve consistency**

- **for airspace changes which lead to significantly increased overflight, to set a new minimum threshold of an increase of 3 dB L_{Aeq}, which leaves a household in the 54 dB $L_{Aeq,16h}$ contour or above as a new eligibility criterion for assistance with noise insulation"**

TECHNICAL GUIDANCE

General

The technical guidelines which inform the air noise assessment are set out in this section.

World Health Organisation (WHO) – Guidelines for Community Noise (1999)

WHO *Guidelines for Community Noise*[36] provide a range of aspirational noise targets aimed at protecting the health and well-being of the community. They therefore set out noise targets which represent goals for minimising the adverse effects of noise on health as opposed to setting absolute noise limits for planning purposes. These guidelines have recently been updated with the publication of a new set of guidelines in 2018 which are described in Section 6.4 below. Aspects of these older guidelines however have not been superseded, in particular those relating to acceptable internal noise levels within spaces.

WHO Night Noise Guidelines (2009)

Guidance on absolute noise levels at night are given in by the WHO *Night Noise Guidelines* (NNG)[37]. These report findings from the WHO concerning night noise from transportation sources and its effects on health and sleep. These guidelines acknowledge that the effect of noise on people at night depends not just on the magnitude of noise of a single event but also the number of events. It considers that in the long term, over a year, these effects can be described using the $L_{night,outside}$ index. This is essentially equivalent to the $L_{Aeq,8h}$ index commonly used in the UK, but instead of being based on aircraft activities during the average summer night, is based on the average annual night.

---

[36] Berglund, B. et al (1999). Guidelines for community noise. [Online]. Available at: http://apps.who.int/iris/bitstream/handle/10665/66217/a68672.pdf?sequence=1&isAllowed=y [Checked: 30/08/2018].

[37] World Health Organisation Europe (2009). Night Noise Guidelines for Europe, [Online]. Available at: http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf [Checked 7/09/ 2018].

These guidelines were prepared by a working group set up to provide scientific advice to the Member States for the development of future legislation and policy action in the area of assessment and control of night noise exposure. The working group reviewed available scientific evidence on the health effects of night noise, and derived health-based guideline values. Although this provides guidance to the European Community in general and has no policy status, it provides a description of recent research into the health effects of noise and provides guidance on noise targets.

The following night noise guideline values are recommended by the working group for the protection of public health from night noise:

- Night noise guideline (NNG) $L_{night,outside}$ equal to 40 dB
- Interim target (IT) $L_{night,outside}$ equal to 55 dB

The NNG is a health based limit to aspire towards whereas the IT represents a feasibility based intermediate target. This is borne out to some extent by the Strategic Noise Mapping work undertaken across European Member States in compliance with the Environmental Noise Directive[19]. For night noise, Member States are required to produce noise maps in terms of the $L_{night,outside}$ index no lower than 50 dB for strategic planning purposes.

The relationship between night noise exposure and health effects as defined by WHO can be summarised as shown in Table 21.

$L_{night,outside}$	Relationship between night noise exposure and health effects
<30	No effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to night noise
30 – 40	There is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night,outside}$ are harmful to health
40 – 50	Adverse health effects are observed at the level above 40 dB $L_{night,outside}$, such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives
>55	Cardiovascular effects become the major public health concern, which are likely to be less dependent on the nature of the noise

Table 21: WHO (2009) guidance on the relationship between night noise exposure and health effects

WHO Environmental Noise Guidelines for the European Region (2018)

The WHO have (October 2018) published their updated *Environmental Noise Guidelines*[38]. These guidelines "strongly recommend" that aircraft noise does not exceed 45 dB L_{den} or 40 dB L_{night}.

These recommendations have not yet been adopted as policy in the UK and it is considered unlikely that these could be adopted as thresholds without imposing very significant restrictions on the current permitted operations of major airports throughout Europe.

There has been some criticism[39] of these levels, primarily that there is a high degree of variation between studies and that some studies are acknowledged to contain bias but have been included in the study.

Relating to annoyance, it is stated in the WHO 2018 document (5.5) that it is important to note the uncertainties in the quantification of the health impacts, where it recommends:

> "*It is therefore not possible to determine the "exact value" of %HA for each exposure level in any generalized situation. Instead, data and exposure-response curves derived in a local context should be applied wherever possible to assess the specific relationship between noise and annoyance in a given situation.*"

On this basis it is considered that recent UK research and government guidance, such as SoNA 2014[31], is more appropriate for the selection of criteria for daytime noise levels.

Relating to night noise, it is stated in the WHO 2018 document (2.6.3) that:

"*The current environmental noise guidelines for the European Region supersede the CNG from 1999. Nevertheless, the GDG recommends that all CNG indoor guideline values and any values not covered by the current guidelines (such as industrial noise and shopping areas) should remain valid.*"

---

[38] World Health Organization Regional Office for Europe (2018). Environmental Noise Guidelines for the European Region. [Online]. Available at: http://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf [Checked: 25/10/2018].
[39] Gjestland, T. 'A Systematic Review of the Basis for WHO's New Recommendation for Limiting Aircraft Noise Annoyance', International Journal of Environmental Research and Public Health 2018, 15(12), 2717; https://doi.org/10.3390/ijerph15122717

The 1999 Community Noise Guidelines (CNG) gives a guideline internal noise level of 30 dB $L_{Aeq,8h}$ for "sleep disturbance" in the night-time period. This can be equated to an outdoor noise level of 45 dB $L_{Aeq,8h}$ based on the estimated difference between indoor and outdoor levels of 15 dB for "tilted or half open" windows given in the WHO 2018 document. This then equates to an outdoor noise level of 55 dB $L_{Aeq,8h}$ if windows are closed (assuming 25 dB difference between indoor and outdoor noise levels). These are therefore considered to be appropriate indicators of the onset of effects.

BS 8233 Sound insulation and noise reduction in buildings – code of practice

The British Standard *BS8233:2014 Sound insulation and noise reduction for buildings – Code of practice*[40] provides guidance on the control of external noise. The standard presents a number of design ranges for indoor noise levels for different types of space.

Internal ambient noise guideline levels for dwellings are given in Table 22.

Activity	Location	07:00 to 23:00	23:00 to 07:00
Resting	Living room	35 dB $L_{Aeq,16h}$	-
Dining	Dining room/area	40 dB $L_{Aeq,16h}$	-
Sleeping (daytime resting)	Bedroom	35 dB $L_{Aeq,16h}$	30 dB $L_{Aeq,8h}$

Table 22: BS 8233:2014 Indoor ambient noise guideline levels for dwellings

Regular individual noise events (for example, scheduled aircraft or passing trains) can cause sleep disturbance. A guideline value may be set in terms of SEL or L_{AFmax}, depending on the character and number of events per night. Sporadic noise events could require separate values.

These guideline noise levels can be used for rooms for residential purposes including hotels, hostels, halls of residence, school boarding houses, hospices and residential care homes.

Guidance is also given for external noise levels:

"7.7.3.2 Design criteria for external noise

[40] British Standards Institution (2014). BS 8233:2014 Sound insulation and noise reduction for buildings – Code of practice. [Online]. Available at: https://shop.bsigroup.com/ProductDetail/?pid=000000000030241579&_ga=2.85437209.1462736480.1535108011-979344642.1535108011 [Checked: 24 /08/2018].

For traditional external areas that are used for amenity space, such as gardens and patios, it is desirable that the external noise level does not exceed 50 dB $L_{Aeq,T}$, with an upper guideline value of 55 dB $L_{Aeq,T}$ which would be acceptable in noisier environments. However, it is also recognized that these guideline values are not achievable in all circumstances where development might be desirable. In higher noise areas, such as city centres or urban areas adjoining the strategic transport network, a compromise between elevated noise levels and other factors, such as the convenience of living in these locations or making efficient use of land resources to ensure development needs can be met, might be warranted. In such a situation, development should be designed to achieve the lowest practicable levels in these external amenity spaces, but should not be prohibited."

BS8233:2014 also gives guideline ambient noise levels in non-domestic buildings. These are given in Table 23**.**

Activity	Location	Design range, $L_{Aeq,T}$
Speech or telephone communications	Department store, cafeteria, canteen, kitchen	50 to 55
	Concourse, corridor, circulation space	45 to 55
Study and work requiring concentration	Library, gallery, museum	40 to 50
	Staff/meeting room, training room	35 to 45
	Executive office	35 to 40
Listening	Place of worship, counselling, meditation, relaxation	30 to 35

Table 23: BS 8233:2014 Indoor ambient noise guideline levels for non-domestic buildings

Department of Education - Acoustic design of schools: performance standards BB93

The Department of Education's *BB93*[41] gives upper limits for indoor ambient noise level in terms of $L_{Aeq,30min}$ for new and refurbished schools, and schools formed by a material change of use, are as follows:

[41] Department of Education (2015). Acoustic design of schools: performance standards Building bulletin 93, [Online]. Available at: https://www.gov.uk/government/publications/bb93-acoustic-design-of-schools-performance-standards [Checked 24/08/2018]

- Classroom and general teaching area - 35 dB $L_{Aeq,30min}$; and
- Teaching space (special communication needs) - 30 dB $L_{Aeq,30min}$.

For classrooms and teaching spaces with natural ventilation, these levels can be achieved if the external noise level does not exceed 55 dB $L_{Aeq,30min}$.

These standards, while not required by legislation to be achieved within those existing schools built prior to their introduction, provide a guide to determine potential impacts on existing schools.

Department of Health - Specialist Services, Health Technical Memorandum 08-01: Acoustics

Guidance on recommended internal noise levels for healthcare facilities is given in the Department of Health's *HTM 08-1*[42]. This recommends internal noise levels for healthcare facilities as follows:

- Hospital wards, daytime - 40 dB $L_{Aeq,1h}$;
- Hospital wards, night - 35 dB $L_{Aeq,1h}$;
- Hospital wards, night - 45 dB $L_{Amax,F}$;
- Operating theatres, night - 40 dB $L_{Aeq,1h}$; and
- Operating theatres, night - 50 dB $L_{Amax,F}$.

The L_{Amax} limit is applicable to events that occur several times during the night (for example passing trains) rather than sporadic events.

These criteria would be relaxed for emergency situations and sporadic events (such as helicopter flights) subject to agreement by the local authority or other relevant body.

For hospital wards with natural ventilation, these levels can be achieved if the external noise level does not exceed 55 dB $L_{Aeq,1h}$ and 50 dB $L_{Aeq,1h}$ during the day and night respectively.

For the control of noise in external areas in hospitals the following provisions should apply, with the most stringent taking precedence:

---

[42] Department of Health (2013). Specialist Services, Health Technical Memorandum 08-01: Acoustics, [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/144248/HTM_08-01.pdf [Checked 24/08/2018].

- Noise levels at the site boundary should meet reasonable standards required by the local authority or other relevant body;
- Noise outside the buildings should be controlled to allow the internal noise criteria to be achieved (with windows or trickle vents open for ventilation if the space is naturally ventilated); and
- Open external areas should be protected. Noise from services should not exceed the existing daytime background noise level or 50 dB L_{A90}, whichever is the higher. This limit should be achieved in any areas normally occupied by staff (except maintenance staff, notwithstanding the requirements of the Control of Noise at Work Regulations 2005[43]) or the public (for example open courtyards and accessible landscaped areas). This means that noisy plantrooms should not face normally occupied external areas unless adequate acoustic control is provided.

ASSESSMENT CRITERIA

Air noise assessment criteria

General

The UK Government, as set out in the APF [30] and supported by SoNA 2014[31], confirms that the current convention in the UK is to assess the impact of daytime aircraft noise in terms of daytime $L_{Aeq,16h}$ noise contours determined from an average summer day of aircraft movements. As a result, emphasis on the assessment of daytime noise in this chapter is placed on the UK methodology and $L_{Aeq,16h}$ unit. This unit has been used historically within the UK and at Dublin Airport over the past 30 years to rate community response to aircraft noise.

For night-time, the recent publication of the UK Government's response to the air space change consultation confirms the use of $L_{Aeq,8h}$ noise exposure contours determined from an average summer night of aircraft movements for describing aircraft noise at night. These contours are also prepared and published annually for the UK designated airports such as Heathrow, Stansted and Gatwick, along with daytime $L_{Aeq,16h}$ contours. The L_{night} index is also referenced, alongside the $L_{Aeq,8h}$ index, as both are very similar.

[43] The Control of Noise at Work Regulations 2005. No. 1643. [online]. Available at: http://www.legislation.gov.uk/uksi/2005/1643/contents/made [checked 21/11/2018]

In Europe, noise indicators based on the L_{Aeq} unit, known as the L_{den} and L_{night}, are used to rate environmental noise and are used to prepare Strategic Noise Maps. Noise contours, in terms of L_{den} and L_{night}, are therefore produced on a five-yearly basis for all major airports, including Dublin Airport.

The L_{den} is a unit that considers an average annual day of air traffic (although it can be applied equally to either rail or road traffic) over a 24 hour period, providing greater emphasis, by way of adding noise penalties of 5 dB and 10 dB to noise levels arising from evening (19:00-23:00) and night (23:00-07:00) traffic respectively. For many airports, the L_{den} equates approximately to the $L_{Aeq,16h}$ index by the relationship $L_{den} = L_{Aeq,16h} + 2$ dB. The precise relationship however depends on the mix of aircraft traffic over the 24 hour period. At Dublin Airport this relationship generally holds true, although as the cross runway (16/34) is used more at night, the contribution from this runway is greater in the L_{den} metric than the $L_{Aeq,16h}$ metric.

The L_{night} equates approximately to the $L_{Aeq,8h}$ index commonly used to rate night noise in the UK with the exception that it is based on an average annual night mix of aircraft movements rather than an average summer mix.

While average exposure noise contours of this type are well established and important at demonstrating trends in total noise around an airport, it is recognised in the APF that people do not experience noise in an averaged manner and that the L_{Aeq} indicator does not necessarily reflect all aspects of the perception of aircraft noise. Alternative indices are therefore considered as part of this air noise assessment which better reflect how aircraft noise is experienced in different localities. The purpose of this is to ensure a better understanding of noise impacts and to inform the development of targeted noise mitigation measures.

The Number above (“N”) index is becoming more commonly used to describe aircraft noise, often using the N70 or N65 parameter for daytime and N60 parameter for night-time aircraft noise assessment. This index, originating from Australia, describes the number of times in a defined period, either the daytime or night-time, that a receptor will experience a maximum noise level as a result of an aircraft passby. For example, an N70 of 20 means that a receptor will experience 20 aircraft events producing 70dB(A) L_{ASmax} or more during the defined period of time. This allows an understanding of how, for a given noise level and above, the number of flights during the daytime might alter when comparing two scenarios, such as with or without an airport development.

In undertaking an assessment, it is necessary to establish those effects that are considered to be adversely or beneficially significant. The thresholds to be adopted for this purpose are discussed later in this Assessment Criteria section.

Daytime - Residential

The UK Government, in the APF[30], acknowledges research in recent years which suggests that the balance of probability is that people are now relatively more sensitive to aircraft noise than in the past. At that time, the UK Government considered there was insufficient evidence to indicate a clear threshold noise level denoting the "*onset of significant community annoyance*". As a result, they retained within the APF the 57 dB $L_{Aeq,16h}$ contour as the average level of daytime aircraft noise marking the approximate onset of significant public annoyance.

In 2017, following the UK Government's response to the UK Air Space Change consultation[33], the UK Government set out policies that provide an update to some of the policies on aviation noise contained within the APF. They advised that these should be viewed as the current UK Government policy. Specifically, it advised that a level of 54 dB $L_{Aeq,16h}$ is now acknowledged to correspond to the onset of significant community annoyance and replaces the 57 dB $L_{Aeq,16h}$ level in the APF.

The UK Government also advise that some adverse effects of annoyance can now be seen to occur down to 51 dB $L_{Aeq,16h}$ and that this should be used as the Lowest Observed Adverse Effect Level (LOAEL) when assessing and comparing noise impacts of airspace changes.

Based on UK Government guidance as described above, the following contour values are relevant in terms of assessing daytime airborne aircraft noise:

a) 51 dB $L_{Aeq,16h}$ which the UK Government recognises as a threshold below which there are no observed adverse effects from air noise; i.e. imperceptible/negligible effects.

b) 54 dB $L_{Aeq,16h}$ which currently provides an indication of the onset of significant community annoyance in the UK; i.e. not significant effects

c) 63 dB $L_{Aeq,16h}$ which denotes the level at which the UK Government recommends that sound insulation is provided. It is also the level which currently defines the Inner Airport Noise Zone in the Fingal Development Plan.; i.e. significant effects.

d) 69 dB $L_{Aeq,16h}$ which denotes the level at which UK Government guidance is for consideration to be given by airports to assist in the costs of re-locating people from exposed dwellings, or, under certain circumstances, to offer to purchase such dwellings; i.e. profound effects.

The subjective description of the absolute levels of air noise, expressed in terms of the air noise contour bands are given in Table 24.

Subjective Description of Effect	Daytime Noise Level, dB $L_{Aeq,16h}$
Imperceptible/ Negligible	51
Not significant	54
Slight	57
Moderate	60
Significant	63
Very Significant	66
Profound	69

Table 24: Air noise assessment criteria – subjective, outdoors (daytime)

N65 contours are used in this assessment to illustrate how, for a given point on the ground, the number of aircraft events producing 65 dB L_{Amax} or more will change between two scenarios.

The level of 65 dB L_{Amax} (outdoors, daytime) is linked to residents experiencing speech interference indoors, rather than being a threshold for significant annoyance. 70 L_{Amax} has also been used in this context, for example in Australia where the metric was conceived. SoNA 2014[31] found that it was preferable to use N65 over N70 as noise events in many areas are below 70 L_{Amax} where average noise metric values are between 51 and 54 dB $L_{Aeq,16h}$.

Night-time - Residential

It is recognised in the 2009 WHO guidelines[37] that undisturbed sleep of sufficient length is essential for daytime alertness and performance, quality of life, and health. Noise has been shown to fragment sleep, reduce sleep continuity, and reduce total sleep time. There is overwhelming evidence that chronically disturbed or curtailed sleep is associated with negative health outcomes.

Night-time aircraft noise can be assessed in a number of different ways. The most common method is to rate night noise in terms of noise exposure, using the $L_{Aeq,8h}$ index and the L_{night} index (for the period 23:00 to 07:00). Another common method is to assess the noise of individual aircraft, in terms of SEL or L_{Amax}.

The WHO sets out night noise guidelines[37 38] in terms of L_{night} which are commonly used to rate the acceptability of environmental noise at night. While the 2018 guidance recommends that a level of 40 dB L_{night} is not exceeded, as this has not yet been adopted as policy in the UK and for reasons discussed earlier, this is considered unlikely to be set as a threshold without significantly restricting current permitted operations at major airports throughout Europe.

Currently, the UK Government recognise 45 dB L_{night} as representing the Lowest Observed Adverse Effect Level (LOAEL) while adopting the 45 dB $L_{Aeq,8h}$ index for this purpose for consistency with the $L_{Aeq,16h}$ daytime noise index.

The $L_{Aeq,8h}$ index differs only slightly from the L_{night} index in that it relates to an average summer day of aircraft activity, as opposed to an average annual day. As summer activity is generally higher than at other times of the year, the adoption of the $L_{Aeq,8h}$ unit, in place of the L_{night} unit represents a conservative approach.

This assessment has therefore adopted the subjective description of the absolute levels of night-time air noise given in Table 25.

Subjective Description of Effect	Night-time Noise Level, dB $L_{Aeq,8h}$/ L_{night}
Imperceptible/ Negligible	45
Not significant	48
Slight	51
Moderate	54
Significant	55
Very Significant	60
Profound	63

Table 25: Air noise assessment criteria – subjective, outdoors (daytime)

Research reported for the 2018 WHO guidelines records the findings of a more developed method of assessing sleep disturbance, stating that the gold standard for measuring sleep is polysomnography, which involves EEG but also eye movement and muscle tone measurement. This research results in a method for estimating the probability of a sleep stage change to awake based on the noise of individual events, such as from aircraft, rail traffic or road vehicles.

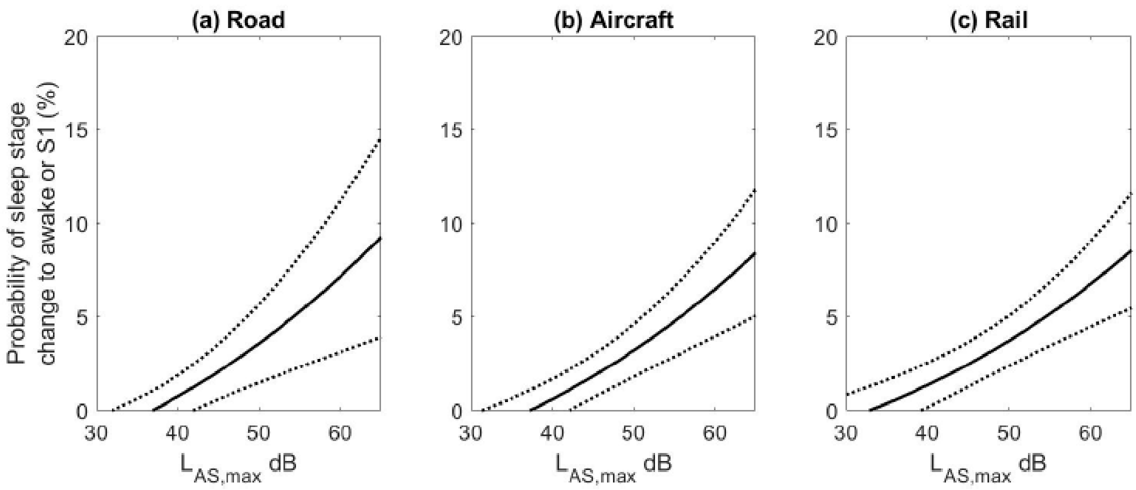


Figure 6. Probability of additional sleep stage changes to awake or S1 in a 90 s time window following noise event onset depending on the maximum indoor sound pressure level ($L_{AS,max}$) for (**a**) road (STRAIN and DEUFRAKO, *N* = 94 subjects); (**b**) aircraft (STRAIN, *N* = 61); and (**c**) rail noise (DEUFRAKO, *N* = 33). 95% confidence intervals (dashed lines). Results are for the three unadjusted models.

The above graphs indicates that, for an indoor sound level of 45 dB L_{Amax}, there is around a 2% probability of an additional sleep stage change to awake. At 65 dB L_{Amax}, this increases to around 8%. It is relevant to note that individuals will not only awaken during the night due to noise events but also spontaneously.

This latest research has not yet been translated into any direct guidance for the assessment of aircraft noise from individual events at night, indeed in the 2018 WHO guidance the effects of single events are disregarded as the body of evidence is too small. The assessment of the effects of individual aircraft events are therefore based on the following in this noise chapter.

The 1999 WHO guidelines[36] provide advice that for a good sleep, indoor sound pressure levels should not exceed approximately 45 dB L_{Amax} more than 10-15 times per night. This guidance on internal noise levels remains current. Accounting for sleeping with a bedroom window slightly open (and a reduction from outside to inside of 15 dB), this translates to an outside sound pressure level of 60 dB L_{Amax}.

N60 contours are therefore used in this assessment to illustrate how, for a given point on the ground, the number of aircraft events producing a level of 60 dB L_{Amax} or more will change between various scenarios.

Non-Residential Receptors - schools

BB93[41] sets out performance standards for indoor ambient noise levels within different types of room in terms of the $L_{Aeq,30min}$ index as given in Table 26.

Location	Upper limit for indoor ambient noise level, $L_{Aeq,30min}$ (new school)
Classroom and general teaching area	35 dB
Teaching space (special communication needs)	30 dB

Table 26: Schools – Indoor Ambient Noise Levels

To achieve the internal ambient noise level inside a classroom using natural ventilation, external noise levels should not exceed 55 dB $L_{Aeq,30min}$.

Noise levels in unoccupied playgrounds, playing fields and other outdoor areas should not exceed 55 dB $L_{Aeq,30min}$.

BAP have reviewed the variation in movement numbers during the daytime at Dublin Airport. This finds that, assuming each aircraft made the same noise level, the $L_{Aeq,30min}$ for the loudest 30 minute period in the day would be approximately 2 dB higher than the $L_{Aeq,16h}$. Therefore a criteria of 53 dB $L_{Aeq,16h}$ has been adopted for consistency with other metrics.

Non-Residential Receptors - *Healthcare Facilities*

Guidance on recommended internal noise levels for healthcare facilities is given in HTM 08-1 (2013)[42] For hospital wards, the criteria for noise intrusion from external sources are as follows (to be met inside the space):

- Daytime: 40 dB $L_{Aeq,1h}$
- Night: 35 dB $L_{Aeq,1h}$
- Night: 45 dB $L_{Amax,F}$ (events that occur several times per night)

An external noise limit of 55 dB $L_{Aeq,1h}$ would ensure recommended levels inside a ward are not exceeded during the daytime, and a limit of 50 dB $L_{Aeq,1h}$ would apply at night, assuming a partly open window.

BAP have reviewed the variation in movement numbers during the daytime at Dublin Airport. This finds that, assuming each aircraft made the same noise level, the $L_{Aeq,1h}$ for the loudest hour in the day would be approximately 2 dB higher than the $L_{Aeq,16h}$. Similarly, the $L_{Aeq,1h}$ for the loudest hour in the night would be approximately 8 dB higher than the $L_{Aeq,8h}$. Therefore criteria of 53 dB $L_{Aeq,16h}$ and 42 dB $L_{Aeq,8h}$ have been adopted for consistency with other metrics.

Non-Residential Receptors - *Places of Worship*

Guidance is given for places of worship in BS8233:2014. This advises that the indoor ambient noise levels should not normally exceed 30-35 dB $L_{Aeq,T}$. This is considered equivalent to the guidance for dwellings (35 dB $L_{Aeq,16h}$ and 30 dB $L_{Aeq,8h}$). Therefore places of worship have been assessed on the same basis as dwellings, i.e. with an outdoor criteria for significant noise effects of 63 dB $L_{Aeq,16h}$ and 55 dB $L_{Aeq,8h}$.

Non-Residential Receptors - *Quiet Areas*

8 Quiet Areas were defined as part of the 2013-2018 Dublin Agglomeration Noise Action Plan. These have not been changed as part of the 2018-2023 Action Plan.

The Action Plan defines the following absolute values as a criterion for defining a Quiet Area:

- < 45 dB L_{night}
- < 55 dB L_{day}
- < 55 dB L_{den}

Although no specific criteria exist for the assessment of quiet areas, it would seem appropriate to ensure that these noise levels are not exceeded for the identified quiet areas.

Strictly L_{day} has not been assessed as part of this work, however for airports open during the night (as Dublin Airport is), the L_{den} contour is typically larger than the L_{day} contour. Therefore if a Quiet Area is < 55 dB L_{den} then it will also be < 55 dB L_{day}.

Change in Noise Level

In addition to absolute noise level, the relative change in noise level between operational scenarios is used to assess air noise. A potential significance rating for a change in level is given in Table 27. A semantic scale of this type, based on the Institute of Environmental Management and Assessment (IEMA) *Guidelines on Environmental Noise Impact Assessment* [44], has been used successfully in various airport Public Inquiries.

Change in noise level, dB(A)	Subjective impression	Potential effect classification
0 to 2	Imperceptible change	Imperceptible/Negligible
2 to 3	Barely perceptible change	Not significant
3 to 6	Perceptible change	Moderate
6 to 9	Up to a halving or a doubling of loudness	Significant
>9	Equal to or more than a halving or doubling of loudness	Very significant

Table 27: Air noise assessment criteria – subjective, outdoors (daytime)

Overall Effects

To assess the overall effect of a change in noise, consideration needs to be given both to the change in noise level as well as the absolute level when assessing the effects of the resulting noise impacts. If, for example, the noise level at a dwelling were to change from 40 dB to 45 dB $L_{Aeq,16h}$, the overall magnitude of effect for the occupants would be less than if the same change were to increase the noise level from 60 dB to 65 dB $L_{Aeq,16h}$.

There is no clearly accepted method of how to rate the magnitude of the effect of a change in the absolute air noise level and the associated change in noise level. Some guidance however has been provided in the UK's NPPG[29] which states:

"*In cases where existing noise sensitive locations already experience high noise levels, a development that is expected to cause even a small increase in the overall noise may result in a significant adverse effect occurring even though little or no change in behaviour would be likely to occur.*"

[44] Institute of Environmental Management and Assessment (2014). Guidelines on Environmental Noise Impact Assessment. London: IEMA.

Table 28 is used in this assessment to indicate those dwellings that will be exposed both to a given level of absolute noise and a change in noise, resulting from a change in operations from one scenario to another. Example values are given for the $L_{Aeq,16h}$ metric; a similar table is used for assessment of other metrics. Table 29 then shows how the primary air noise indicators are interpreted into magnitude of effect. A potential significant effect (adverse or beneficial) is considered to arise if in Table 29 the magnitude of the effect is rated as medium or higher. Whether a significant effect then arises would depend on context, such as the number of noise sensitive receptors affected and how often it occurs.

Subjective description and absolute level	Beneficial or Adverse Change	Change in Noise Level, dB Potential Impact Classification					
		Imperceptible / Negligible 0-2 dB	Not Significant 2-3 dB	Moderate 3-6 dB	Significant 6-9 dB	Very Significant >9 dB	Total
Imperceptible / Negligible, 51 dB $L_{Aeq,16h}$	Beneficial						
	Adverse						
Not significant, 54 dB $L_{Aeq,16h}$	Beneficial						
	Adverse						
Slight, 57 dB $L_{Aeq,16h}$	Beneficial						
	Adverse						
Moderate, 60 dB $L_{Aeq,16h}$	Beneficial						
	Adverse						
Significant, 63 dB $L_{Aeq,16h}$	Beneficial						
	Adverse						
Very Significant, 66 dB $L_{Aeq,16h}$	Beneficial						
	Adverse						
Profound, 69 dB $L_{Aeq,16h}$	Beneficial						
	Adverse						
Total	Beneficial						
	Adverse						

Table 28: Dwellings exposed to absolute air noise and change in air noise, future without development to future with development, $L_{Aeq,16h}$

Receptor Type	Outdoor Noise Level	Magnitude of effect				
		Very Low	Low	Medium	High	Very High
Residential, Day (07:00-23:00)	$51 \leq L_{Aeq,16h} < 63$	0-2	2-3	3-6	6-9	>9
	$L_{Aeq,16h} \geq 63$	0-1	1-2	2-4	4-7	>7
Residential, Night (23:00-07:00)	$45 \leq L_{Aeq,8h} < 55$ $45 \leq L_{night} < 55$	0-2	2-3	3-6	6-9	>9
	$L_{Aeq,8h} \geq 55$ $L_{night} \geq 55$	0-1	1-2	2-4	4-7	>7
Residential, 24h	$55 \leq L_{den} < 65$	0-2	2-3	3-6	6-9	>9
	$L_{den} \geq 65$	0-1	1-2	2-4	4-7	>7
Schools	$L_{Aeq,30min} \geq 55$	0-2	2-3	3-6	6-9	>9
Places of worship, Day (07:00-23:00)	$L_{Aeq,16h} \geq 63$	0-1	1-2	2-4	4-7	>7
Places of worship, Night (07:00-23:00)	$L_{Aeq,8h} \geq 55$	0-1	1-2	2-4	4-7	>7
Healthcare facilities, Day (07:00-23:00)	$L_{Aeq,16h} \geq 55$	0-1	1-2	2-4	4-7	>7
Healthcare facilities, Night (07:00-23:00)	$L_{Aeq,8h} \geq 50$	0-1	1-2	2-4	4-7	>7
Quiet areas, Day (07:00-23:00)	$L_{den} \geq 55$	0-1	1-2	2-4	4-7	>7
Quiet areas, Night (07:00-23:00)	$L_{night} \geq 45$	0-1	1-2	2-4	4-7	>7

Table 29: Summary of magnitude of effect – air noise