6 NO_x to NO_2 Relationship

6.1 Nitrogen dioxide (NO_2) concentrations have been calculated from the predicted NOx concentrations using the 'NO_2 from NOx calculator' available on the Defra air quality website[26]. This calculator requires an estimate of the proportion of primary NO_2 (f-NO_2). This was calculated individually for each receptor based on the relative contribution of different sources to total locally-generated NOx concentrations. For road vehicles, representative values of f-NO_2 are contained within the 'NO_2 from NOx calculator'. For aircraft, f-NO_2 values obtained from the National Atmospheric Emissions Inventory were used[27]. For all other sources, including APUs, GSE and terminal boiler plant, f-NO_2 values of either 5% or 15% were assumed.

6.2 The calculator also requires an estimate of the regional ozone, NOx and NO_2 concentrations above the surface layer, which provides information on the amount of available oxidant: this is done by selecting a local authority, which allows the calculator to provide default values. The "Newry and Morne" district was selected to define these terms. It is also necessary to specific the "representative traffic mix"; this was assumed to be "all UK traffic". These assumptions have been based on guidance issued by NRA[7].

[26] Defra (2020) Available at http://www.defra.gov.uk/environment/quality/air/airquality

[27] NAEI available at http://naei.defra.gov.uk/datawarehouse

7 Spatial and Temporal Representation of Emissions

7.1 Emissions occur at different locations and over different time periods. The spatial representation of sources has been undertaken using a combination of line, point, area and volume sources. Aircraft taxiing and holding emissions were represented as line sources based on schematic taxi routes from the stands, to and from the runways. Emissions during take-off roll were distributed between the start-of-roll point on the runways and the estimated point of 'wheels-off'.

7.2 Aircraft movements, including taxiing, take-off, initial climb, climb-out, approach and landing roll-out are all contained within an "airfile" in ADMS-Airport. This file contains information on the geometry of individual aircraft, the engine exhaust parameters (exit velocity, temperature and diameter), the geometry of the LTO cycle (e.g. taxiway start and end points, take-off start and end points, approach start and end points etc.), the times in mode, and the aircraft emissions.

7.3 Each aircraft movement between spatial nodes is included as a separate line in the airfile. ADMS-Airport then treats each source as a series of fixed jet sources between each node point. Each line of the airfile is assigned an "NT number", which is the number of fixed jet sources along its length. For each part of the LTO cycle, there is a maximum jet source spacing, which is used to calculate NT. i.e. NT = (distance between aircraft start and end points) / (max jet-source spacing).

7.4 The emission rates contained within the airfile are annual average emission rates based on the number of movements of a particular aircraft or group of aircraft, assuming 100% usage of both Runway 10 (or 10R/10L) and Runway 28 (or 28R/28L). A time-varying emission file was then used to apportion the movements to the runways on an hour-by-hour basis, depending on wind direction. This time-varying file also accounts for the runway usage based on the mode of operation permitted by Condition 3a-c.

7.5 There are a small number of aircraft movements operating on the Cross Runway (16/34) in 2018 (~4%) and a smaller number (about 1%) assigned to the Cross Runway in future years with the North Runway in operation. In terms of annual mean pollutant concentrations, which are the principal focus of this assessment and the health impact assessment, these movements will have an indiscernible effect. For practical reasons, movements on the Cross Runway have been assigned to the main runway(s) on a proportional basis.

7.6 The mode of North Runway operation will be primarily assigned to Option 7b as defined in the 2007 planning permission, and is based on segregated mode. When winds are westerly, Runway 28L is preferred for arriving aircraft, with Runway 28R used for departing aircraft. During easterly operations Runway 10R is preferred for departing aircraft, with Runway 10L used for arriving aircraft. These modes have been applied to all future year operations.

7.7 Climb-out and approach trajectories have been calculated from information provided by the Airport. This includes the minimum angle of approach as well as indicative times between lift-off and throttle-back, approach and landing, and estimated aircraft speeds during these movements.

7.8 Emissions from airside ground activities, including the use of APUs and MGPUs, airside vehicle movements and aircraft main engine idling on stand (the time between engine start-up and start of taxi-out on departure) have been modelled as a series of volume sources, covering the main apron areas. Airside vehicle emissions and MGPU emissions are low-level and have therefore been modelled as volume sources with a depth of 2m and a source centre height of 1m. APU and aircraft main engine idling emissions have an initial release height, as the jet engines/APU units are elevated on the aircraft fuselage, and the emissions are hot, giving them a degree of buoyancy. To account for this, APU and aircraft idling emissions have been modelled as volume sources with a depth of 5m and a source centre height of 7.5m.

7.9 Emissions from the landside road network were calculated and assigned on a link-by-link basis. Road speeds were based on local speed limits, and were reduced close to junctions to take account of decelerating and accelerating vehicles, queuing and congestion.

8 Model Verification

8.1 The process of model verification compares modelled and measured values in order to evaluate the performance of the model at the local scale. Most nitrogen dioxide (NO_2) is produced in the atmosphere by reaction of nitric oxide (NO) with ozone. It is therefore most appropriate to verify the model in terms of primary pollutant emissions of nitrogen oxides ($NOx = NO + NO_2$). The model has been run to predict the annual mean NOx concentrations during 2018 at the Dublin Airport automatic monitor and at the network of diffusion tube monitoring sites. Concentrations have been modelled at 2.4 m, the height of the monitors. A summary of the 2018 measured nitrogen dioxide concentrations is shown in Table 6.

Table 6: Measured annual mean nitrogen dioxide concentrations 2018 (µg/m^3)

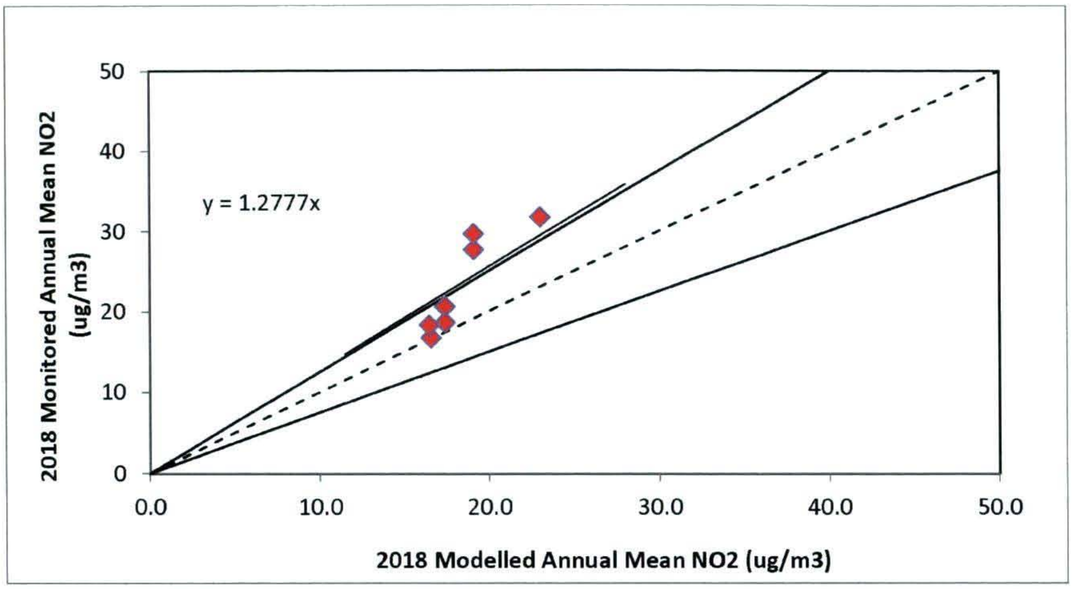
Site ID	Site Location	Annual Mean Nitrogen Dioxide Concentration 2018
Continuous Analyser	Dublin Airport	27.6
A1	Forrest Little Golf Club	20.6
A2	Kilreesk Lane, St Margaret's	16.7
A3	Ridgewood Estate West, Swords	17.4
A4	St Margaret's School and Parish House	18.6
A5	Fire Station, Huntstown, Dublin Airport	29.6
A6	Southern Boundary Fence, Dublin Airport	31.7
A7	Western Boundary Fence, Dublin Airport	30.0
A8	St. Nicholas of Myra School, Malahide Road	18.2
A9	Naomh Mearnog GAA Club	15.2
A10	Oscar Papa Site, Portmarnock	15.7

Note: Data for the continuous analyser derived from Dublin Airport Air Quality Monitoring Annual Report 2018 (HSSE Environment); data for the diffusion tube sites provided by daa.

8.2 Monitoring sites A9 and A10 are in background locations well away from major airport or road emissions sources and the annual mean concentrations measured at these sites in 2018 are slightly lower than the background concentrations measured at the Swords automatic monitoring station (as presented in Table 5). As such, these two sites have been discounted from the model verification. Monitoring sites A3 and A7 have also been discounted; site A3 is at a background location where the model over-predicts concentrations before any adjustment, and site A7 is very close to the R108, which is not included in the model domain.

8.3 An initial comparison of model outputs was carried out against measured NO_2 concentrations, based on combined "road-NOx" and "airport-NOx" concentrations (then converted to NO_2 in Defra's "NOx:NO_2 calculator") together with estimated background NO_2 values. This shows an average under-prediction of 27.8% compared to measured concentrations, as shown in Figure 3.

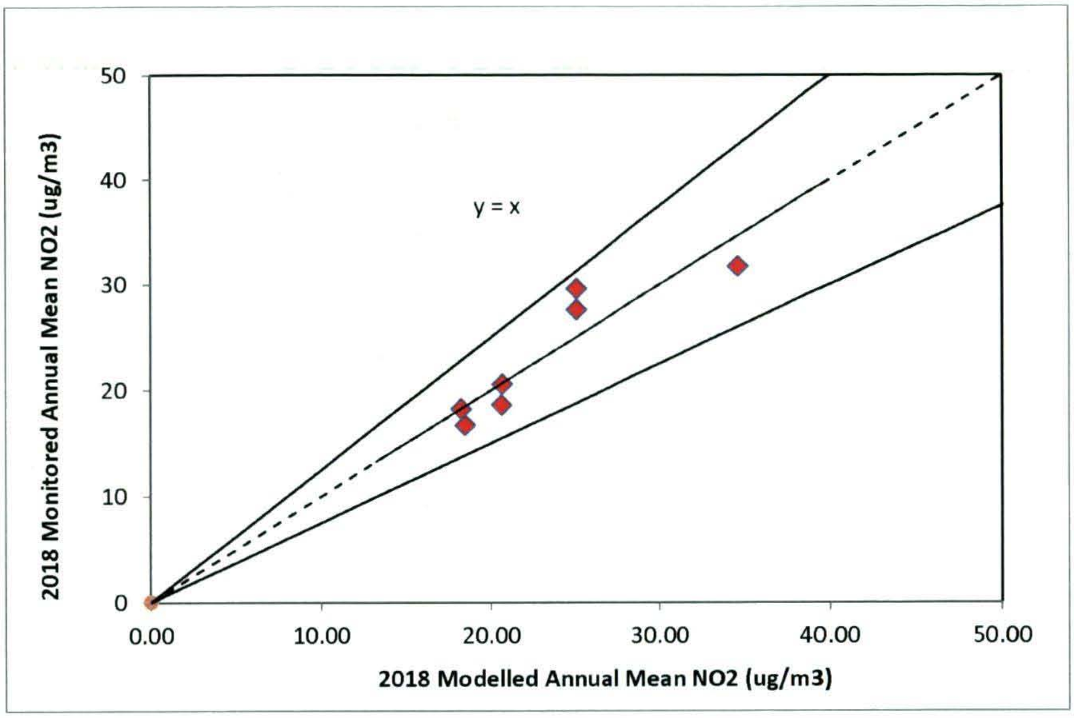
Figure 3: Modelled vs Measured NO_2



8.4 To adjust the model, the predicted "road-NOx" and predicted "airport-NOx" were combined and compared to the measured NOx at the diffusion tube sites (where measured NOx has been calculated using the NOx:NO_2 calculator). This generates a model NOx adjustment factor of 2.551. This adjustment factor has then been applied to uplift the predicted "road-NOx" and "airport-NOx" concentrations, and the total NO_2 recalculated using the NOx:NO_2 calculator. A comparison of predicted NO_2 with measured NO_2 indicates a secondary NO_2 adjustment of 1.06 is required.

8.5 LAQM.TG16 provides guidance on the evaluation of model performance. Based on the final adjusted modelled NO_2 concentrations the Root Mean Square Error (RMSE) is 2.5, the Fractional Bias is 0.0 and the correlation co-efficient is 0.9. LAQM.TG16 notes that where RMSE values are above 25% of the limit value (i.e. 10 µg/m³) that model outputs and verification should be checked. It further notes that "ideally, an RMSE value with 10% of the limit value (4 µg/m³) should be achieved. The ideal value for the Fractional Bias is 0.0. Based on these criteria, the model performance in this assessment is considered to be good. The final modelled vs measured NO_2 comparison is shown in Figure 4.

Figure 4: Adjusted Model Comparison



9 Description of Impacts

9.1 Guidance published by EPUK & IAQM Planning for Air Quality Error! Bookmark not defined. has been used to describe the magnitude of the impacts. This includes defining descriptors of the impacts at individual receptors which take account of the percentage change in concentrations relative to the limit value, rounded to the nearest whole number, and the absolute concentration relative to the limit value.

9.2 The impact descriptors express the magnitude of incremental change as a proportion of the relevant assessment level, and then examine this change in the context of the new, total concentration, and its relationship to the assessment criterion. Table 7 sets out the method for determining the impact descriptor for annual mean concentrations at individual receptors, and has been adapted from the table in the EPUK/IAQM guidance document. The Air Quality Assessment Level (AQAL) refers to the annual mean limit values. Impacts may be adverse or beneficial, depending on whether the change in concentration is positive or negative.

Table 7: Air Quality Impact Descriptors for Individual Receptors [a]

Long-Term Average Concentration At Receptor In Assessment Year [b]	Change in concentration relative to AQAL [c]				
	0%	1%	2-5%	6-10%	>10%
75% or less of AQAL	Negligible	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Negligible	Slight	Moderate	Moderate
95-102% of AQAL	Negligible	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Negligible	Moderate	Moderate	Substantial	Substantial
110% or more of AQAL	Negligible	Moderate	Substantial	Substantial	Substantial

a Values are rounded to the nearest whole number.

b This is the "Without Scheme" concentration where there is a decrease in pollutant concentration and the "With Scheme" concentration where there is an increase.

c AQAL = Air Quality Assessment Level, which may be an air quality objective, EU limit or target value, or an Environment Agency 'Environmental Assessment Level (EAL)'.

10 Glossary

AADT	Annual Average Daily Traffic
ADMS-Airport	Atmospheric Dispersion Modelling System model for Airports
ADMS-Roads	Atmospheric Dispersion Modelling System model for Roads
AQC	Air Quality Consultants
AQAL	Air Quality Assessment Level
AQMA	Air Quality Management Area
CHP	Combined Heat and Power
Defra	Department for Environment, Food and Rural Affairs
EFT	Emission Factor Toolkit
EPUK	Environmental Protection UK
EU	European Union
HDV	Heavy Duty Vehicles (> 3.5 tonnes)
IAQM	Institute of Air Quality Management
ICCT	International Council on Clean Transportation
LAQM	Local Air Quality Management
LDV	Light Duty Vehicles (<3.5 tonnes)
$\mu g/m^3$	Microgrammes per cubic metre
NAEI	National Atmospheric Emissions Inventory
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides (taken to be NO_2 + NO)
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides
PM_{10}	Small airborne particles, more specifically particulate matter less than 10 micrometres in aerodynamic diameter
$PM_{2.5}$	Small airborne particles less than 2.5 micrometres in aerodynamic diameter

Standards A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal

11 Appendices

A1 Input Data Assumptions

Table A1.1: Aircraft Movements 2018 Existing Environment (All Aircraft >1,000 Annual ATMs)

Aircraft Type	Number of Movements
Airbus A306	1,038
Airbus A319	4,075
Airbus A320	57,713
Airbus A321	7,081
Airbus A330	11,974
ATR 72	17,672
Avro RJ85	5,621
Boeing 737-400	1,432
Boeing 737-700	2,021
Boeing 737-800	83,524
Boeing 737 MAX	2,084
Boeing 757	3,616
Boeing 767	2,051
Boeing 777	3,072
Boeing 787	2,612
Bombardier CS300	486
Bombardier Dash 8	4,194
Embraer E190/E195	6,588
Embraer E190-E2	6
Other	15,204
Helicopters	820
Military	2

Table A1.2: Aircraft Movements 2022 Permitted Operations (Do-Nothing) and Relevant Action Operations (Do-Something) (All Aircraft >1,000 Annual ATMs)

Aircraft Type	Number of Movements	
	Do-Nothing	**Do-Something**
Airbus A306	1,264	1,223
Airbus A319	5,373	5,196
Airbus A320	61,631	60,217
Airbus A320neo	2,528	2,445
Airbus A321	8,217	7,947
Airbus A321neo	5,689	8,559
Airbus A330	13,906	13,755
Airbus 72	1,264	1,223

ATR 72	17,699	17,423
Boeing 737-400	2,528	2,445
Boeing 737-700	4,425	4,280
Boeing 737-800	75,853	87,727
Boeing 737 MAX	17,699	14,672
Boeing 767	632	1,222
Boeing 777	1,896	1,834
Boeing 787	7,585	7,336
Bombardier CS300	1,896	1,834
Bombardier Dash 8	2,528	2,445
Embraer E190/E195	7,585	8,253
Other	8,217	14,060
Helicopters	0	1,223

Table A1.3: Aircraft Movements 2022 with 32 Million Passengers Scenario, Permitted Operations (Do-Nothing) and Relevant Action Operations (Do-Something) (All Aircraft >1,000 Annual ATMs)

Aircraft Type	Number of Movements	
	Do-Nothing	**Do-Something**
Airbus A306	1,220	1,220
Airbus A319	5,184	5,184
Airbus A320	58,245	58,245
Airbus A320neo	1,220	1,220
Airbus A321	7,319	7,319
Airbus A321neo	1,830	1,830
Airbus A330	13,418	13,418
ATR 72	17,077	17,077
Boeing 737-400	2,440	2,440
Boeing 737-700	4,269	4,269
Boeing 737-800	72,578	72,578
Boeing 737 MAX	11,588	11,588
Boeing 767	610	610
Boeing 777	1,830	1,830
Boeing 787	6,709	6,709
Bombardier CS300	1,830	1,830
Bombardier Dash 8	2,440	2,440
Embraer E190/E195	6,709	6,709

Other	7,929	7,929

Table A1.4: Aircraft Movements 2027 Permitted Operations (Do-Nothing) and Relevant Action Operations (Do-Something) (All Aircraft >1,000 Annual ATMs)

Aircraft Type	Number of Movements	
	Do-Nothing	**Do-Something**
Airbus A320	42,817	41,643
Airbus A320neo	22,668	22,046
Airbus A321	3,148	3,062
Airbus A321neo	12,593	14,391
Airbus A330	11,964	10,717
Airbus 72	4,722	3,981
ATR 72	19,520	18,984
Boeing 737-700	4,093	3,981
Boeing 737-800	68,318	77,775
Boeing 737 MAX	28,020	23,271
Boeing 777X	1,259	1,225
Boeing 787	7,556	6,430
Bombardier CS300	1,889	1,837
Bombardier Dash 8	4,408	4,287
Embraer E190/E195	8,186	8,574
Other	7,556	14,085
Helicopters	0	1,225

Table A1.5: 2018 Baseline Aircraft Group Assignments

Group Name	Description	Aircraft in Group[1]	Engine Assignment	No. Engines	Engine Type	Engine Mounting	Wake Category
MCAT01	Boeing 737	**Boeing 737-800,** 737-400, 737-700, 737-MAX	CFM56-7B27	2	Turbofan	Wing	M
MCAT02	Airbus A319-A321	Airbus A319, **A320**, A321	CFM56-5B4/P	2	Turbofan	Wing	M
MCAT03	Large Turboprops	**ATR-72**, Airbus 72, Bombardier Dash-8	PW127	2	Turboprop	Wing	M
MCAT04	Regional Jets	**Embraer E190,** E195, E190-E2 Bombardier CS300	CF34-10E7	2	Turbofan	Wing	M
MCAT05	Airbus A330	**Airbus A330-200**	GE CF6-80E1A4	2	Turbofan	Wing	H
MCAT06	Boeing 777	**Boeing 777-300ER**	GE90-115B	2	Turbofan	Wing	H
MCAT07	Boeing 787	**Boeing 787**	Trent 1000-J2	2	Turbofan	Wing	H
MCAT08	Narrow Body Jets	**Boeing 757**, Boeing 767, Airbus A306	RB211-535E4B	2	Turbofan	Wing	M
MCAT09	Other	**Cessna Citation V**, Learjet 45, business jets, general aviation flights, military and helicopters	AE3007C1	2	Turbofan	Wing	M

1 The "lead" aircraft assigned in each group is shown in bold

Table A1.6: 2022 and 2027 Permitted (Do-Nothing) and Relevant Action (Do-Something) Operations Aircraft Group Assignments

Group Name	Description	Aircraft in Group[1]	Engine Assignment	No. Engines	Engine Type	Engine Mounting	Wake Category
MCAT01	Current Generation Boeing 737	**Boeing 737-800**	CFM56-7B27	2	Turbofan	Wing	M
MCAT02	Current Generation Airbus A319-A321	Airbus A319, **A320**, A321	CFM56-5B4/P	2	Turbofan	Wing	M
MCAT03	Large Turboprops	**ATR-72**, Airbus 72, Bombardier Dash-8	PW127	2	Turboprop	Wing	M
MCAT04	Regional Jets	**Embraer E190,** E195, E195-2, Bombardier CS300	CF34-10E7	2	Turbofan	Wing	M
MCAT05	Airbus A320 neo	**Airbus A320 neo**	LEAP-1A26/26E1	2	Turbofan	Wing	M
MCAT06	Airbus A321 neo	**Airbus A321 neo**	LEAP-1A35A /33/33B2 /32/30	2	Turbofan	Wing	M
MCAT07	Large Wide Body Jets	**Boeing 787**, Boeing 777, Airbus A330 neo	Trent 1000-J2	2	Turbofan	Wing	H
MCAT08	Boeing 737 MAX	**Boeing 737 MAX**	LEAP-1B27	2	Turbofan	Wing	M
MCAT09	Small Wide Body Jets	**Airbus A330-200**, Boeing 767, Airbus A306	GE CF6-80E1A4	2	Turbofan	Wing	H
MCAT10	Other	**Cessna Citation V**, Learjet 45, business jets, general aviation flights, and helicopters	AE3007C1	2	Turbofan	Wing	M

1 The "lead" aircraft assigned in each group is shown in bold.

Table A1.7: Times-in-Mode

Mode	Time (sec)	Thrust Setting
	Departures	
Taxi to Runway	See Table A1.	7%
Hold at Runway End	582	7%
Start of roll to lift off	38	100%
Initial climb to throttle-back	44	100%
Climbout to 915m	73	85%
	Arrivals	
Approach (915 to touchdown)	246	30%
Landing roll	30	7%
Taxi from Runway	See Table A1.	7%

Table A1.8: Taxi-Times

Runway	Stand Group	Taxi Time (sec)
	Departures (Taxi out to runway)	
28L	100	263
	200	210
	300	143
	400	138
10R	100	425
	200	291
	300	490
	400	656
28R	100	324
	200	359
	300	430
	400	429
10L	100	361
	200	396
	300	468
	400	467
	Arrivals (Taxi in to stand)	
28L	100	359
	200	297
	300	381
	400	462
10R	100	259

	200	206
	300	259
	400	283
28R	100	326
	200	360
	300	432
	400	431
10L	100	282
	200	317
	300	389
	400	388

Table A1.9: Traffic Data

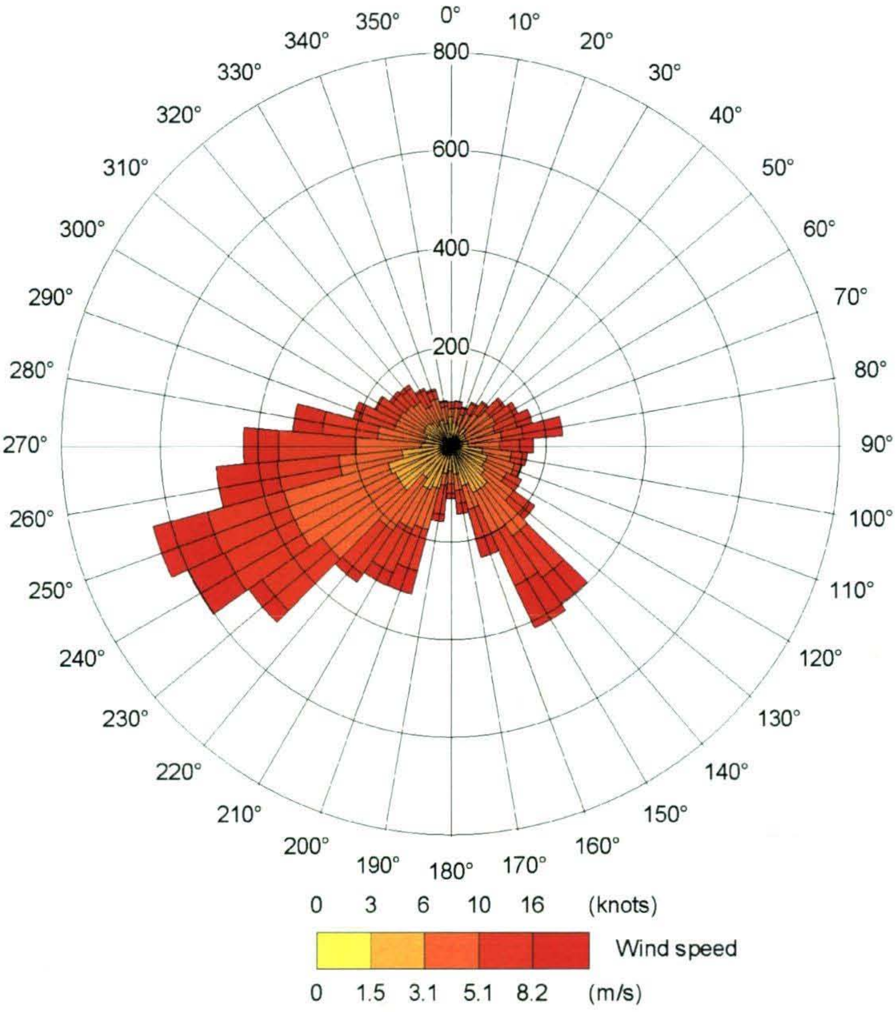
Road Link	2018 Baseline		2022 [a]		2027	
	AADT	%HDV	AADT	%HDV	AADT	%HDV
Naul Road	9,888	7.9	14,821	7.9	15,790	7.9
R123 Swords Road (North of Airport)	19,145	10.2	28,933	10.2	31,206	10.2
M1 Link Road	42,355	3.2	67,727	3.2	78,946	3.2
M1 Motorway (South of Airport Interchange)	135,018	5.1	144,011	5.1	153,890	5.1
R123 Swords Road (South of Airport)	17,728	14.5	27,132	14.5	29,803	14.5
Old Airport Road	10,008	10.3	15,030	10.3	16,060	10.3
M50 Motorway	138,525	7.9	144,421	7.9	151,215	7.9

Source: Data provided by Aecom

[a] Traffic data for both the 2022 core scenario and the 2022 32 mppa scenario are assumed to be the same.

A2 Wind Rose

Figure A2.1 Wind Rose for Dublin Airport 2018



A3 Results

2018 Baseline Results

Table A3.1: Modelled Annual Mean Baseline Concentrations of NO_2, PM_{10} and $PM_{2.5}$ (µg/m[3])

Receptor [a]	NO_2	PM_{10}	$PM_{2.5}$
1	25.8	11.3	**7.0**
2	27.2	11.4	**7.1**
3	23.6	11.3	**7.0**
4	31.2	11.6	**7.2**
5	39.1	11.9	**7.4**
6	26.7	11.5	**7.2**
7	28.8	11.6	**7.2**
8	26.7	11.5	**7.2**
9	21.3	11.2	**7.0**
10	17.7	11.0	**6.8**
11	19.8	11.1	**6.9**
12	18.8	11.1	**6.8**
13	18.8	11.1	**6.8**
14	18.0	11.0	**6.8**
15	21.3	11.2	**6.9**
16	23.7	11.3	**7.0**
17	23.5	11.3	**7.0**
18	19.5	11.1	**6.9**
19	20.1	11.1	**6.9**
20	19.2	11.1	**6.9**
21	19.1	11.1	**6.9**
22	18.0	11.0	**6.8**
23	27.0	11.5	**7.1**
24	21.7	11.2	**6.9**
25	19.7	11.1	**6.9**
26	20.2	11.1	**6.9**
27	20.1	11.1	**6.9**
28	20.9	11.2	**6.9**
29	20.7	11.2	**6.9**
30	21.0	11.2	**6.9**
31	19.3	11.1	**6.9**
32	21.7	11.2	**7.0**
33	26.5	11.5	**7.2**

34	23.7	11.2	**7.0**
35	19.9	11.1	**6.9**
36	24.5	11.4	**7.1**
37	19.2	11.1	**6.9**
38	18.5	11.1	**6.8**
39	20.7	11.1	**6.9**
40	24.5	11.4	**7.2**
41	19.1	11.1	**6.9**
42	19.9	11.1	**6.9**
43	18.2	11.1	**6.8**
44	18.5	11.1	**6.8**
45	19.6	11.1	**6.9**
46	18.3	11.0	**6.8**
47	18.3	11.1	**6.8**
48	18.5	11.1	**6.8**
49	20.7	11.1	**6.9**
50	18.3	11.1	**6.8**
51	32.4	11.6	**7.2**
52	20.8	11.1	**6.9**
Objective	40	40	20 [b]

[a] Receptors modelled at a height of 1.5 m.

[b] Objective as of 2020.

Nitrogen Dioxide Results

Table A3.2: Predicted Impacts on Annual Mean NO_2 Concentrations in 2022 (µg/m^3)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	22.4	22.5	0	**Negligible**
2	24.0	24.4	1	**Negligible**
3	19.6	19.7	0	**Negligible**
4	24.9	24.9	0	**No Change**
5	31.2	31.3	0	**Negligible**
6	21.5	21.1	-1	**Negligible**
7	24.1	24.0	0	**Negligible**
8	28.5	29.6	3	**Negligible**
9	22.5	23.2	2	**Negligible**
10	15.3	15.3	0	**Negligible**
11	18.2	18.3	0	**Negligible**
12	16.8	16.9	0	**Negligible**

13	16.7	16.9	0	**Negligible**
14	15.7	15.7	0	**Negligible**
15	22.5	23.6	3	**Negligible**
16	24.1	24.9	2	**Negligible**
17	22.7	23.2	1	**Negligible**
18	16.9	17.0	0	**Negligible**
19	18.3	18.5	1	**Negligible**
20	17.1	17.2	0	**Negligible**
21	16.8	17.0	1	**Negligible**
22	15.6	15.7	0	**Negligible**
23	22.3	22.2	0	**Negligible**
24	18.2	18.3	0	**Negligible**
25	16.8	16.9	0	**Negligible**
26	18.6	18.7	0	**Negligible**
27	18.0	18.1	0	**Negligible**
28	19.1	19.4	1	**Negligible**
29	18.2	18.4	0	**Negligible**
30	19.0	19.3	1	**Negligible**
31	17.8	17.8	0	**Negligible**
32	27.5	29.4	5	**Negligible**
33	20.0	19.2	-2	**Negligible**
34	22.0	22.9	2	**Negligible**
35	17.9	18.1	1	**Negligible**
36	21.3	21.7	1	**Negligible**
37	16.3	16.2	0	**Negligible**
38	16.2	16.3	0	**Negligible**
39	19.0	19.3	1	**Negligible**
40	20.1	20.1	0	**Negligible**
41	18.2	18.6	1	**Negligible**
42	20.7	21.5	2	**Negligible**
43	16.2	16.2	0	**Negligible**
44	16.9	17.1	1	**Negligible**
45	17.7	17.9	1	**Negligible**
46	15.8	15.8	0	**Negligible**
47	15.7	15.7	0	**Negligible**
48	15.7	15.7	0	**Negligible**
49	17.2	17.2	0	**Negligible**
50	16.1	16.2	0	**Negligible**
51	26.1	26.1	0	**Negligible**

52	19.7	20.3	1	**Negligible**
Objective	40		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

Table A3.3: Predicted Impacts on Annual Mean NO_2 Concentrations in 2022 (32 mppa scenario) (µg/m³)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	22.2	22.1	0	**Negligible**
2	23.7	23.9	1	**Negligible**
3	19.5	19.5	0	**Negligible**
4	24.9	24.8	0	**Negligible**
5	31.1	31.2	0	**Negligible**
6	21.2	20.7	-1	**Negligible**
7	23.8	23.6	-1	**Negligible**
8	27.6	28.2	1	**Negligible**
9	21.9	22.2	1	**Negligible**
10	15.2	15.2	0	**Negligible**
11	17.9	17.8	0	**Negligible**
12	16.6	16.6	0	**No Change**
13	16.6	16.6	0	**Negligible**
14	15.6	15.6	0	**Negligible**
15	21.8	22.5	2	**Negligible**
16	23.4	23.8	1	**Negligible**
17	22.1	22.3	1	**Negligible**
18	16.8	16.8	0	**Negligible**
19	17.9	18.0	0	**Negligible**
20	16.8	16.9	0	**Negligible**
21	16.6	16.7	0	**Negligible**
22	15.5	15.6	0	**Negligible**
23	22.1	21.8	-1	**Negligible**
24	18.1	18.1	0	**Negligible**
25	16.7	16.7	0	**Negligible**
26	18.3	18.1	0	**Negligible**
27	17.7	17.6	0	**Negligible**
28	18.7	18.8	0	**Negligible**
29	17.9	17.9	0	**Negligible**
30	18.6	18.6	0	**Negligible**
31	17.6	17.4	-1	**Negligible**

32	26.4	27.5	3	**Negligible**
33	19.8	18.9	-2	**Negligible**
34	21.3	21.8	1	**Negligible**
35	17.6	17.6	0	**Negligible**
36	20.7	20.8	0	**Negligible**
37	16.2	16.1	0	**Negligible**
38	16.0	16.1	0	**Negligible**
39	18.6	18.7	0	**Negligible**
40	19.7	19.4	-1	**Negligible**
41	17.9	18.1	0	**Negligible**
42	20.1	20.6	1	**Negligible**
43	16.1	16.0	0	**Negligible**
44	16.7	16.7	0	**Negligible**
45	17.5	17.6	0	**Negligible**
46	15.7	15.7	0	**Negligible**
47	15.6	15.6	0	**Negligible**
48	15.7	15.7	0	**Negligible**
49	17.2	17.1	0	**Negligible**
50	16.0	16.0	0	**Negligible**
51	26.0	26.0	0	**Negligible**
52	19.4	19.7	1	**Negligible**
Objective	40		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

Table A3.4: Predicted Impacts on Annual Mean NO_2 Concentrations in 2027 ($\mu g/m^3$)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	19.1	19.4	1	**Negligible**
2	20.4	20.9	1	**Negligible**
3	16.7	16.9	0	**Negligible**
4	20.2	20.3	0	**Negligible**
5	24.5	24.6	0	**Negligible**
6	18.6	18.6	0	**Negligible**
7	20.5	20.7	1	**Negligible**
8	26.0	27.2	3	**Negligible**
9	20.7	21.3	2	**Negligible**
10	13.4	13.5	0	**Negligible**
11	16.5	16.7	1	**Negligible**
12	15.0	15.2	0	**Negligible**

13	15.0	15.2	0	**Negligible**
14	13.8	13.9	0	**Negligible**
15	20.8	21.9	3	**Negligible**
16	22.2	23.1	2	**Negligible**
17	20.6	21.3	2	**Negligible**
18	14.9	15.0	0	**Negligible**
19	16.5	16.9	1	**Negligible**
20	15.3	15.5	1	**Negligible**
21	15.0	15.3	1	**Negligible**
22	13.8	13.9	0	**Negligible**
23	19.2	19.4	1	**Negligible**
24	15.7	15.9	0	**Negligible**
25	14.7	14.8	0	**Negligible**
26	17.0	17.1	0	**Negligible**
27	16.2	16.4	0	**Negligible**
28	17.5	17.9	1	**Negligible**
29	16.5	16.8	1	**Negligible**
30	17.3	17.8	1	**Negligible**
31	16.1	16.1	0	**Negligible**
32	26.4	28.1	4	**Negligible**
33	17.5	17.3	0	**Negligible**
34	20.4	21.7	3	**Negligible**
35	16.1	16.5	1	**Negligible**
36	19.7	20.4	2	**Negligible**
37	14.2	14.2	0	**Negligible**
38	14.4	14.5	0	**Negligible**
39	17.3	17.8	1	**Negligible**
40	18.4	18.8	1	**Negligible**
41	16.5	16.9	1	**Negligible**
42	19.1	19.9	2	**Negligible**
43	14.4	14.4	0	**Negligible**
44	15.1	15.3	1	**Negligible**
45	15.6	15.9	1	**Negligible**
46	13.9	13.9	0	**Negligible**
47	13.7	13.8	0	**Negligible**
48	13.7	13.8	0	**Negligible**
49	14.9	14.9	0	**Negligible**
50	14.3	14.4	0	**Negligible**
51	20.9	21.0	0	**Negligible**

52	17.6	18.2	1	**Negligible**
Objective	40		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

PM_{10} Results

Table A3.5: Predicted Impacts on Annual Mean PM_{10} Concentrations in 2022 (µg/m^3)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	10.9	10.9	0	**Negligible**
2	10.9	10.9	0	**Negligible**
3	10.8	10.8	0	**Negligible**
4	11.0	11.0	0	**Negligible**
5	11.3	11.3	0	**Negligible**
6	11.0	11.0	0	**Negligible**
7	11.2	11.2	0	**Negligible**
8	11.2	11.3	0	**Negligible**
9	10.9	10.9	0	**Negligible**
10	10.6	10.6	0	**Negligible**
11	10.6	10.6	0	**Negligible**
12	10.6	10.6	0	**Negligible**
13	10.6	10.6	0	**Negligible**
14	10.6	10.6	0	**Negligible**
15	10.8	10.8	0	**Negligible**
16	10.9	11.0	0	**Negligible**
17	10.9	10.9	0	**Negligible**
18	10.6	10.6	0	**Negligible**
19	10.6	10.6	0	**Negligible**
20	10.6	10.6	0	**Negligible**
21	10.6	10.6	0	**Negligible**
22	10.6	10.6	0	**Negligible**
23	11.0	11.0	0	**Negligible**
24	10.7	10.7	0	**Negligible**
25	10.6	10.6	0	**Negligible**
26	10.7	10.7	0	**Negligible**
27	10.7	10.7	0	**Negligible**
28	10.7	10.7	0	**Negligible**
29	10.7	10.7	0	**Negligible**
30	10.7	10.7	0	**Negligible**

31	10.7	10.7	0	**Negligible**
32	11.0	11.1	0	**Negligible**
33	10.9	10.9	0	**Negligible**
34	10.7	10.7	0	**Negligible**
35	10.6	10.6	0	**Negligible**
36	10.8	10.8	0	**Negligible**
37	10.6	10.6	0	**Negligible**
38	10.6	10.6	0	**Negligible**
39	10.7	10.7	0	**Negligible**
40	10.8	10.9	0	**Negligible**
41	10.7	10.7	0	**Negligible**
42	10.7	10.8	0	**Negligible**
43	10.6	10.6	0	**Negligible**
44	10.6	10.6	0	**Negligible**
45	10.6	10.7	0	**Negligible**
46	10.6	10.6	0	**Negligible**
47	10.6	10.6	0	**Negligible**
48	10.6	10.6	0	**Negligible**
49	10.7	10.7	0	**Negligible**
50	10.6	10.6	0	**Negligible**
51	11.1	11.1	0	**Negligible**
52	10.7	10.7	0	**Negligible**
Objective	40		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

Table A3.6: Predicted Impacts on Annual Mean PM_{10} Concentrations in 2022 (32 mppa scenario) ($\mu g/m^3$)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	10.9	10.9	0	**Negligible**
2	10.9	10.9	0	**Negligible**
3	10.8	10.8	0	**Negligible**
4	11.0	11.0	0	**Negligible**
5	11.3	11.3	0	**Negligible**
6	11.0	11.0	0	**Negligible**
7	11.2	11.2	0	**Negligible**
8	11.2	11.2	0	**Negligible**
9	10.9	10.9	0	**Negligible**
10	10.6	10.6	0	**Negligible**

11	10.6	10.6	0	**Negligible**
12	10.6	10.6	0	**Negligible**
13	10.6	10.6	0	**Negligible**
14	10.6	10.6	0	**Negligible**
15	10.8	10.8	0	**Negligible**
16	10.9	10.9	0	**Negligible**
17	10.9	10.9	0	**Negligible**
18	10.6	10.6	0	**Negligible**
19	10.6	10.6	0	**Negligible**
20	10.6	10.6	0	**Negligible**
21	10.6	10.6	0	**Negligible**
22	10.6	10.6	0	**Negligible**
23	11.0	11.0	0	**Negligible**
24	10.7	10.7	0	**Negligible**
25	10.6	10.6	0	**Negligible**
26	10.7	10.6	0	**Negligible**
27	10.7	10.6	0	**Negligible**
28	10.7	10.7	0	**Negligible**
29	10.7	10.7	0	**Negligible**
30	10.7	10.7	0	**Negligible**
31	10.7	10.7	0	**Negligible**
32	11.0	11.0	0	**Negligible**
33	10.9	10.9	0	**Negligible**
34	10.7	10.7	0	**Negligible**
35	10.6	10.6	0	**Negligible**
36	10.8	10.8	0	**Negligible**
37	10.6	10.6	0	**Negligible**
38	10.6	10.6	0	**Negligible**
39	10.6	10.6	0	**Negligible**
40	10.8	10.8	0	**Negligible**
41	10.7	10.7	0	**Negligible**
42	10.7	10.7	0	**Negligible**
43	10.6	10.6	0	**Negligible**
44	10.6	10.6	0	**Negligible**
45	10.6	10.6	0	**Negligible**
46	10.6	10.6	0	**Negligible**
47	10.6	10.6	0	**Negligible**
48	10.6	10.6	0	**Negligible**
49	10.6	10.6	0	**Negligible**

50	10.6	10.6	0	**Negligible**
51	11.1	11.1	0	**Negligible**
52	10.7	10.7	0	**Negligible**
Objective	40		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

Table A3.7: Predicted Impacts on Annual Mean PM_{10} Concentrations in 2027 (μg/m^3)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	10.5	10.5	0	**Negligible**
2	10.6	10.6	0	**Negligible**
3	10.4	10.4	0	**Negligible**
4	10.7	10.7	0	**Negligible**
5	11.0	11.0	0	**Negligible**
6	10.7	10.7	0	**Negligible**
7	10.9	10.9	0	**Negligible**
8	10.9	11.0	0	**Negligible**
9	10.6	10.6	0	**Negligible**
10	10.2	10.2	0	**Negligible**
11	10.3	10.3	0	**Negligible**
12	10.3	10.3	0	**Negligible**
13	10.2	10.3	0	**Negligible**
14	10.2	10.2	0	**Negligible**
15	10.5	10.5	0	**Negligible**
16	10.6	10.6	0	**Negligible**
17	10.5	10.6	0	**Negligible**
18	10.3	10.3	0	**Negligible**
19	10.3	10.3	0	**Negligible**
20	10.3	10.3	0	**Negligible**
21	10.2	10.3	0	**Negligible**
22	10.2	10.2	0	**Negligible**
23	10.7	10.7	0	**Negligible**
24	10.3	10.4	0	**Negligible**
25	10.3	10.3	0	**Negligible**
26	10.3	10.3	0	**Negligible**
27	10.3	10.3	0	**Negligible**
28	10.3	10.3	0	**Negligible**
29	10.3	10.3	0	**Negligible**
30	10.3	10.3	0	**Negligible**

31	10.4	10.4	0	**Negligible**
32	10.7	10.7	0	**Negligible**
33	10.6	10.6	0	**Negligible**
34	10.4	10.4	0	**Negligible**
35	10.3	10.3	0	**Negligible**
36	10.4	10.5	0	**Negligible**
37	10.3	10.3	0	**Negligible**
38	10.2	10.2	0	**Negligible**
39	10.3	10.3	0	**Negligible**
40	10.5	10.5	0	**Negligible**
41	10.3	10.3	0	**Negligible**
42	10.4	10.4	0	**Negligible**
43	10.2	10.2	0	**Negligible**
44	10.3	10.3	0	**Negligible**
45	10.3	10.3	0	**Negligible**
46	10.2	10.2	0	**Negligible**
47	10.2	10.2	0	**Negligible**
48	10.2	10.2	0	**Negligible**
49	10.3	10.3	0	**Negligible**
50	10.3	10.3	0	**Negligible**
51	10.7	10.7	0	**Negligible**
52	10.4	10.4	0	**Negligible**
Objective	40		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

$PM_{2.5}$ Results

Table A3.8: Predicted Impacts on Annual Mean $PM_{2.5}$ Concentrations in 2022 ($\mu g/m^3$)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	6.6	6.6	0	**Negligible**
2	6.7	6.7	0	**Negligible**
3	6.6	6.6	0	**Negligible**
4	6.7	6.7	0	**Negligible**
5	6.9	6.9	0	**Negligible**
6	6.7	6.7	0	**Negligible**
7	6.8	6.8	0	**Negligible**
8	7.0	7.0	0	**Negligible**

9	6.7	6.8	0	**Negligible**
10	6.4	6.4	0	**Negligible**
11	6.5	6.5	0	**Negligible**
12	6.5	6.5	0	**Negligible**
13	6.5	6.5	0	**Negligible**
14	6.4	6.4	0	**Negligible**
15	6.6	6.7	0	**Negligible**
16	6.7	6.8	0	**Negligible**
17	6.7	6.7	0	**Negligible**
18	6.5	6.5	0	**Negligible**
19	6.5	6.5	0	**Negligible**
20	6.5	6.5	0	**Negligible**
21	6.4	6.5	0	**Negligible**
22	6.4	6.4	0	**Negligible**
23	6.7	6.7	0	**Negligible**
24	6.5	6.5	0	**Negligible**
25	6.5	6.5	0	**Negligible**
26	6.5	6.5	0	**Negligible**
27	6.5	6.5	0	**Negligible**
28	6.5	6.5	0	**Negligible**
29	6.5	6.5	0	**Negligible**
30	6.5	6.5	0	**Negligible**
31	6.6	6.6	0	**Negligible**
32	6.8	6.9	0	**Negligible**
33	6.7	6.7	0	**Negligible**
34	6.6	6.6	0	**Negligible**
35	6.5	6.5	0	**Negligible**
36	6.6	6.7	0	**Negligible**
37	6.4	6.4	0	**Negligible**
38	6.4	6.4	0	**Negligible**
39	6.5	6.5	0	**Negligible**
40	6.7	6.7	0	**Negligible**
41	6.5	6.5	0	**Negligible**
42	6.6	6.6	0	**Negligible**
43	6.4	6.4	0	**Negligible**
44	6.5	6.5	0	**Negligible**
45	6.5	6.5	0	**Negligible**
46	6.4	6.4	0	**Negligible**
47	6.4	6.4	0	**Negligible**

48	6.4	6.4	0	**Negligible**
49	6.5	6.5	0	**Negligible**
50	6.5	6.5	0	**Negligible**
51	6.7	6.7	0	**Negligible**
52	6.5	6.6	0	**Negligible**
Objective	20		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

Table A3.9: Predicted Impacts on Annual Mean $PM_{2.5}$ Concentrations in 2022 (32 mppa scenario) (μg/m^3)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	6.6	6.6	0	**Negligible**
2	6.7	6.7	0	**Negligible**
3	6.6	6.5	0	**Negligible**
4	6.7	6.7	0	**Negligible**
5	6.9	6.9	0	**Negligible**
6	6.7	6.7	0	**Negligible**
7	6.8	6.8	0	**Negligible**
8	6.9	6.9	0	**Negligible**
9	6.7	6.7	0	**Negligible**
10	6.4	6.4	0	**Negligible**
11	6.5	6.5	0	**Negligible**
12	6.5	6.5	0	**Negligible**
13	6.4	6.4	0	**Negligible**
14	6.4	6.4	0	**Negligible**
15	6.6	6.6	0	**Negligible**
16	6.7	6.7	0	**Negligible**
17	6.7	6.7	0	**Negligible**
18	6.5	6.5	0	**Negligible**
19	6.5	6.5	0	**Negligible**
20	6.5	6.5	0	**Negligible**
21	6.4	6.4	0	**Negligible**
22	6.4	6.4	0	**Negligible**
23	6.7	6.7	0	**Negligible**
24	6.5	6.5	0	**Negligible**
25	6.5	6.5	0	**Negligible**
26	6.5	6.5	0	**Negligible**
27	6.5	6.5	0	**Negligible**

28	6.5	6.5	0	**Negligible**
29	6.5	6.5	0	**Negligible**
30	6.5	6.5	0	**Negligible**
31	6.6	6.6	0	**Negligible**
32	6.8	6.8	0	**Negligible**
33	6.7	6.7	0	**Negligible**
34	6.6	6.6	0	**Negligible**
35	6.5	6.5	0	**Negligible**
36	6.6	6.6	0	**Negligible**
37	6.4	6.4	0	**Negligible**
38	6.4	6.4	0	**Negligible**
39	6.5	6.5	0	**Negligible**
40	6.7	6.7	0	**Negligible**
41	6.5	6.5	0	**Negligible**
42	6.6	6.6	0	**Negligible**
43	6.4	6.4	0	**Negligible**
44	6.5	6.5	0	**Negligible**
45	6.5	6.5	0	**Negligible**
46	6.4	6.4	0	**Negligible**
47	6.4	6.4	0	**Negligible**
48	6.4	6.4	0	**Negligible**
49	6.5	6.5	0	**Negligible**
50	6.4	6.4	0	**Negligible**
51	6.7	6.7	0	**Negligible**
52	6.5	6.5	0	**Negligible**
Objective	20		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

Table A3.10: Predicted Impacts on Annual Mean $PM_{2.5}$ Concentrations in 2027 ($\mu g/m^3$)

Receptor [a]	Without Scheme	With Scheme	% Change [b]	Impact Descriptor
1	6.4	6.4	0	**Negligible**
2	6.4	6.4	0	**Negligible**
3	6.3	6.3	0	**Negligible**
4	6.4	6.4	0	**Negligible**
5	6.6	6.6	0	**Negligible**
6	6.4	6.5	0	**Negligible**
7	6.5	6.6	0	**Negligible**
8	6.7	6.7	0	**Negligible**

9	6.4	6.5	0	**Negligible**
10	6.1	6.1	0	**Negligible**
11	6.2	6.2	0	**Negligible**
12	6.2	6.2	0	**Negligible**
13	6.2	6.2	0	**Negligible**
14	6.1	6.1	0	**Negligible**
15	6.3	6.4	0	**Negligible**
16	6.5	6.5	0	**Negligible**
17	6.4	6.4	0	**Negligible**
18	6.2	6.2	0	**Negligible**
19	6.2	6.2	0	**Negligible**
20	6.2	6.2	0	**Negligible**
21	6.2	6.2	0	**Negligible**
22	6.1	6.1	0	**Negligible**
23	6.4	6.5	0	**Negligible**
24	6.2	6.2	0	**Negligible**
25	6.2	6.2	0	**Negligible**
26	6.2	6.2	0	**Negligible**
27	6.2	6.2	0	**Negligible**
28	6.2	6.2	0	**Negligible**
29	6.2	6.2	0	**Negligible**
30	6.2	6.2	0	**Negligible**
31	6.3	6.3	0	**Negligible**
32	6.5	6.6	0	**Negligible**
33	6.4	6.4	0	**Negligible**
34	6.3	6.3	0	**Negligible**
35	6.2	6.2	0	**Negligible**
36	6.3	6.4	0	**Negligible**
37	6.1	6.2	0	**Negligible**
38	6.1	6.1	0	**Negligible**
39	6.2	6.2	0	**Negligible**
40	6.4	6.5	0	**Negligible**
41	6.2	6.2	0	**Negligible**
42	6.3	6.3	0	**Negligible**
43	6.2	6.2	0	**Negligible**
44	6.2	6.2	0	**Negligible**
45	6.2	6.2	0	**Negligible**
46	6.1	6.1	0	**Negligible**
47	6.1	6.1	0	**Negligible**

48	6.1	6.1	0	**Negligible**
49	6.2	6.2	0	**Negligible**
50	6.2	6.2	0	**Negligible**
51	6.4	6.4	0	**Negligible**
52	6.3	6.3	0	**Negligible**
Objective	20		-	-

[a] Receptors modelled at a height of 1.5 m.

[b] % changes are relative to the objective and have been rounded to the nearest whole number.

Odour Results

Table A3.11: Predicted Odour Concentrations (OU_E/m^3) (98th Percentile)

Receptor [a]	2018	2022 Permitted	2022 Proposed	2022 32mppa Permitted	2022 32mppa Proposed	2027 Permitted	2027 Proposed
1	0.13	0.15	0.16	0.14	0.14	0.13	**0.14**
2	0.11	0.19	0.23	0.19	0.21	0.18	**0.20**
3	0.12	0.11	0.11	0.10	0.10	0.10	**0.10**
4	0.12	0.10	0.10	0.10	0.09	0.09	**0.10**
5	0.06	0.07	0.07	0.07	0.07	0.06	**0.07**
6	0.31	0.21	0.23	0.21	0.21	0.19	**0.21**
7	0.33	0.24	0.21	0.23	0.19	0.21	**0.21**
8	0.26	0.66	0.79	0.62	0.71	0.61	**0.69**
9	0.17	0.31	0.33	0.29	0.30	0.29	**0.31**
10	0.03	0.03	0.04	0.03	0.03	0.03	**0.03**
11	0.16	0.28	0.27	0.27	0.25	0.25	**0.25**
12	0.10	0.16	0.17	0.16	0.15	0.15	**0.15**
13	0.11	0.17	0.18	0.16	0.16	0.15	**0.17**
14	0.06	0.08	0.08	0.07	0.07	0.07	**0.07**
15	0.16	0.45	0.55	0.42	0.49	0.41	**0.45**
16	0.24	0.48	0.56	0.45	0.50	0.44	**0.49**
17	0.22	0.37	0.42	0.34	0.38	0.33	**0.37**
18	0.07	0.09	0.09	0.08	0.08	0.08	**0.08**
19	0.20	0.33	0.36	0.32	0.32	0.29	**0.32**
20	0.13	0.21	0.23	0.20	0.21	0.19	**0.21**
21	0.12	0.19	0.21	0.18	0.19	0.17	**0.19**
22	0.05	0.08	0.08	0.07	0.07	0.07	**0.07**
23	0.33	0.24	0.21	0.23	0.19	0.21	**0.21**

24	0.10	0.10	0.10	0.10	0.09	0.09	**0.10**
25	0.08	0.08	0.08	0.07	0.07	0.07	**0.07**
26	0.18	0.28	0.26	0.27	0.23	0.25	**0.23**
27	0.18	0.17	0.16	0.16	0.15	0.15	**0.15**
28	0.22	0.33	0.35	0.32	0.31	0.29	**0.32**
29	0.20	0.17	0.18	0.16	0.16	0.15	**0.16**
30	0.21	0.23	0.24	0.22	0.22	0.20	**0.21**
31	0.15	0.25	0.25	0.23	0.24	0.22	**0.23**
32	0.18	0.35	0.38	0.33	0.34	0.33	**0.35**
33	0.24	0.22	0.24	0.22	0.22	0.20	**0.22**
34	0.33	0.70	0.76	0.66	0.68	0.62	**0.69**
35	0.18	0.31	0.34	0.30	0.31	0.28	**0.31**
36	0.41	0.36	0.40	0.35	0.36	0.32	**0.37**
37	0.09	0.07	0.08	0.07	0.07	0.06	**0.07**
38	0.08	0.12	0.13	0.11	0.12	0.11	**0.12**
39	0.23	0.39	0.44	0.37	0.39	0.35	**0.40**
40	0.40	0.32	0.34	0.31	0.30	0.28	**0.30**
41	0.10	0.15	0.17	0.14	0.15	0.13	**0.15**
42	0.15	0.27	0.29	0.26	0.26	0.24	**0.26**
43	0.08	0.11	0.11	0.11	0.10	0.10	**0.10**
44	0.08	0.10	0.11	0.10	0.10	0.09	**0.10**
45	0.08	0.13	0.15	0.12	0.14	0.11	**0.13**
46	0.05	0.05	0.05	0.05	0.05	0.05	**0.05**
47	0.06	0.05	0.05	0.05	0.05	0.05	**0.05**
48	0.06	0.05	0.06	0.05	0.05	0.04	**0.05**
49	0.12	0.09	0.09	0.08	0.08	0.07	**0.08**
50	0.07	0.10	0.11	0.09	0.10	0.09	**0.10**
51	0.06	0.06	0.06	0.06	0.06	0.05	**0.06**
52	**0.12**	**0.23**	**0.27**	**0.23**	**0.25**	**0.21**	**0.24**

[a] Receptors modelled at a height of 1.5 m.

Appendices: 13A-E

Aircraft Noise and Vibration

13A. Legislation, policy, technical guidelines and assessment criteria relevant to air noise and vibration

13A.1 Introduction

13A.1.1 This appendix of the Environmental Impact Assessment Report (EIAR), prepared by Bickerdike Allen Partners LLP, sets out details of the legislation and planning policy considered relevant to the assessment.

13A.1.2 Chapter 6 of the EIAR contains details of the strategic planning context, national planning policy, and local planning policy. Further details of the strategic planning context are given in Section 13A.2. Relevant UK policy, standards and guidance are considered in Section 13A.3, and other international policy, standards and guidance in Section 13A.4.

13A.1.3 There are various noise metrics available for the assessment of the impacts of air noise. These are described in detail in Section 13A.5.

13A.1.4 The derivation of the effect scales used in the air noise assessment are discussed in Section 13A.6.

13A.2 Strategic Planning Context

S.I. No. 549/2018– Environmental Noise Regulations 2018

13A.2.1 This Statutory Instrument gives effect to Directive (EC) 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise, as amended by Commission Directive (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods.

13A.2.2 The regulations are to be known as the European Communities (Environmental Noise) Regulations 2018 and came into operation on the 31 December 2018. They require the production of strategic noise maps for set agglomerations, major roads, major railways, and major airports. They also require the production of subsequent action plans.

EU Regulation 598/2014

13A.2.3 The European Commission introduced EU Regulation 598/2014[1] in 2016 to account for developments in the aviation world. This repeals 2002/30/EC[2] 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.

13A.2.4 There are seven key elements of the new regulatory regime which are:

- Designation of a separate, independent statutory entity as the Competent Authority;

[1] 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].

[2] 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].

- 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.

13A.2.5 Regulation (EU) No 598/2014 under Article 5 requires that member states shall ensure that the Balanced Approach is adopted in respect of aircraft noise management at those airports where a noise problem has been identified. To that end, they shall ensure that the Noise Abatement Objective (NAO) for that airport is defined. This then allows the measures available to reduce the noise impact to be identified, and the likely cost-effectiveness of the noise mitigation measures to be thoroughly evaluated.

Aircraft Noise (Dublin Airport) Regulation Act, 2019

13A.2.6 The Aircraft Noise (Dublin Airport) Regulation Act 2019 (The Aircraft Noise Act) implements EU Regulation 598/2014 on the establishment of rules and procedures with regard to the introduction of noise related operating restrictions at European Union Airports within the Balanced Approach.

13A.2.7 The Aircraft Noise Act amends the Planning and Development Act 2000 as amended, to cater for the situation where development at Dublin Airport may give rise to an aircraft noise problem and where an airport wishes to apply to revoke, amend or replace operating restrictions at the airport.

13A.2.8 The Aircraft Noise Act was enacted on 22nd May 2019. It was subsequently amended on 1st September 2019, following the removal of Airport infrastructure from the Seventh Schedule of the PDA and thus the strategic infrastructure development planning process is no longer applicable to it.

13A.2.9 Fingal County Council has been designated as the competent authority for the purposes of aircraft noise regulation at Dublin Airport by section 3(1) of the Aircraft Noise (Dublin Airport) Regulation Act 2019.

13A.2.10 The Aircraft Noise Act amends the PDA by inserting a number of new sections in Part 3 of the PDA, which deals with control of development. These sections introduce a number of new measures for planning applications at Dublin Airport that may necessitate noise-related actions or that may require a new operating restriction.

13A.2.11 Section 34C of the PDA permits an applicant who is currently subject to a planning permission for development at the airport, that includes an operating restriction, to make an application under Section 34 of the PDA to revoke, amend, replace or take other action in respect of the operating restriction. Pursuant to Section 34C (23) of the PDA this is defined as a proposed 'Relevant Action'. In this regard, daa is enabled to make this application for a proposed relevant action as it seeks to make changes to the operating restrictions imposed by the North Runway Permission.

ICAO Balanced Approach

13A.2.12 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, constituting the 'balanced approach' to aircraft noise management, which encourages ICAO member states to address the following points:

13A.2.13 Mitigate aviation noise through selection at a local level of 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);

13A.2.14 Select the most cost-effective range of measures; and

13A.2.15 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.

13A.2.16 As detailed in the ANCA report titled Aircraft Noise Mitigation at Dublin Airport, the Balanced Approach to aircraft noise management is an internationally agreed approach to managing noise at large airports. Noise reduction is explored through four principal elements with the objective to address noise problems in the most cost-effective manner, and only apply operating restrictions as a last resort measure.

13A.3 Relevant UK Policy, Standards and Guidance

National Planning Policy Framework

13A.3.1 The National Planning Policy Framework (NPPF)[3] originally published 27th March 2012 and updated in July 2018 and February 2019, 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.

13A.3.2 Government's current planning policy concerning noise is embodied in the NPPF (and more specifically the Noise Policy Statement for England or NPSE). The aim of planning policies and decisions with respect to noise is addressed in paragraph 180 of the NPPF:

13A.3.3 "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:

a) 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 the quality of life;

b) *Identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason;"*

13A.3.4 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. That research has not yet resulted in clarification on numerical levels.

Noise Policy Statement for England (2010)

13A.3.5 The Noise Policy Statement for England (NPSE)[4] 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:

13A.3.6 Avoid significant adverse impacts on health and quality of life from environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development;

[3] 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].
[4] 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].

13A.3.7 *Mitigate and minimise adverse impacts on health and quality of life from environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development, and*

13A.3.8 *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 Government policy on sustainable development.*

13A.3.9 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:

13A.3.10 NOEL – No observed effect level. This is the level below which no effect can be detected;

13A.3.11 LOAEL – Lowest observed adverse effect level. This is the level above which adverse effects on health and quality of life can be detected, and

13A.3.12 SOAEL – Significant observed adverse effect level. This is the level above which significant adverse effects on health and quality of life occur.

13A.3.13 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 which was published in March 2014[5].The advice is that noise above the SOAEL should be avoided using appropriate mitigation while taking into account the guiding principles of sustainable development.

13A.3.14 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.

13A.3.15 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.

13A.3.16 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.

13A.3.17 As well as assisting with the interpretation of the NPSE, the Planning Practice Guidance 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."*

13A.3.18 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).

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[5] Defra (2014). National Planning Policy Guidance, Planning Practice Guidance, Noise, [online] Available at: https://www.gov.uk/guidance/noise--2 [Checked 21/08/2018].

13A.3.19 The guidance includes a table that summarises the noise exposure hierarchy based on the likely average response. This is reproduced in Table 13A-1.

Table 13A-1: Noise exposure hierarchy based on the likely average response

Perception	Examples of Outcomes	Increasing Effect Level	Action
Not present	No Effect	No Observed Effect	No specific measures required
	Noise can be heard, but does not cause any change in behaviour, attitude or other physiological response. 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		
Present and Intrusive	Noise can be heard and causes small changes in behaviour, attitude or other physiological response, 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 small actual or perceived change in the quality of life.	Observed Adverse Effect	Mitigate and reduce to a minimum
	Significant Observed Adverse Effect Level		
Present and disruptive	The noise causes a material change in behaviour, attitude or other physiological response, 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
Present and very disruptive	Extensive and regular changes in behaviour, attitude or other physiological response and/or an inability to mitigate effect of noise leading to psychological stress, e.g. regular sleep deprivation/awakening; loss of appetite, significant, medically definable harm, e.g. auditory and non-auditory.	Unacceptable Adverse Effect	Prevent

13A.3.20 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.

13A.3.21 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.

National Planning Practice Guidance

13A.3.22 The National Planning Practice Guidance is a web based resource which supports the National Planning Policy Framework (NPPF). Further details are given above under the Noise Policy Statement for England (2010).

UK Aviation Policy Framework (2013)

13A.3.23 The Aviation Policy Framework (APF) was published in March 2013[6] by the Department for Transport (DfT). The APF defines the Government's objectives and policies on the impacts of aviation in the UK.

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

13A.3.24 On managing aviation's environmental impacts, and specifically noise, it states in paragraph 3.12 that the 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"*.

13A.3.25 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."*

13A.3.26 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 LAeq,16hour"*.

13A.3.27 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."*

13A.3.28 In paragraph 3.17 the interpretation of the contour is given as *"We will continue to treat the 57 dB LAeq,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."*

13A.3.29 Under the heading "Noise insulation and compensation" the APF states that:

13A.3.30 "The Government continues to expect airport operators to offer households exposed to levels of noise of 69 dB LAeq,16h or more, assistance with the cost of moving.

13A.3.31 *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 LAeq,16h or more. Where acoustic insulation cannot provide an appropriate or cost-effective solution, alternative mitigation measures should be offered."*

Survey of Noise Attitudes 2014 (2017)

13A.3.32 The Civil Aviation Authority Survey of Noise Attitudes 2014 (or SoNA 2014)[7] includes the results of a survey to noise attitudes to civil aircraft. SoNA 2014 largely replaces Attitudes to noise from aviation sources in England (or ANASE)[8], the last large scale survey on attitudes to aircraft noise published in 2007.

13A.3.33 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 $L_{Aeq,16h}$.

13A.3.34 The survey resulted in 54 dB $L_{Aeq,16h}$ becoming the threshold of community annoyance rather than 57 dB $L_{Aeq,16h}$ which was based on the UK Aircraft Noise Index Study (or ANIS) from 1985[9].

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

13A.3.35 Although the APF[10] 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

[7] 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].
[8] Le Masurier, Paul et al (2007). Attitudes to noise from aviation sources in England (ANASE): Final Report for Department for Transport. Norwich: HMSO.
[9] 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.
[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:

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".*

13A.3.36 Based on this report, the 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;
- 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 $L_{Aeq,16h}$. A 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 Government consider it appropriate to use 45 dB $L_{Aeq,8h}$ as the LOAEL for air space change assessment, for consistency with daytime noise).

13A.3.37 As part of this consultation the Department for Transport published their draft Air navigation guidance on airspace and noise management and environmental objectives[11]. 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.

Aviation 2050

13A.3.38 In December 2018, the Government published 'Aviation 2050: The Future of UK Aviation' (Aviation 2050) which outlines proposals for a new aviation strategy and addresses a wide range of associated issues. The Green Paper (among other things) sets out a robust policy framework and package of measures to reduce the harmful effects of aviation on the environment including in respect of noise. In the Green Paper, the Government recognises that there has been uncertainty on how current policy (to limit and, where possible, reduce the number of people in the UK significantly affected by aircraft noise) should be interpreted, measured and enforced. The Strategy sets out that the Government intends to put in place a stronger and clearer framework in order to ensure the sector is sufficiently incentivised to reduce noise, or to put mitigation measures in place where reductions are not possible. New measures are proposed including (among others):

- Setting a new objective to limit, and where possible, reduce total adverse effects on health and quality of life from aviation noise;
- Developing a new national indicator to track the long term performance of the sector in reducing noise;
- Routinely setting noise caps as part of planning approvals (for increases in passengers or flights); and
- Requiring all major airports to set out a plan which commits to future noise reduction, and to review this periodically.

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].

[11] 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].

13A.3.39 While Aviation 2050 describes the current intentions of the UK Government regarding the above measures, the final Aviation Strategy is still awaited and no fixed date for its publication is yet available.

BS 8233:2014 Sound insulation and noise reduction in buildings – code of practice

13A.3.40 The British Standard BS8233:2014 Sound insulation and noise reduction for buildings – Code of practice[12] 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.

13A.3.41 The internal ambient noise guideline levels for dwellings are given in Table 13A-2.

Table 13A-2: Dwelling noise exposure hierarchy based on the likely average response

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 $L_{Aeq,8h}$

13A.3.42 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.

13A.3.43 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.

13A.3.44 BS8233:2014 also gives guideline ambient noise levels in non-domestic buildings. These are given in Table 13A-3.

Table 13A-3: Non=domestic noise exposure hierarchy based on the likely average response

Activity	Location	Design range $L_{Aeq,T}$ (dB)
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

Department of Education - Acoustic design of schools: performance standards BB93 (2015)

13A.3.45 The Department of Education's BB93[13] 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:

- Classroom and general teaching area - 35 dB $L_{Aeq,30min}$; and

[12] 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].
[13] 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]

- Teaching space (special communication needs) - 30 dB $L_{Aeq,30min}$.

13A.3.46 For classrooms and teaching spaces with natural ventilation, these levels can be achieved if the external noise level does not exceed 55 dB $L_{Aeq,30min}$.

13A.3.47 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 (2013)

13A.3.48 Guidance on recommended internal noise levels for healthcare facilities is given in the Department of Health's HTM 08-01[14]. 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 $L_{Amax,F}$.

13A.3.49 The L_{Amax} limit is applicable to events that occur several times during the night (for example passing trains) rather than sporadic events.

13A.3.50 These criteria would be relaxed for emergency situations and sporadic events subject to agreement by the local authority or other relevant body.

13A.3.51 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.

CAP1616a Airspace Change: Environmental requirements technical annex

13A.3.52 This guidance document[15] produced in 2017 by the Civil Aviation Authority for airspace change sponsors providing guidance on the seven-stage airspace change process used for permanent changes to the published airspace design. The document guides the user through each stage and describes what will happen at each stage of it, and why.

13A.3.53 CAP 1616a forms a technical annex to this document and gives an outline of relevant methodologies for use in environmental assessment.

BS7445 Description and measurement of environmental noise

13A.3.54 The aim of this British Standard is to provide authorities with material for the description of noise in community environments. The first part of the standard defines the basic quantities to be used and describes basic procedures for the determination of these quantities. The second part concerns the acquisition of data pertinent to land use, and the third part is a guide to application to noise limits.

[14] 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].

[15] Civil Aviation Authority (2017). CAP1616: Airspace Design: Guidance on the regulatory process for changing airspace design including community engagement requirements, [online]. Available at: https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=8127 [Checked 2/10/2018].

13A.4 Other International Policy, Standards and Guidance

ICAO Convention on International Civil Aviation, Annex 16, Volume 1

13A.4.1 ICAO has 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.

13A.4.2 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.

13A.4.3 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.

13A.4.4 Chapter 14 was adopted by the ICAO in 2014. It represents an increase in stringency of 7 dB compared with Chapter 4 and applies to new aircraft submitted for certification after 31st December 2017.

Environmental Noise Directive 2002/49/EC

13A.4.5 The Environmental Noise Directive (END)[17] 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.

EU Commission Directive 2020/367

13A.4.6 Commission Directive (EU) 2020/367 of 4 March 2020 amends Annex III to Directive 2002/49/EC of the European Parliament and of the Council as regards the establishment of assessment methods for harmful effects of environmental noise. The amendment is to *Annex III Assessment Methods for Harmful Effects* and includes the introduction of formulae which compute a value for the proportion of a population highly annoyed or highly sleep disturbed from noise from specific sources, including aircraft.

WHO Guidelines for community noise (1999)

13A.4.7 WHO Guidelines for Community Noise[18] 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.

13A.4.8 For outside areas of dwellings, the WHO Guidelines state that to protect the majority of people from being seriously annoyed during the daytime, the outdoor sound level from steady, continuous noise should not exceed 55 dB L_{Aeq} on balconies, terraces and in outdoor living areas. To protect the majority of people from being moderately annoyed during the daytime, the outdoor sound level should not exceed 50 dB L_{Aeq}. Where it is practical and feasible, the lower outdoor sound level should be considered the

[16] ICAO (2017), Annex 16 to the Convention on International Civil Aviation, Volume 1 8th Edition. ICAO.
[17] 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].
[18] 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].

maximum desirable sound level for new development. The WHO guidance cites a 16 hour period as applicable to the above limits.

13A.4.9 Although the attainment of these steady noise target values is not always achievable in practice, particularly where a dwelling is located close to a busy road or railway, controlling the daytime noise level to 55 dB $L_{Aeq,16h}$ or below in some gardens and amenity areas can sometimes be achieved for developments near roads and railways by the use of screening achieved using other buildings, fences or purpose made noise barriers.

WHO Night Noise Guidelines for Europe (2009)

13A.4.10 Guidance on absolute noise levels at night are given in by the WHO Night Noise Guidelines (NNG)[19]. 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.

13A.4.11 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 provided a description of then recent research into the health effects of noise and provided guidance on noise targets.

13A.4.12 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

13A.4.13 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. 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.

13A.4.14 The relationship between night noise exposure and health effects as defined by these WHO guidelines can be summarised as shown in Table 13A-4.

Table 13A-4: WHO guidance on the relationship between night noise exposure and health effects

Lnight,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

[19] 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].

WHO Environmental Noise Guidelines for the European Region (2018)

13A.4.15 In October 2018 the WHO published their updated Environmental Noise Guidelines[20] which contain the following recommendations:

13A.4.16 For average noise exposure, the GDG (Guideline Development Group) strongly recommends reducing noise levels produced by aircraft below 45 dB L_{den}, as aircraft noise above this level is associated with adverse health effects.

13A.4.17 For night noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft during night-time below 40 dB L_{night}, as night-time aircraft noise above this level is associated with adverse effects on sleep.

13A.4.18 These WHO guidelines could not be adopted as thresholds without imposing very significant restrictions on the current permitted operations of most major airports. As an example, even a single Airbus A320 or Boeing 737-800 aircraft operating once per night could expose hundreds of people to noise levels in excess of the guideline 40 dB L_{night} value at an airport in a relatively rural location. 10 aircraft events during the daytime (07:00-19:00) period (or smaller numbers in the evening and night periods) could expose a similar number of people to noise levels in excess of the 45 dB L_{den} parameter.

13A.4.19 These guidelines have not yet been adopted as UK policy, and there is no current indication that they will be. In December 2018, the UK Government published the consultation document Aviation 2050, which included the following regarding the WHO Guidelines:

13A.4.20 "3.106 There is also evidence that the public is becoming more sensitive to aircraft noise, to a greater extent than noise from other transport sources, and that there are health costs associated from exposure to this noise. The government is considering the recent new environmental noise guidelines for the European region published by the World Health Organization (WHO). It agrees with the ambition to reduce noise and to minimise adverse health effects, but it wants policy to be underpinned by the most robust evidence on these effects, including the total cost of an action and recent UK specific evidence which the WHO report did not assess."

13A.5 Noise Metrics for Assessment of Impacts of Air Noise

13A.5.1 In the UK, the Independent Commission on Civil Aviation Noise (ICCAN) is a body created to act as an independent, impartial voice on civil aviation noise and how it affects communities. They have recently undertaken a review of aviation noise metrics[21].

13A.5.2 The review notes that metrics aim to quantify noise in a meaningful way and that in terms of trying to determine the effect caused by noise there are two ways to look at noise measurements, the absolute value and the relative change. *"Absolute levels are important from a regulatory point of view, whereas the relative change in noise might be more informative for assessing annoyance, because of the way the human ear perceives sound."*

13A.5.3 The background section reports that *"since the early 1970s, research found that the L_{Aeq} metric was most closely associated with subjective response. The $L_{Aeq,T}$ is a notional continuous A-weighted sound level over a given time period, T, that contains the same sound energy as the actual time varying signal over the same time period"*. Both L_{den} and L_{night} are L_{Aeq} based metrics in addition to others such as $L_{Aeq,16h}$ and $L_{Aeq,8h}$.

13A.5.4 "Most of these metrics are well-established within the aviation sector, with an extensive existing knowledge base. This makes them useful for research into annoyance, as well as other health and social issues (WHO, Environmental Noise Guidelines for the European Region, 2018)."

13A.5.5 The review classifies these metrics as giving averaged results as they relate to a period of time during which a number of events may occur and return a value based on the noise across the period. In the

[20] 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].

[21] ICCAN A review of aviation noise metrics and measurement July 2020
https://iccan.gov.uk/wp-content/uploads/2020_07_16_ICCAN_review_of_aviation_noise_metrics_and_measurement.pdf

case of L_{den} the metric also includes weighting with noise during the evening and at night treated as more significant when the overall level is determined. Table 1 of the review summarises some of the exposure noise metrics. The entries for metrics used in this assessment are included in Table 13A-5.

Table 13A-5: Exposure noise metrics based on L_{Aeq}

Metric	What it is	What if does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
$L_{Aeq,T}$	The L_{eq} with the A indicating that the frequencies in the sound have been adjusted using the A weighting curve.	Provides an average value of the A weighted sound energy contained in the sound measured over a period, T.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in various legislation, policy and standards associated with different time periods (T).	Generally felt to be a good indicator of likely annoyance and other health effects. Values can be influenced by a few very noisy events which could give a similar score to a large number of quieter events.
$L_{Aeq,16h}$	The $L_{Aeq,T}$ averaged over a 16 hour period. Conventionally that time period is 07:00 hours to 23:00 hours local time.	When determined for an average summer's day between the 16 June and 15 September, it is the main measure of aircraft noise impact	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in British Standards, such as BS 8233:2014. The summer average day value appears in Government policy on aviation noise management. This metric has been used by the UK for examining aircraft noise since 1990.	An Exposure Response Function (ERF) exists between this metric and annoyance. This is thought to have changed over time. Also, some ERFs exist for other health effects.
$L_{Aeq,8h}$	The $L_{Aeq,T}$ averaged over an 8 hour period. Conventionally that time period is 23:00 hours to 07:00 hours local time (i.e. the night period).	When determined for an average summer's night between the 16 June and 15 September, it is one of the measures of aircraft noise impact at night	Yes. The frequencies in the sound have been weighted using the A weighting curve	Appears in British Standards, such as BS 8233:2014. The summer average night value appears in Government policy on aviation noise management	The summer average night value is used to determine the percentage of people expressing self reported sleep disturbance – although strictly, the correct measure to use is L_{night}.
L_{night}	The $L_{Aeq,8h}$ averaged over the period of one year	Provides a measure of the annual average night noise impact, measured outside.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in the regulations that transpose EC Directive 2002/49/EC, the Environmental Noise Directive	There is an ERF between this measure and determining the percentage of people expressing self reported sleep disturbance for aircraft noise (and road and rail noise).
L_{den}	The annual average $L_{Aeq,T}$, combining L_{day}, $L_{evening}$, and L_{night} but with the $L_{evening}$ value weighted by the addition of 5 dB and the L_{night} value weighted by the addition of 10 dB.	Provides a single measure of the overall annual average noise impact.	Yes. The frequencies in the sound have been weighted using the A weighting curve. $L_{evening}$ has been weighted by the addition of 5 dB. L_{night} has been weighted by the addition of 10 dB	Appears in the regulations that transpose EC Directive 2002/49/EC; The Environmental Noise Directive (END) which is translated into English legislation: The Environmental Noise (England) Regulations 2006 (UK) Statutory Instruments, The Environmental Noise (England) Regulations, 2006, as well as for the devolved nations.	There is an ERF between this measure and annoyance for aircraft noise (and road and rail noise). Also, some ERFs with other health effects.

Metric	What it is	What if does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
$L_{Aeq,30mins}$	The $L_{Aeq,T}$ averaged over a 30 minute period.	Provides a measure of the average noise impact in a 30-minute period.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Appears in Building Bulletin 93 – Acoustic design of schools: performance standards.	Some links with the impact of noise on teaching and learning.
$L_{Aeq,1h}$	The $L_{Aeq,T}$ averaged over a 1 hour period	Provides a measure of the average noise impact in a 1-hour period. For aircraft noise, sometimes used to describe the impact during the period 06:00 – 07:00.	Yes. The frequencies in the sound have been weighted using the A weighting curve.	Can be found in BS 4142:2014+A1:2019 and BS 8233:2014. The value in the period 06:00 – 07:00 is sometimes used a control metric at some airports	No formal relationships exist.

13A.5.6 The report also considers a different class of metrics, those related to single events. These describe the noise impact of a single aircraft movement or over-flight in terms of its intrusiveness, loudness, or noisiness. These can be simpler to present and understand but are not suitable for assessing the overall effects from multiple movements. Table 3 of the review summarises some of the single event metrics. The entries for metrics used in this assessment are included in Table 13A-6.

Table 13A-6: Single event noise metrics

Metric	What it is	What if does	Weighting	Presence in UK Legislation, Policy and Standards	Links to effects on annoyance and other health issues
L_{Amax}	The maximum A-weighted sound level of an aircraft event. It is derived from the root mean square of the varying sound pressure. To be meaningful, a response time has to be defined.	Gives the value of the maximum sound level from an event.	Yes. The various frequencies in the sound have been weighted using the A weighting curve.	Does not appear on its own as it requires information about the response time to be meaningful.	Frequently used in noise disturbance research. Some correlation found with sleep disturbance and speech interference. Strength of correlation unclear. Can be modified to the maximum noise experienced in the bedroom ($L_{Amax,inside}$) (CAA, 2009).
$L_{Amax,S}$	The L_{Amax} measured with a slow response time.	Gives the value of the maximum sound level from an event.	Yes. The various frequencies in the sound have been weighted using the A weighting curve.	Is used to define the maximum level from aircraft noise events.	Research tends not to differentiate between fast or slow response times
Nx	The number of events (flyovers or movements) that cause the maximum noise to be X dB or higher. It needs to have a time period associated with it, but at present does not regularly have	Provides an indication of the number of events likely to cause disturbance. The extent of the impact depends on the value chosen for X.	Yes, insofar as X is usually defined as the $L_{Amax,S}$.	Does not appear on its own as it requires information about the time period over which the value applies to be meaningful.	Depending on the value of X, there is some implied relationship with annoyance.