Written Representation by Michael Reddington
Unique Reference: 20037459

Note: I have recently become a member of the Noise Insulation Scheme Sub-Committee of the London Luton Airport Consultative Committee, although I submit this Written Representation in a personal capacity

Table of Contents

1 Overview

1.1 Objection

1.1.1 The Applicant is proposing within this DCO submission to increase throughput at London Luton Airport from 18 mppa to 32mppa between now and 2043 despite there being a climate emergency, national obligations to Net Zero, and the financial and environmental damage.

1.1.2 The Applicant is proposing to destroy a mature country park as part of the construction process.

1.1.3 As a long-term resident of Wigmore since 1994, I have seen the airport grow almost uncontrolled from some 1.9 million passengers per annum (mppa) to 18mppa in 2019, pre-Covid.

1.1.4 There is almost constant ground noise at night and during the day as well as the noise of arriving and departing aircraft. Our property backs onto a park which itself is in line with the north east end of the runway. We can see arriving and departing aircraft just after take-off and just before landing, when the noise it at its loudest.

1.1.5 We have to sleep in the front bedroom but visitors cannot use the back bedrooms because of night noise. Even so there is no respite in the front because a neighbour's house across the street is oriented at 90 degrees to ours, and airport noise bounces off the solid gable wall which is a perfect sound reflector.

1.1.6 We cannot relax in our garden because of the noise, especially on weekends when there appears to be no break at all.

1.1.7 I believe there is fuel 'dumping' due ot the acrid smell and taste of volatile compounds.

1.1.8 There is widespread illegal parking on public roads, probably due to the high parking charges at the airport. Luton Borough Council's response is to start to implement residential parking permit schemes, i.e. residents now have to pay an added tax because of the airport's charges rather than LBC policing illegal parking using wardens, and hypothecating the fines.

1.1.9 Therefore I object to these DCO proposals unreservedly.

1.2 DCO Documentation

1.2.1 Despite all these major inconveniences set out above, we do not qualify for any sort of compensation such as insulation because of the criteria used by the Applicant.

1.2.2 The DCO consists of some 25,000 pages, a significant portion of which contains detailed technical data. It is almost impossible for a layperson to provide a comprehensive set of comments against the entire DCO.

1.2.3 Instead, this Written Representation confines itself to comments on noise mitigation through insulation.

1.3 Insulation Proposals

1.3.1 The Applicant's insulation proposals and eligibility criteria are not fit for purpose. They are lacking in detail, optimistic, incomplete, even contradictory, and do not meet the requirements of quoted DCO reference documentation.

1.3.2 As an example, the Applicant excludes Ground Noise from insulation eligibility criteria contrary to the Luton Local Plan.

1.3.3 There are no commitments to a prioritised programme of insulation works just a vague comment that there may be delays in getting insulation installed.

1.3.4 The insulation proposals rely heavily on dB L_{Aeq} T contours which are averages, and do not take account of the physiological and psychological effects of individual noise events particularly at night time.

1.3.5 The proposals do not consider internal noise levels within properties, their limits and testing methodology nor the treatment of 'legacy properties that have already had insulation.

1.3.6 It is my concern that this situation will not improve should the Applicant be successful in his current DCO submission (ref. performance under Project Curium, below) so I have put forward a suggested testing methodology in Section 6.

1.4 Comments on DCO Documents

1.4.1 This Written Representation provides comments upon, and a detailed cross reference to, the Applicant's documents and other relevant data sources:

Section 2: AS080 (Chapter 16: Noise and Vibration Rev 1) Comments
Section 3: AS096 (Chapter 16.1 Noise and Vibration Information Rev 1) Comments
Section 4: Chapter 16.2 Operational Noise Management Plan Comments
Section 5: AS128 (Chapter 7.10 Compensation Policy and Measures Rev 2) Comments
Section 6: App 5.02 Appendix 5.3 Noise Requirements and Compliance CAP 1616A Comments

1.4.2 Section 7: CAP 1588:2018 "Aircraft Noise and Annoyance: Recent findings"

1.4.3 It is hoped that the ExA will ask the Applicant to provide a comprehensive proposal that responds to observations raised and provide full relevant details.

1.4.4 It is hoped that the ExA will ask the Applicant will take into consideration CAP 1588: "Aircraft Noise and Annoyance: Recent findings" (Ref. 6) which is summarised in Section 7 and provides guidance on how annoyance is measured and what actions could be taken to mitigate noise impacts.

1.5 App 5.02 Appendix 5.3 Noise Requirements and Compliance CAP 1616A

1.5.1 The Government initiated the Independent Commission on Civil Aviation Noise (ICCAN) to provide best practice, in the mitigation of aircraft noise in properties. ICCAN produced a number of recommendations in their document "ICCAN review of airport noise insulation schemes March 2021" (Ref 7) but was then disbanded and subsumed into CAP 1616A which has not been updated.

1.5.2 It was expected that the Applicant would produce an insulation test programme as part of the DCO to back up the Compensation event of insulation provision. No such test programme has been forthcoming so the Applicant does not have a strategy to determine (a) what is being insulated; (b) whether the insulation is effective or (c) whether best practice is being followed.

1.6 Project Curium (doubling of passengers from 9mppa to 18mppa)

1.6.1 The Applicant has so far failed to carry out the requisite testing on insulation provided as part of Project Curium, despite achieving the maximum 18mppa by 2019 with attendant noise increases.

1.6.2 An insulation programme should have had similar momentum to the increase in passenger numbers but there was no commensurate prioritisation.

1.6.3 It is acknowledged that long-term exposure to noise is damaging to health yet many residents of Luton have not had noise mitigation via insulation, even where eligible. Nor has a testing regime been carried out to confirm insulation efficacy.

2 AS080 (Chapter 16: Noise and Vibration Rev 1) Comments

2.1.1 Page 1 Footnote

2.1.1.1 For the avoidance of doubt the following definitions apply throughout this document:

"

1. Air noise is defined as noise emissions from all aircraft movements in the landing and take-off cycle associated with the airport

2. Ground noise is defined as noise emissions from aircraft taxiing between stand and runway, engine testing, Auxiliary Power Units (APU) and fire training ground activities "

2.1.2 Page 9: Table 16.2

2.1.2.1 Paragraph 2.24 of NPSE states: "The second aim of the NPSE refers to the situation where the impact lies somewhere between LOAEL and SOAEL. It requires that all reasonable steps should be taken to mitigate and minimise negative effects on health and quality of life while also taking into account the guiding principles of sustainable development (paragraph 1.8). This does not mean that such negative effects cannot occur"

2.1.2.2 Daytime eligibility criterion for insulation is 54dB L_{Aeq},16h i.e. it lies between Daytime LOAEL of 51dB L_{Aeq} and Daytime SOAEL of 63dB L_{Aeq}, so meeting the requirement.

2.1.2.3 However, for Night-time noise there is no eligibility for insulation between LOAEL (45dB L_{Aeq} 8h) and SOAEL (55dB L_{Aeq}, 8h), so there is no provision made for levels between LOAEL and SOAEL.

2.1.2.4 Therefore the proposal does not meet NPSE paragraph 2.24 for levels between LOAEL and SOAEL. (Levels above UAEL are treated separately by either Voluntary Acquisition or Hardship)

2.1.3 Page 11: Table 16.2 'The Aviation Policy Framework (APF) (2013) (ref. 16.18)' – response.

2.1.3.1 Currently there is no Next generation technology and this is unlikely to be in general circulation until the mid 2030s. More importantly however; there is no guarantee that it will reduce noise.

2.1.4 Page 12: Table 16.2

2.1.4.1 'Beyond the horizon, The future of UK aviation: Making best use of existing runways (2018) (Ref. 16.22) ' The Applicant uses the 'making best use of existing runways' to argue for this egregious expansion to 32mppa, construction of a new terminal and the destruction of a country wildlife park.

2.1.4.2 However This document does not anticipate major increases in airports outside Heathrow for 'making most efficient use of runways'. Paragraph 1.28 states: "*Given the likely increase in ATMs that could be achieved through making best use of existing runways is relatively small (2% increase in ATMs "without Heathrow expansion" scenario; 1% "with Heathrow"), we do not expect that the policy will have significant implications for our overall airspace capacity……t."*

2.1.5 Page 15: Table 16.2 (in respect of insulation)

2.1.5.1 'Levels of Contributions affecting take-up'. There has been no assessment by the Applicant during or after the expansion from 9mppa to 18mppa n of levels of take up, whether it is acceptable or not, and the underlying reasons We have no confidence that the Applicant will be any more proactive this time round.

2.1.6 Page 15: Table 16.2 (in respect of insulation)

2.1.6.1 The Government disbanded ICCAN and subsumed it into CAP 1616. CAP1616 deals with Airspace Changes which is a national issue, not insulation which is a local and completely different issue, and is therefore not the most obvious forum for this topic. We have included a section on ICCAN recommendations later in this document

2.1.7 Page 15: Table 16.2 (in respect of insulation)

2.1.7.1 '...54dB L_{Aeq} 16hr contour or above as a new eligibility criterion for assistance with noise insulation.' This statement sets out a reduced level of noise as an insulation eligibility criterion for DAYTIME noise (and is reflected in the compensation criteria later on) but there is no mention of a similar reduction for NIGHT-TIME noise level eligibility. See also comment under Page 9 above (NPSE paragraph 2.24).

2.1.8 Page 17: 16.2.4

2.1.8.1 The Applicant picks and chooses elements of the ANPS to suit his argument, for example giving voice to the 'making best use of existing runways' but ignoring the restriction on night flights at Heathrow's third runway.

2.1.9 Page 18: Table 16.3

2.1.9.1 'Provision of noise insulation...' It may help within dwellings but no provision has been made to reduce external noise in gardens or on balconies, such as a reduction in night flights..

2.1.10 Page 25: Table 16.4

2.1.10.1 WHO Night Noise guidelines are discussed in this document under CAP 1616 issues (Section 6).

2.1.11 Page 30: Table 16.5 Paragraph 4.5.10

2.1.11.1 Noted that BS5228 is referenced for Construction noise, but not referenced for Air or Ground noise within premises.

2.1.12 Page 31: Table 16.5 Paragraph 4.5.14

2.1.12.1 The Applicant has altered significantly the eligibility criteria and provisions for insulation compared to the existing policy, without justification. The Applicant thus fails to meet Paragraph 4.5.14.

2.1.12.2 Of particular concern is that the Applicant refers to the existing 'Air Noise' insulation policy except that existing policy includes insulation against Ground noise as well as Air noise. These alterations are discussed under Chapter 7.10 ''Compensation'.

2.1.12.3 Current eligibility criteria for insulation in Residential properties:

- Air Noise Daytime: Habitable rooms within the 63dB L_{Aeq} 16h contour
- Air Noise Night-time: Habitable rooms within the 55dB L_{Aeq} 8h contour
- Ground Noise Daytime: Bedrooms within the 55dB L_{Aeq} 16h contour
- Ground Noise Night-time: Bedrooms within the 45dB L_{Aeq} 8h contour
- Any property experiencing noise greater than 90dB SEL at least once per night

Note 1: Noise levels stated are external to properties, not internal to properties
Note 2: There are sliding scales of compensation related to noise levels
Note 3: The threshold for Ground Noise is 10dB lower than that for Air Noise.

2.1.13 Page 33: 16.3.11

2.1.13.1 Ground Noise study area is included with the Construction Noise study area. Construction is a temporary phenomenon (if one can call 14 years 'temporary), the other is Permanent. Noise monitors placed along Eaton Green Road area only. The Applicant does not state how long will these monitors stay in situ and how will the outputs be recorded and disseminated.

2.1.14 Page: 34: Table 16.6

2.1.14.1 The Construction Programme shows construction taking place for eleven years between 2025 and 2040. There is a big gap between 2027 and 2033 when allegedly no construction operatives will be on site. However through incentivisation by LBC I have seen acceleration in airport throughput between 2014 and 2019 which was not supposed to take place until 2028 and which resulted in exceeding noise limits. I assume this situation should be managed under 'Green Controlled Growth'.

2.1.15 Page: 35 Footnote 7

2.1.15.1 It is all very well having a place of 'tranquillity' but this cannot normally be accessed after dark or during inclement weather. What residents need is ‘tranquillity’ in their own property.

2.1.16 Page 42:16.3.19

2.1.16.1 The Local Authority (LBC) should undertake that they will maintain the highway outside the Proposed development to the same high standard as within.

2.1.17 Page 56: 16.5.55 final sentence

2.1.17.1 Luton Airport expanded from 2014 to 2019 with little mitigation (and breached noise limits on several occasions). Therefore already high levels of noise are being increased.

2.1.18 Page 65: 16.6.9

2.1.18.1 Sensitivity tests assume next generation aircraft will be no noisier than current aircraft and maybe even a little bit quieter. The Applicant has carried out a sensitivity test assuming quieter aircraft but has neglected to do the same for aircraft being noisier.

2.1.19 Page 68: 16.6.18 Ground Noise model assumptions and limitations

2.1.19.1 DCO states: “

16.6.18 Ground noise modelling is limited to predictions, and it has not been possible to validate the predictions to the same extent as air noise due to the dominance of air noise and the inability to distinguish between ground noise and air noise from noise monitoring terminal data. “

Paragraph 16.6.19 sets out the underlying assumptions.

2.1.19.2 Note 1: Figures are Based on Predictions not Actuals.

2.1.19.3 Note 2: Ground noise is more long-term than air noise which although dominant tends to dissipate quickly My experience is that I can hear ground noise almost continuously on busy days, interspersed with the take-off and landing noise which lasts a short time but which is much louder.

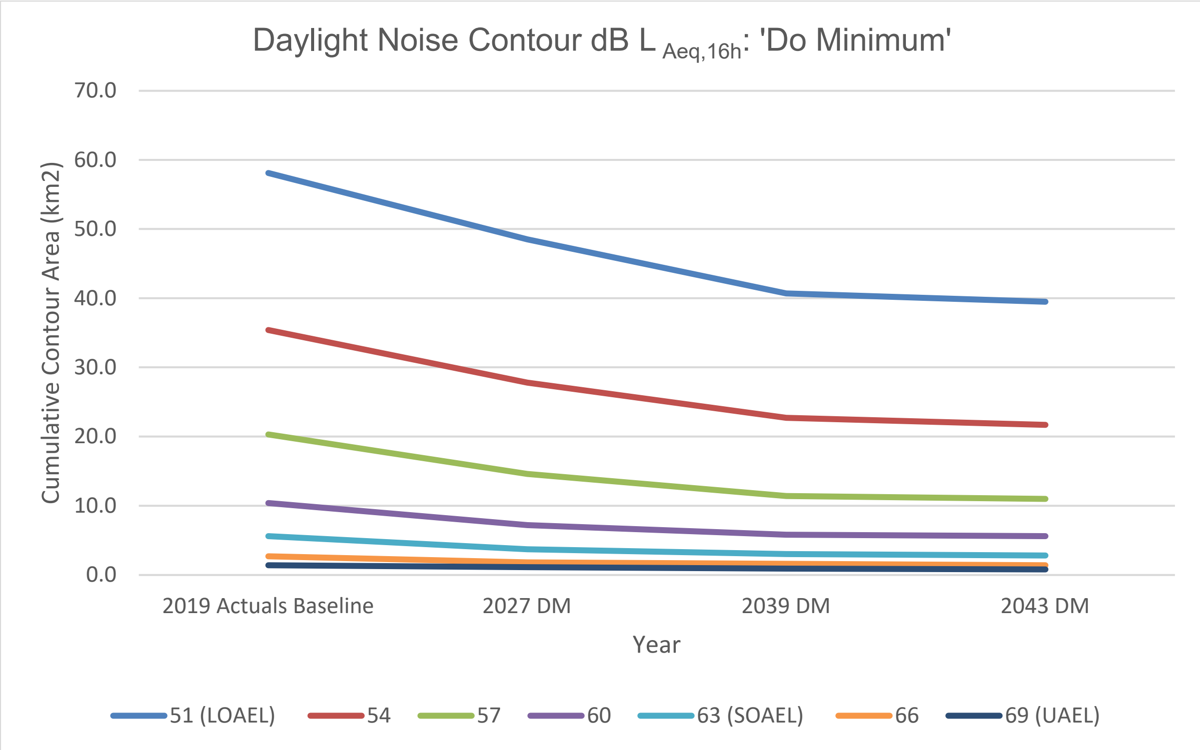
2.1.20 Page 71: 16.7.2

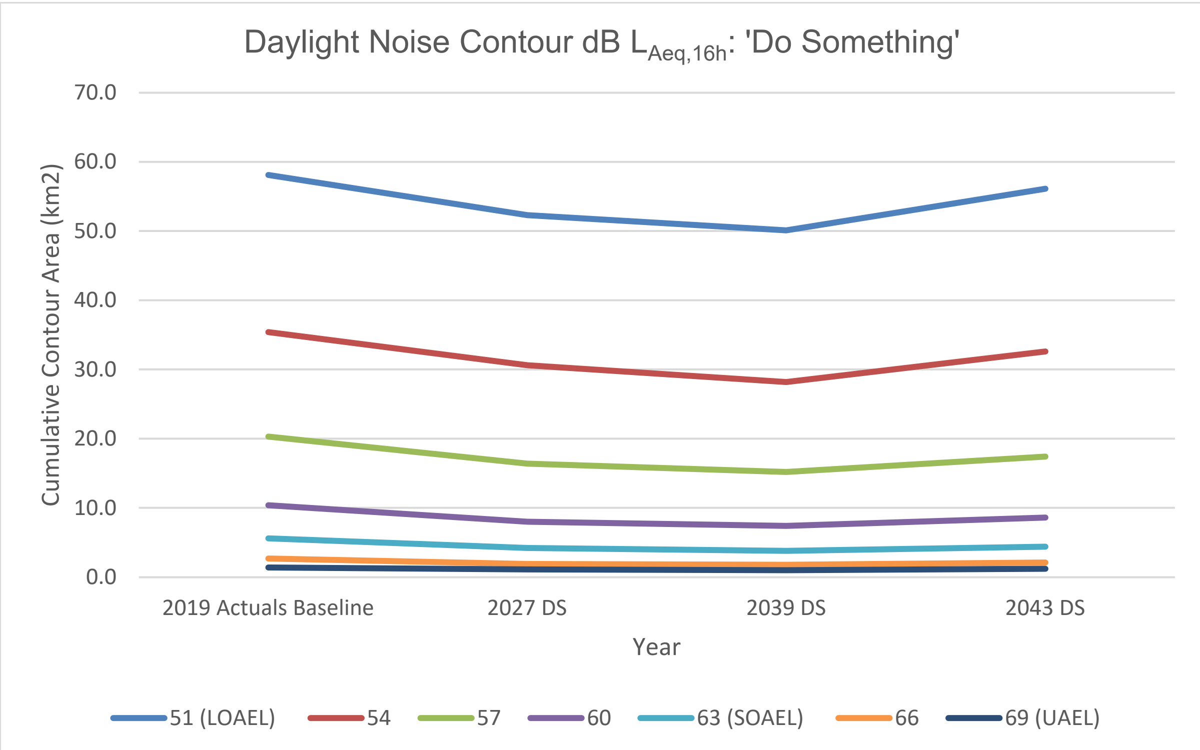
2.1.20.1 Paragraph states: '....*it can be concluded that there are no significant effects for any other receptors in the study area'*. The Applicant does not specify what would happen if significant ground noise was detected.

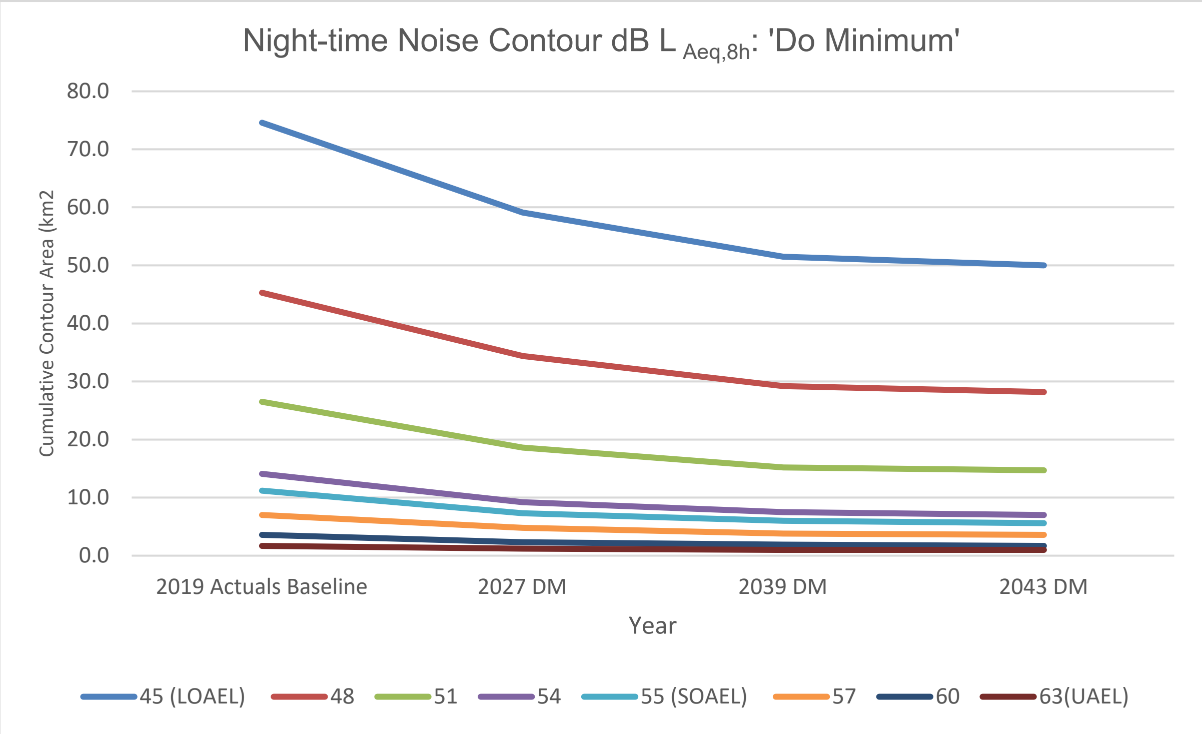
2.1.21 Page 77: 16.7.17

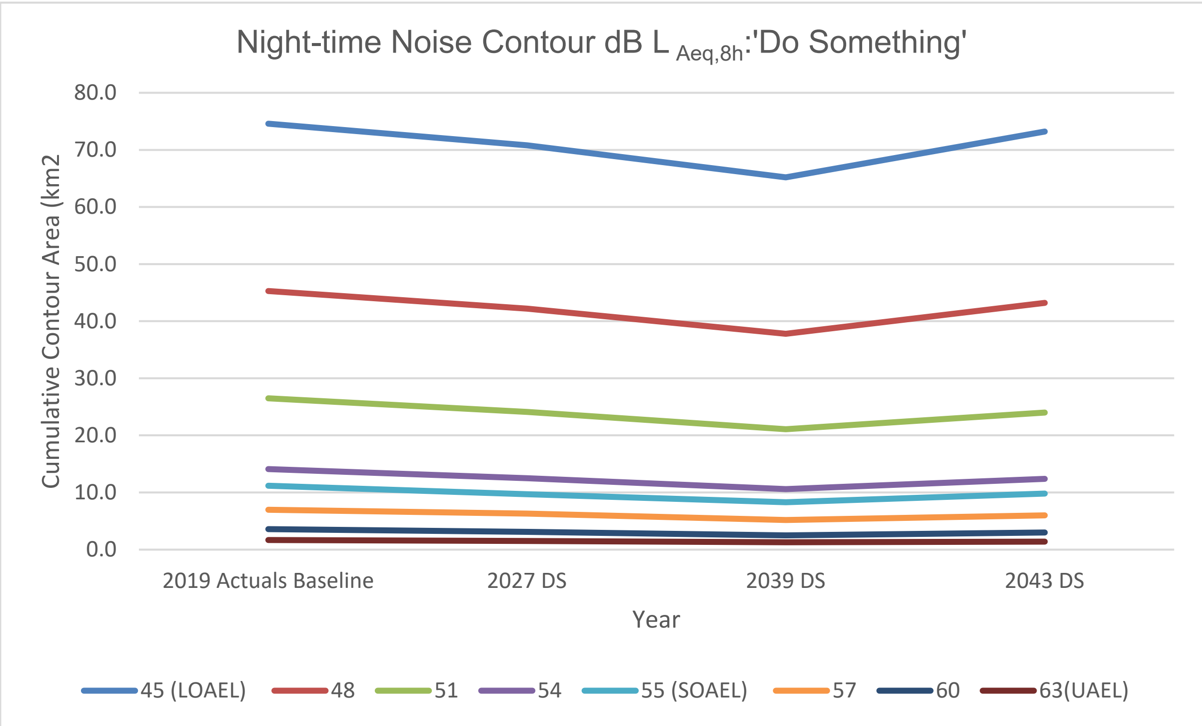
2.1.21.1 Noise contour tables are presented in Tables 16.26, 16.34, 16.41, 16.48: ‘Evolution of daytime air noise baseline’ and Tables 16.27, 16.35, 16.42, 16:49: ‘Evolution of night-time air noise baseline’ for the DM and DS scenarios.

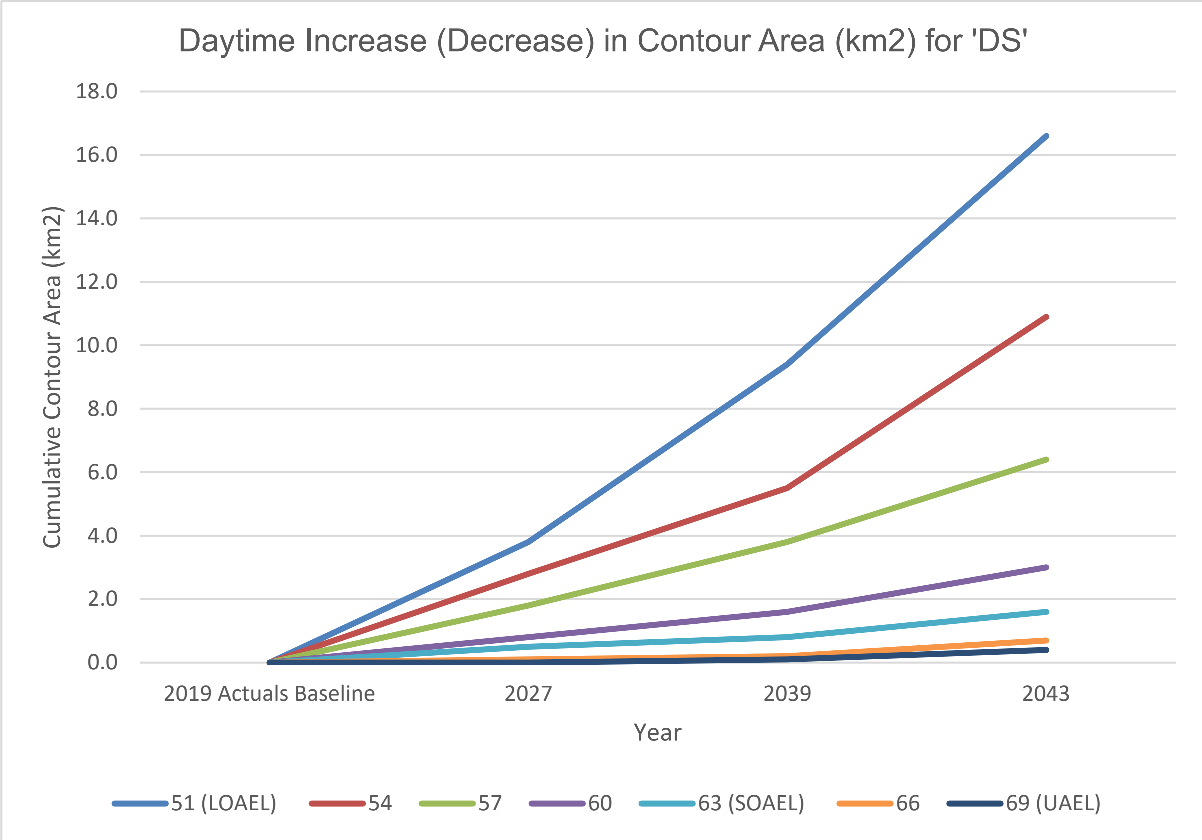
2.1.21.2 However, it is not until the data are presented in graphical form (below) that the true scale of the affected area is revealed. Note this is the area affected by Air Noise contours only and does not include other effects such as Ground Noise and other sources, nor the cumulative effect of them. The overall impression given by the Applicant is that these changes are 'insignificant'. Clearly they are not, and more residents will be affected.

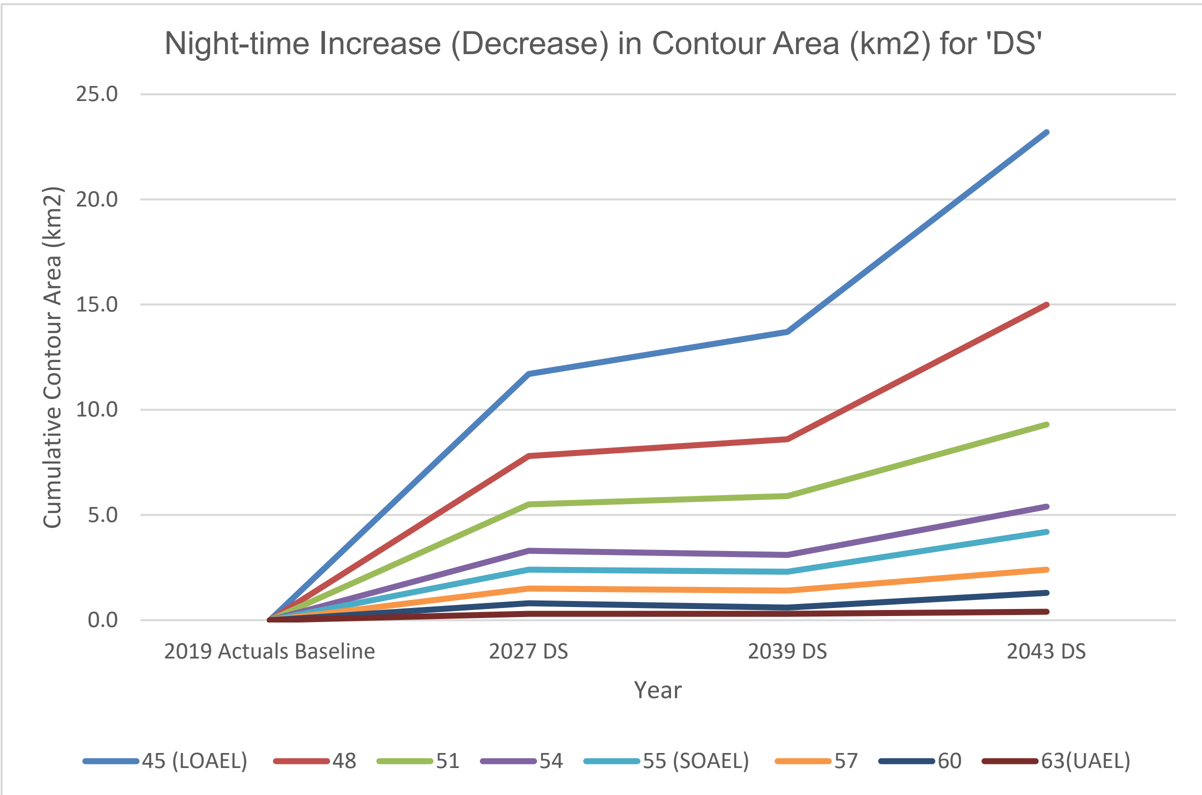





Night-time Noise Contour dB L Aeq,8h: 'Do Minimum'
Cumulative Contour Area (km2
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2019 Actuals Baseline
2027 DM
2039 DM
2043 DM
Year
45 (LOAEL)
48
51
54
55 (SOAEL)
57
60
63(UAEL)


Night-time Noise Contour dB L Aeq,8h:'Do Something'
Cumulative Contour Area (km2
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2019 Actuals Baseline
2027 DS
2039 DS
2043 DS
Year
45 (LOAEL)
48
51
54
55 (SOAEL)
57
60
63(UAEL)


Daytime Increase (Decrease) in Contour Area (km2) for 'DS'
Cumulative Contour Area (km2)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2019 Actuals Baseline
2027
2039
2043
Year
51 (LOAEL)
54
57
60
63 (SOAEL)
66
69 (UAEL)


Night-time Increase (Decrease) in Contour Area (km2) for 'DS'
Cumulative Contour Area (km2)
25.0
20.0
15.0
10.0
5.0
0.0
2019 Actuals Baseline
2027 DS
2039 DS
2043 DS
Year
45 (LOAEL)
48
51
54
55 (SOAEL)
57
60
63(UAEL)

2.1.22 Page 83:16.8.12 Airbus A321 Neo

2.1.22.1 The noise from this aircraft, measured by the Airport Operator in some locations, has been louder than that of the A321CEO at the same location, and it offers no perceptible noise reduction particularly on arrivals.

2.1.23 Page 84: 16.8.19

2.1.23.1 No specification provided as to the attenuation provided by the acoustic barrier.

2.1.23.2 It is assumed that Ground noise contours for the 2027 DS scenario onwards includes the effect of this barrier in any case.

2.1.24 Page 85: 16.8.22

2.1.24.1 It is not clear what type of environmental/noise barrier and its performance will be installed on the Airport Access Road (AAR) to minimise noise onto Eaton Green Road.

2.1.25 Page 88:16.9.9

2.1.25.1 Surface Access Noise will be insulated against if it is found to be above SOAEL after construction. The Applicant does not specify how, or whether this will be dealt with by the relevant sub-committee.

2.1.26 Page 88: 16.9.11

2.1.26.1 As commented previously (2.1.2.3 above) the reduction to 54dB L_{Aeq} applies for Daytime but there is no reduction for Night-time.

2.1.26.2 Note this paragraph does not distinguish between Air and Ground noise but this is distinguished elsewhere.

2.1.27 Page 102: 16.9.81

2.1.27.1 These comparisons are misleading. For instance, a change in aircraft fleet composition will happen anyway, as a result of the drive to Net Zero and general technological advances driven by manufacturers and operators profits which produce New and Next generation aircraft. Therefore, if the airport supports even the same number of ATMs as in 2019, there will be less noise - assuming the fleet composition will be the same for each (DM, DS) scenario.

2.1.27.2 Page 108 16.9.97 As commented previously (2.1.2.3 above) the reduction to 54dB L_{Aeq} applies for Daytime but there is no reduction for Night-time.

2.1.28 Page 123:16.9.143

2.1.28.1 The proposed increase in ATMs is totally unacceptable. By Phase 2B: Daytime increase = 62% and Night-time increase = 76% (and also allowing for the Night Quota limit of 9650 movements from 23:30 to 06:00.).

2.1.28.2 The shoulder period 23:00-23:30 and 06:00-07:00 will be unimaginably busy.

2.1.29 Page 128: 16.9.162 (also applies to 16.9.180 and 16.9.199)

2.1.29.1 This optimistic forecast compares the DS case to 2019, but does not mention that comparing the DM case to 2019 provides better results, i.e. less people exposed to fewer ATMs. Also assumes new generation aircraft will be less noisy but as per the A321 Neo (see 2.1.22 above) this may not be the case.

2.1.30 Page 146: 16:9.229 states:

2.1.30.1 "*Many properties in the vicinity of Crawley Green Road, either side of Wigmore Lane, are expected to experience minor increases in surface access noise as a result of traffic increases on Crawley Green Road. Given these increases are likely to result in little change to the overall acoustic environment, significant adverse effects at these properties are unlikely, excepting where the absolute DS noise level is above the SOAEL. These properties (approximately 55) are located close to Crawley Green Road, between Vauxhall Way and Hedley Rise* "

2.1.30.2 I have the following concerns:

1. The section of Wigmore Lane in front of ASDA will be made into a 4-lane section, with signallised junctions at either end. Other roundabouts will be similarly converted to signallised junctions. This will serve only to increase noise due to acceleration from lights as well as deceleration approaching them.

2. Furthermore, there will be an increase in traffic heading for the new Terminal 2 along the whole of Wigmore Lane, a two-lane carriageway (from Hitchin A505) and this is likely to cause congestion when one considers that there are three schools in its vicinity: Ramridge Primary, Wigmore Primary and Queen Elizabeth school. Not only will there be more noise there will be more pollution.

3. The Applicant be asked to clarify if the modelling actually allows for the development of some 660 and 1400 properties that are planned around Mangrove and Cockernhoe (NHDC 16/02014/1 and 17/00830/1 respectively). The traffic to this development will use Crawley Green Road. Under the library document '21.2 Short List of Other development' it is noted that 16/02014/1 was not included in the Transport Assessment (although it is appreciated that this may not refer to this DCO it requires clarification).

2.1.31 Page 152: 16.9.255 'Combined Effects' states:

2.1.31.1 "The potential for combined noise effects due to exposure to multiple sources of noise has been considered qualitatively as there is no reliable means of quantitatively assessing the overall noise effects resulting from combined exposure to multiple noise sources".

2.1.31.2 The Applicant does not consider that there are any significant combined effects from a combination of Air, Ground, Surface Access and Construction noise. This is clearly not true. Receptors along Eaton Green Road for example will be subject to Air, Ground and Construction noise as well as surface access noise, which will be cumulative.

2.1.31.3 The Applicant makes similar comments in App 5.01 Chapter 21: "In-combination and Cumulative Effects", just by way of example:

"21.2.20 The changes in operational air noise associated with the Proposed Development has the potential to have a significant effect upon human (residential) receptors due to exceedances in the SOAEL (as defined in Chapter 16 of this ES [TR020001/APP/5.01]). This would impact upon those human (residential) receptors in close proximity to the Proposed Development and/or under the flight path. ….. All other individual noise effects upon human (residential) receptors are considered negligible to minor adverse and not significant.

21.2.21 Air noise impacts experienced by residents under the flight path (as identified in Chapter 16 of this ES [TR020001/APP/5.01]) would likely occur …."

2.1.31.4 It is notable in 21.2.20 that the Applicant completely ignores the effect of Ground Noise and only addresses Air Noise.

2.1.32 Page 152: Table 16.74 19 mppa planning consent

2.1.32.1 There is no sensitivity test for the situation where the 19mppa is not granted.

2.1.33 Page 152: Table 16.74 'Faster Growth Scenario'.

2.1.33.1 The Applicant has in the past gone for faster growth. If he achieves 23mppa in 2027 rather than the planned 21.5 mppa, this will just generate more noise and more emissions. The sensitivity tests are meaningless and go on to conclude that there are no significant effects relative to the 2019 scenario. The Applicant ignores one vital point - the level of insulation of eligible properties from 2014-2019 is extremely low so many people are already exposed to very high noise levels either because they have not responded to the insulation offer in time (and been 'locked out' for 5 years) or have just moved into the area.

2.1.33.2 The Proposed development merely exposes them to even higher noise levels – although the Applicant generally describes the differences as ' insignificant'..

2.1.33.3 It has to be assumed that Green Controlled Growth (GCG) strategy will deal effectively with this situation

2.1.34 Page 154: Table 16.74 'Next Generation Aircraft are quieter in future ears'.

(See also Paragraph 16.10.10)

2.1.34.1 The Jet Zero strategy has been criticised as largely aspirational.

2.1.34.2 The sensitivity test used by the Applicant is biased in his favour, i.e. less noisy Next gen. aircraft. However there is no sensitivity test for Next Generation aircraft being noisier, particularly electric aircraft on arrival due to no weight reduction during the journey, and hydrogen aircraft in general due to a larger airframe.

2.1.35 Page 159: 16.10.5 ‘Air noise insulation’ states:

"As part of the Proposed Development, the current air noise insulation scheme administered by LLAOL will be updated if development consent is granted. The updated noise insulation scheme improves on the current scheme and goes beyond the government proposals set out in Aviation 2050. The proposed residential noise insulation scheme sets a five-tiered scheme as follows:…..

2.1.35.1 It has ot be emphasised that the current insulation scheme is not limited to Air Noise but includes Ground Noise as well.

2.1.35.2 Noise Insulation issues are further discussed under 'Chapter 7.10 Compensation'

2.1.36 Page 160: 16.10.9

2.1.36.1 The Applicant provides no numerical data to determine the performance expected of the insulation.

2.1.37 Page 162: 16.11.4

2.1.37.1 If past performance is anything to go by (see later Sections), these 'temporary adverse effects' due to lack of insulation are likely to be long term. This applies to all Phases.

2.1.38 Page 163: 16.11.9 Ground Noise (All phases)

2.1.38.1 This paragraph talks about Air Noise, not Ground Noise (which has yet to be measured as opposed to modelled).

3 AS096 (Chapter 16.1 Noise and Vibration Information Rev 1) Comments

3.1.1 Page 196: Table 7.41: Daytime 2019 Actuals Baseline v DS 2027 Air Noise Analysis – Households

L_{Aeq},16h dB Noise Contour	2019 Actuals Baseline Cumulative Number of Households	2027 DS Cumulative Number of Households	Change in Cumulative Number of Households
51 (LOAEL)	**20,900**	**16,500**	**-4,400**
54	11,400	7,750	-3,650
57	6,000	4,400	-1,600
60	2,800	1,450	-1,350
63 (SOAEL)	**650**	**150**	**-500**
66	<50	0	-<50
69 (UAEL)	**0**	**0**	**0**

3.1.2 Page 197: Table 7.44: Night-time 2019 Actuals Baseline v DS 2027 Air Noise Analysis – Households

L_{Aeq},8h dB Noise Contour	2019 Actuals Baseline Cumulative Number of Households	2027 DS Cumulative Number of Households	Change in Cumulative Number of Households
45 (LOAEL)	**32,950**	**27,150**	**-5,800**
48	15,200	12,000	-3,200
51	7,100	6,200	-900
54	3,950	3,100	-850
55 (SOAEL)	**2,650**	**1,950**	**-700**
57	1,150	700	-450
60	50	<50	-<50
63 (UAEL)	**0**	**0**	**0**

But: from the 2023 Insulation Eligibility Document for Residential Dwellings (based on 2019 actuals) we get:

	No. of Dwellings
Air Noise Daytime 63 dB L_{Aeq},16h	813
Air Noise Night-time 55 dB L_{Aeq},8h	1,761

3.1.2.1 The Applicant does not explain the apparent anomalies between these figures.

3.1.3 Page 204: Paragraph 8.1.1

3.1.3.1 This states that '*improved aircraft taxi routes will reduce time spent by aircraft travelling between aircraft stands and the runway'*. Surely this only applies when the wind direction favours the shortest route; if the prevailing wind determines that the aircraft take off from the farthest end of the runway there is no saving.

3.1.3.2 If Air Noise and Ground Noise are to be treated equally (as per paragraph 8.1.2: "…*the LOAEL and SOAEL for air noise presented in Table 7.2 are considered applicable to ground noise*") then it must be assumed that insulation against Ground noise is treated equally as for Air noise.

3.1.4 Page 204: Paragraph 8.2.2

3.1.4.1 This sets out the sources of ground noise but does not include the noise of fuel bowsers which must travel between the (relocated) fuel storage depot and the stands.

3.1.5 Page 209: Table 8.3

3.1.5.1 This sets out Ground Noise predictions for 2027. Daytime Ground noise ranges from 52.1 L_{Aeq} 16h at GR21 (Eaton Place Area) to 62,5 dB L_{Aeq} 16h at GR4 (Dane Street).

3.1.5.2 Night-time Ground noise ranges from 47.31 L_{Aeq} 8h at GR21 (Eaton Place Area) to 58.7 dB L_{Ae}q 8h at GR4 (Dane Street).

3.1.5.3 Therefore many of these locations would qualify for insulation on Ground Noise alone assuming eligibility as for Air Noise, particularly 54dB L_{Aeq} 16h (daytime).

4 Chapter 16.2: Operational Noise Management Plan Comments

4.1.1 Section 4: Noise Insulation

4.1.1.1 This contains only two sub-sections

(i) paragraph 4.1 Air Noise
(ii) paragraph 4.2 Surface Access Noise

4.1.1.2 Section 4 does not mention Ground Noise Insulation AT ALL.

4.1.1.3 This is contrary to Paragraph 3.2.2 of Chapter 16.1 which refers to Luton Local Plan Policy LLP6:

*" c. achieve further noise reduction or no material increase in day or night time noise or otherwise cause excessive noise **including ground noise** at any time of the day or night and in accordance with the airport's most recent Airport Noise Action Plan;*

4.1.1.4 This section fails to meet the requirements of the Luton Local Plan.

5 AS128 (Chapter 7.10 Compensation Policy and Measures Rev 2) Comments

5.1.1 Page 2: 1.1.7 states

"This document sets out discretionary Compensation Policies and Measures that will be an enhancement upon the statutory position and would be secured in a s106 agreement entered into by the Applicant similarly to how the existing noise insulation scheme is secured. In accordance with section 106 of the Town and Country Planning Act 1990, planning obligations secured in such an agreement are enforceable against the Applicant as the entity entering into such an agreement……"

5.1.1.1 The Applicant does not identify all the parties to the Section 106 Agreement and who will carry out Governance and oversight.

5.1.1.2 Currently LLAOL, not the Applicant, provides insulation to their own timescale.

5.1.2 Page 16: 6

5.1.2.1 The Applicant's Insulation Scheme for Residential Properties is as follows:

Insulation Scheme
Scheme 1 – a full package of agreed noise insulation works to habitable rooms;
Scheme 2 – for residential properties inside the 60dBLAeq,16h contour and outside the 63dBL_{Aeq},16h contour, a contribution of up to £20,000 for agreed noise insulation works to habitable rooms;
Scheme 3 – for residential properties inside the 55dBLAeq,8h contour and outside the 60dBL_{Aeq},16h contour, a full package of agreed noise insulation works to bedrooms;
Scheme 4 – for residential properties inside the 57dBL_{Aeq},16h contour and outside the 60dB L_{Aeq},16h contour, a contribution of up to £6,000 for agreed noise insulation works to habitable rooms; and
Scheme 5 – for residential properties inside the daytime 54dB L_{Aeq},16h contour and outside the 57dB L_{Aeq},16h contour, a contribution of up to £4,000 for agreed noise insulation works to habitable rooms

5.1.2.2 The "improved" noise insulation scheme is complex and over-reliant on dB L_{Aeq} T noise contours only.

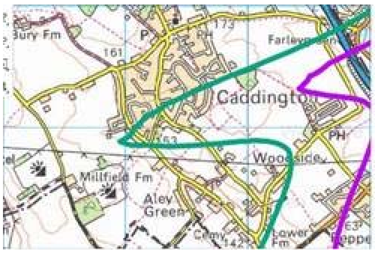
5.1.2.3 The ExA will wish to test whether it is feasible to make a sensible judgement on eligibility for Scheme 3 (for example) in Table 1.1 of AS-128 when the criteria ("*Residential property inside the night-time 55dBL$_{Aeq}$,8h contours and outside the daytime 60dBL$_{Aeq}$,16h contour*") indicate for the most part a vanishingly small area between the blue and orange/blue outlines on the contour maps in AS-126, thinner than the lines themselves.

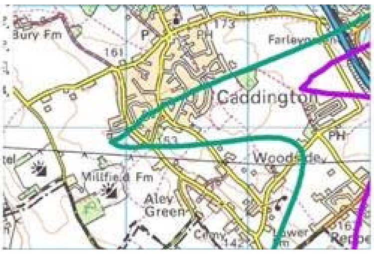
5.1.2.4 Caddington is of particular concern: flight arrivals pass directly over residential areas of the village at low altitude and peak noise levels are equivalent to those in Breachwood Green yet, based on noise contours alone, most of Caddington is ineligible for noise insulation and the fraction which is can only claim under Scheme 5, inside the blue/green and outside the mauve lines on the maps in AS-126: the least effective insulation option.

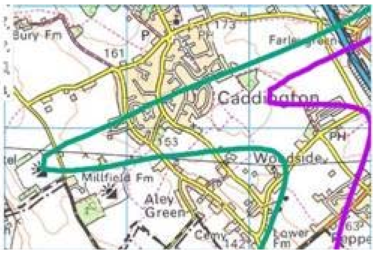
5.1.2.5 Arrivals noise is known to reduce comparatively little if at all for a modernised aircraft compared to one which is unmodernised and of the same size, because on arrival most noise is generated by the airframe.

5.1.2.6 If the fleet becomes modernised towards larger aircraft, then logically the arrivals noise can only progressively worsen.

5.1.2.7 The extracts from AS-126 below show the evolution of the contours over Caddington as numbers of flights increase: by Phase 2b there would be 70% additional night flights per annum, but the increasing contours barely include any additional homes and do not reflect the additional health harms. Basing noise insulation on the N-above contours or on peak noise values measured in homes may be more appropriate in this case.







5.1.2.8 AS128 does not distinguish between Air Noise and Ground Noise whereas AS080, paragraph 16.9.253 states that only Air noise will be insulated against, apart from a few properties in Dane Street and Someries Castle which will be insulated against Ground noise.

5.1.2.9 As commented previously, the insulation policy needs to incorporate all noise sources, not just Air.

5.1.2.10 It is assumed therefore, that Ground Noise, Air Noise, Surface Access and Construction noise all fall under this insulation purview although the ExA may request the Applicant to confirm.

5.1.2.11 Although Air Noise and Ground Noise LOAELs etc. are the same, they are different to Surface Access and Construction Noise LOAELS etc. Thus, Table 1.1 and the text of this document (and related documents) should be updated to reflect.

5.1.3 Page 16: 6.1.1

5.1.3.1 Noise insulation is only a form of compensation, not comprehensive aircraft noise mitigation. Noise insulation is ineffective if people open their windows at night in summer, or use a balcony, or are in the garden, or wish to peaceably enjoy a park or outdoor public space affected by overflights.

5.1.4 Page 16: 6.1.2

5.1.4.1 The Applicant needs to appreciate that not only permanent structures but parked mobile home sites such as those in Half Moon Lane in Pepperstock are directly overflown and badly affected by aircraft noise so will also need the additional insulation where eligible.

5.1.5 Page 16: 6.1.4

5.1.5.1 The insulation eligibility criteria are all based on dB L_{Aeq} which is an average. It does not take into account peak noise which affects residents. See also 5.1.2.2 above.

5.1.5.2 The current scheme provides insulation where a property is subject to greater than 90dB SEL at least once per night thereby reflecting better the impact of short duration high intensity noise.

5.1.5.3 The Applicant does not state whether properties previously insulated to a ‘lower’ standard then now being proposed (under the less financially generous Project Curium arrangements and/or by residents having paid for noise insulation themselves) would be eligible for upgraded insulation due to the significantly increased noise footprint of the proposed expansion. Nor does the Applicant state whether properties that failed to respond to the original Project Curium insulation letter and are ‘locked out’ for five years, will also be approached

5.1.6 Page 17: 6.1.10

5.1.6.1 This insulation proposal does not make sense (refer to 5.1.5 above). Under this system, a property that is exposed to 54dB L_{Aeq} 8h gets no compensation at all even though it is only 1dB below SOAEL, whereas a property exposed to 54dB L_{Aeq} 16h and is 9dB below SOAEL gets £4,000. This is not equitable when receptors are more sensitive to night noise and all measures of LOAEL, SOAEL and UAEL reflect.

5.1.7 Page 18: 6.1.13

5.1.7.1 The existing insulation scheme <u>excludes</u> properties built after 2014, the year the Applicant was permitted to increase throughput from to 18mppa by 2028. The policy was not clear as to whether properties in the process of being built, or who had Planning Permission agreed but not started, are also excluded.

5.1.7.2 The Applicant should specify if there are any similar restrictions in his insulation policy.

5.1.8 Page 18: 6.1.13

5.1.8.1 As part of the Planning Conditions for Project Curium to increase throughput from 9mppa to 18mppa the Applicant was required to introduce a noise insulation scheme. No programme was circulated

5.1.8.2 A throughput of 18mppa together with the significant increase in noise, was achieved in 2019, well ahead of the planned date of 2028. However the Applicant by 2019 had only approached 268 of the 2,300-odd residential properties eligible for some form of insulation and none of the 14 non-residential properties eligible for insulation. This was pre-Covid so the pandemic could not be blamed as a reason for delay.

5.1.9 Page 18:6.1.15

5.1.9.1 This assumes a process of noise measurement. However, Noise monitoring carried out by LLAOL does not include noise monitoring in the areas not directly underneath the flight path, so ignores particularly those defined by the <u>Ground</u> noise contour maps. See for example “2023 Noise Monitoring Schedule” version 1.0. (Ref. 1) Without monitoring of the actual noise experienced by receptors, and its composition, it is difficult to see how the Applicant can confidently produce noise contour maps.

5.1.10 Page 18: 6.1.16

5.1.10.1 There is no commitment to a programme so the Applicant cannot be held to account. This needs to be driven by timescales otherwise residents may be subject to high levels of noise for an extended period. This becomes a Health and Safety issue.

5.1.10.2 What is not clear in the DCO is who has Duty of Care - Luton Borough Council, the Applicant or LLAOL, under the Section 106 Agreement.

5.1.11 Page 18: 6.1.17

5.1.11.1 The Applicant needs to be more specific. To date a first-class stamped envelope has been posted to eligible properties. The enclosed letter does not explain the health issues which insulation is designed to ameliorate and the letter is addressed to the 'occupier'. It is no wonder that few respond especially if they are tenants and not owner-occupiers.

5.1.11.2 Historically here has been a low take up of insulation but no investigation by the Applicant as to the causes and how this could be improved. The Applicant does not set out in detail what the procedure will be in future, for example: (a) whether owners will be traced through the Land Registry, or (b) whether registered post will be used instead of a first class stamp.

5.1.12 Page 18: 6.1.17

5.1.12.1 Currently the addressee has only 30 days (give or take) in which to respond to the insulation offer letter. If they fail to do so they are approached again only after 5 years. The Applicant needs to specify what if any limitations are being proposed in the DCO.

5.1.13 Page 18: 6.1.17 A

5.1.13.1 A pre-procured Contractor will not be able to carry out works to a Listed building without consent, granted to the owner. Therefore there should be a separate Scheme set up which accommodates these instances and potentially where the Applicant pays the owner to employ a specialist contractor once Listed Building consent has been granted.

5.1.14 Page 18: 6.1.18

5.1.14.1 It is assumed this will be included in the letter to the owner.

5.1.15 Page 19: 6.1.21

5.1.15.1 See separate comments below in relation to CAP 1616A.

5.1.16 Page 19: 6.1.21

5.1.16.1 There is no specification of the measurements that should be taken prior to and post installation, nor the expected noise levels within properties after treatment. This does not follow any scientific method and does not call up a traceable specification such as BS8233 (Ref.3), or WHO recommendations.

5.1.17 Page 19: 6.1.22

5.1.17.1 There is little point in appointing a chairman of a committee that has no executive powers to require LLAOL to act in a timely manner.

5.1.18 Page 20: 6.1.28

5.1.18.1 The comments applied above to aircraft noise equally apply here.

6 App 5.02 Appendix 5.3 Noise Requirements and Compliance CAP 1616A Comments

6.1 Introduction to ICCAN

6.1.1 Noise figures presented by government and associated publications discuss levels of noise typically in terms of ‘*dB L_{Aeq} 16h*’. These are figures either generated from models such as AEDT or from long-term measurements made by specialised microphones.

6.1.2 However they share one shortcoming – they are EXTERNAL measurements and do not reflect the level of noise experienced within a property.

6.1.3 The Government initiated the Independent Commission on Civil Aviation Noise (ICCAN) to provide best practice, in the mitigation of aircraft noise in properties. ICCAN produced a number of recommendations in their document “ICCAN review of airport noise insulation schemes March 2021” (Ref 7):

Table 6.1: ICCAN Recommendations

	1. Insulation Products and Systems
1	ICCAN is committed to improving standards related to mitigating the effects of aircraft noise and recommends that a set of guidance should be created directly related to mitigating aircraft noise including the required product standards. This would include examining current British Standards (BS) to determine how effective they are at covering aviation noise.
2	In order to create a more consistent approach to the selection of acoustic insulation products, ICCAN aims to develop a best practice toolkit that can help airports to identify an appropriate range of insulation products.
3	Given the risk of untested insulation products not providing appropriate levels of indoor noise reduction, ICCAN will only recommend the use of products that meet standards for acoustic insulation.
4	To help with the selection process for choosing insulation packages, the toolkit mentioned in recommendation 2 will consider the many different factors and requirements based on noise reduction requirements. This will include performance-based outputs for chosen acoustic insulation products.
	2: Testing of properties
1	ICCAN recommends that external noise monitoring is conducted in parallel to internal noise measurements and we will work with ANC to offer advice on updating their current guidelines.
2	It is important to develop an effective sampling strategy to test sound insulation in-situ. This could include testing a sample of properties of the same build type and surveying individual properties with more unique attributes, such as old stand-alone cottages.

3	The use of accurate and appropriate noise contours should be used for understanding noise levels and insulation performance over long time periods. ICCAN will be using our own forthcoming noise metrics best practice guidance to determine the best approach to the use of noise contours for estimating long-term external noise.
4	Setting a performance based indoor noise reduction target is a good approach to setting realistic expectations with property owners. ICCAN welcomes this approach; however, more work needs to be done to determine the criteria used in setting such targets throughout UK airports.
	3: Installation of insulation
1	ICCAN recommends property inspections and testing, in line with a detailed sampling strategy as mentioned in ICCAN principle 2 of Testing of Properties above.
2	A balance of both pre-determined solutions and tailored solutions should be used, depending on the attributes of the building. The noise contour approach will generally be acceptable for a range of properties with identical build qualities. The tailored approach should be used for unusual build types.
3	ICCAN recommends that airports should appoint approved contractors to install insulation products, but householders should be given the option to make non-technical decisions such as colour or style of window frames.
4	ICCAN recognises that in the majority of cases the 'room' approach to insulation will be appropriate. The 'perimeter' approach can be used at the discretion of the airport, depending on the build type and noise levels experienced.
	4: Building Regulations
1	ICCAN recommends a best practice approach is developed to address overheating. It will also explore the possibility of including an amendment to the Building Regulations, ensuring aviation noise is factored into any acoustic insulation works, including its impact on overheating.
2	The issue of condensation and how to mitigate it should be considered during the early stages of product selection for noise insulation schemes. Details of potential condensation issues and which specialists to contact for advice will feature in the toolkit as mentioned in ICCAN principle 2 under Insulation products and system
	5: Quality management
1	ICCAN recommends that only certified contractors should be used for the installation of noise insulation products.
2	ICCAN would look forward to adopting the role of a facilitator for the collaboration of relevant stakeholders to ensure the development of robust quality management standards relating to installation of acoustic insulation products.

6.2 Applicant Testing

6.2.1 The current insulation Scheme run by the Applicant in conjunction with LLAOL is supposed to carry out tests before and after insulation, as well as carry out post-installation satisfaction surveys, in accordance with the current Airport Noise Action Plan 2019-2023 (Ref. 2). Note that this plan pre-dates ICCAN's 2021 recommendations.

6.2.2 I understand that this has not happened even though the insulation scheme has been running for some years.

6.2.3 Therefore there is no record of insulation efficacy, nor a record of actual internal noise levels at any property to confirm that they are now at NOEL (No Observable Adverse Effect) or below, for example.

6.2.4 Table 6.2 below sets out the current testing regime specified on page 2 of LLAOL document "SEL definition" (Ref. 4) and which should have been followed by the Applicant. The table below also includes my comments on the tests.

Table 6.2: Current Testing Regime with comments

1. Test Arrangements	**Comment**
Acoustic tests are arranged on a sample of residential properties to measure the building both before and after the sound insulation works are carried out.	1.These tests do not reference a traceable standard such as BS8233 2.Sample size is not determined No respondents have yet reported testing being carried out either before or after installation. 3. Accuracy of the test equipment to be specified.
2. Aircraft noise measurements	
Measurements are made in accordance with an International Standard (BS EN ISO 16283-3). This includes simultaneous measurements of aircraft events both outside the house and inside the house. Measurements are made of individual aircraft events. These last around 20-30 seconds. We typically measure around 10 events per room. However, we look for at least 5 measurements of the more typical Easyjet/Wizz flights.	1.Height above ground of the external measuring equipment not stated, e.g. 1.5m for living room and 4m for bedroom. 2. External monitor location not specified e.g. which façade. 3. Free-field or facade measurement to be defined
3. Reverberation/echo measurements	
Aircraft sound levels inside habitable rooms will vary depending on how much reverberation/echo there is in a room. Aircraft noise levels will sound much lower in a living room with thick carpets, lots of soft furnishings, curtains etc. Aircraft noise will sound higher in a room with hard floor	1. Needs to specify acceptable levels of internal noise per room. 2. Need to clarify if there is reverberation caused by the amplitude and frequency spectrum of aircraft nose particularly on take-off and particularly on those premises

finish, blinds rather than curtains and little furniture. We therefore measure the amount of reverberation in the room and correct the results to the acoustic conditions of a standard habitable room. This enables a like for like comparison.	directly under the flight path. (Note: BS8233 defines reverberation as: "*time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped*") 3. Since each room is different, in respect of its response, any sample testing needs to be carefully thought through.
4. Background measurements	
We also must measure and correct for background noise. We need quiet conditions inside homes to measure aircraft noise accurately and residents are helpful at being quiet for our tests. Nevertheless, there will be continuous background sound which interferes with the measurements. This can be from external sources (A1081 and distant M1 noise) or this can be from internal sources (fridge hum). We measure this background noise and correct our results to minimize this effect.	Background noise measurement locations to be stated including internal and external.
5. Calculations	
We calculate the level difference between inside and outside (after correcting for echo/background). This provides a level difference in decibels. Typically, we would expect a performance of around 35 dB for a property treated under the scheme. We present the results of the test using a $D_{at,E,2m,nTw}$ metric. This provides an indication of the difference between inside and out. Therefore, if someone is exposed to 63 dB $L_{Aeq,16h}$ of noise outside then you would expect an internal noise level of 63-35=28 dB inside. This is somewhat of an over-simplification but hopefully provides some context as to the results.	Level difference (Attenuation) should be measured and recorded with windows and/or ventilators open and/or closed. Also if windows and ventilators closed should check internal room temperature and humidity to ensure comfortable conditions in worst case.
6. Review	
The results of the testing provide us with evidence as to whether the installation has "worked". If the result is poor this may indicate that the windows are not well sealed and/or there is an issue with noise coming into the room from a different path (roof for example). We also carry out visual inspections of the installed windows and	Assumes that remedial works will be carried out should any parameters fail the tests and visual inspections. Assume condensation is checked.

vents to see if these have been installed well.	
Assumption 1	Ground noise measured in the same way
Assumption 2	Traffic noise is not measured at all.

6.3 Noise Action Plan (NAP) 2019-2023

6.3.1 Section 4.1 and 4.2 of the NAP 2019-2-23 is reproduced below.

Ref:	Action	Impact	Timescale	Performance Indicator	Numbers Affected	Target
4.1	We will install acoustic insulation in eligible properties as part of our residential and non-residential Noise Insulation schemes.	Ground/ Departure/ Arrival Noise	Ongoing	Noise Insulation Scheme update in QMR and AMR.	Residents within 63dB Lday or 55dB Lnight or any property in which airborne noise level in excess of 90dB SEL occurs.	Continue to spend the full NIS budget annually. . NOTE: Maximum contribution of £3,800 per residence eligible for insulation (2023)
4.2	We will conduct an annual survey of those properties who have received noise insulation to measure the levels of satisfaction with the current Noise Insulation Scheme.	Ground/ Departure/ Arrival Noise	2019-2023	Annual Survey Results.	N/A	Conduct annual survey of insulated properties by the following February. Report results of survey to Noise and Track Sub-Committee

6.3.1.1 Note 1: The Ground Noise limits stated under 'Numbers Affected' differ from the limits specified in the 2023 Eligibility document, i.e. 63dB Lday (above) is reduced to 55dB and 55dB Lnight (above) is reduced to 45dB.

6.3.1.2 Note 2: A draft Noise Action Plan 2024-2028 was circulated for comment and with the exception of the date includes the same text as above.

6.4 Current Situation with ICCAN

6.4.1 ICCAN is now disbanded and its function falls within the scope of CAP1616A, Therefore many of its recommendations have been superseded by events. Those which are superseded have been ‘greyed out’ in Table 6.1.

6.4.2 It is very debatable as to whether and how CAP 1616A is an appropriate forum for insulation testing as CAP 1616A deals with airspace changes.

6.4.3 CAP 1616A has not yet been updated to incorporate the ICCAN recommendations or test methodologies nor set pass/fail limits. It was expected that the Applicant would produce an insulation test programme as part of the DCO to back up the Compensation event of insulation provision.

6.4.3.1 No such test programme has been forthcoming so the Applicant does not have a strategy to determine (a) what is being insulated and (b) whether the insulation is effective.

6.4.3.2 Therefore there is no record of insulation efficacy, nor a record of actual internal noise levels to confirm that they are now at NOEL (No Observable Adverse Effect) or below.

6.4.3.3 It is my concern that this situation will not improve should the Applicant be successful in his DCO submission so I suggest that a testing methodology such as the one set out below is adopted and implemented forthwith.

6.5 Health Impacts of Night Exposure to Aircraft Noise (WHO)

6.5.1 The World Health Organisation has produced a document “Night Noise Guidelines for Europe, 2009 (ISBN 978 92 890 4173 7) and describes in some detail the serious health impacts of noise exposure at night.

6.5.2 It also sets out what are acceptable limits of noise exposure both within and outside a property.

6.6 BS8233: 2014

6.6.1 BS8233:2014, “ Guidance on sound insulation and noise reduction for buildings” is a standard used for the acoustic design of buildings and has adopted WHO guidelines.

6.6.2 BS8233 Section 6.3.2"Prediction of noise from aircraft" as a useful introduction.

6.7 Suggested Testing Procedure

6.7.1 Table 6.3 below sets out a suggested BS8233 test procedure to meet the relevant ICCAN recommendations.

6.7.2 Appendix A provides the text of the referenced sections from BS8233.

Table 6.3: Proposed Insulation Test Procedure

	ICCAN Recommendation	Suggested BS8233:2014 References
	1. Insulation Products and Systems	
3	Given the risk of untested insulation products not providing appropriate levels of indoor noise reduction, ICCAN will only recommend the use of products that meet standards for acoustic insulation.	**See Section 8.3 "Sound Insulation tests"** in respect of laboratory testing of materials.
	2: Testing of Premises	
1	ICCAN recommends that external noise monitoring is conducted in parallel to internal noise measurements and we will work with ANC to offer advice on updating their current guidelines.	Properties are selected based on their location within noise contours but noise contours are not infallible (**see Section 6.3.2**). Measurements should be taken internally and externally, before and after insulation is installed. It is vital that internal and external noise measurements are made for each property BEFOREHAND to determine if insulation is even required - as this could save a lot of time and money.
		The equipment to be used for measuring noise levels should: a) conform to the accuracy requirements specified in BS EN ISO 140,BS EN ISO 10140 or BS 4142, as applicable; or b) if not stated, meet Class 2 or better (see BS EN 61672-1, BS EN 61672-2 and BS EN 60942). **See Section 4: "4 Measuring equipment and accuracy".**

ICCAN Recommendation		Suggested BS8233:2014 References
		Flanking Transmission It is not just the rooms facing the noise source that should be tested. All rooms need to be tested to determine if indirect (i.e. 'flanking') transmission takes place from one room to another. Example: a hallway would not be eligible for insulaton but it may be a noise conduit for other rooms. **See Section 8.3 "Flanking Transmission".**
		Since tests are carried out at different frequencies, the results must be converted to single-figure values. **See Annex C, C.4 "Rating Soud Insulation"**.
		Many variables affect the level of aircraft noise heard on the ground. Contours of daytime LAeq,T levels are available. Where measurements of facade insulation are necessary a test method is described in BS EN ISO 140-5. **See Annex D, D.5 "Aircraft noise"**
2	It is important to develop an effective sampling strategy to test sound insulation in-situ. This could include testing a sample of properties of the same build type and surveying individual properties with more unique attributes, such as old stand-alone cottages.	Sampling strategy has yet to be defined by LLA. But based on their testing procedure (see separate document) would imply that every property is different so requires to be dealt with on an individual basis.

ICCAN Recommendation		Suggested BS8233:2014 References
3	The use of accurate and appropriate noise contours should be used for understanding noise levels and insulation performance over long time periods. ICCAN will be using our own forthcoming noise metrics best practice guidance to determine the best approach to the use of noise contours for estimating long-term external noise.	LLA has been providing noise contours for a considerable period of time although they are now being produced to the Aviation Environmental Design Tool 3e (AEDT) as opposed to the Integrated Noise Model (INM). However, the noise contours refer only to external noise levels averaged over time, and not to Internal noise levels in a property. It is this measurement that determines the real impact on lives.
4	Setting a performance based indoor noise reduction target is a good approach to setting realistic expectations with property owners. ICCAN welcomes this approach; however, more work needs to be done to determine the criteria used in setting such targets throughout UK airports.	ICCAN do not specify any limits on what is an acceptable level of noise wihtin a property whilst BS8233 does**.** **See Section 7.7.2: Ambient noise levels for dwellings**, as well as S**ection 7.7.3.2: "Design criteria for external noise"** It is very possible that the 'acceptable' external noise level cannot be achieved for properties affected by LLA.
	3: Installation of insulation	
1	ICCAN recommends property inspections and testing, in line with a detailed sampling strategy as mentioned in ICCAN principle 2 of Testing of Properties above.	Sampling strategy has yet to be defined by LLA. But based on their testing procedure would imply that every property is different so requires to be dealt with on an individual basis.
2	A balance of both pre-determined solutions and tailored solutions should be used, depending on the attributes of the building. The noise contour approach will generally be acceptable for a range of properties with identical build qualities. The tailored approach should be used for unusual build types.	Irrespective of the determined solution, it must include for appropriate ventilation. **See Section 8.4.5.4**

ICCAN Recommendation		Suggested BS8233:2014 References
4	ICCAN recognises that in the majority of cases the 'room' approach to insulation will be appropriate. The 'perimeter' approach can be used at the discretion of the airport, depending on the build type and noise levels experienced.	LLA have selected the 'room' approach (actually 'room by room') and are unlikely to change this stance.
	4: Building Regulations	
1	ICCAN recommends a best practice approach is developed to address overheating. It will also explore the possibility of including an amendment to the Building Regulations, ensuring aviation noise is factored into any acoustic insulation works, including its impact on overheating.	This is already covered by BS8233 but reference should also be made to the ANC-AVO-Residential-Design-Guide-January-2020-v1.1-1 (Ref. 5).
2	ue of condensation and how to mitigate it should be considered during the early stages of product selection for noise insulation schemes. Details of potential condensation issues and which specialists to contact for advice will feature in the toolkit as mentioned in ICCAN principle 2 under Insulation products and system	This is already covered by BS8233 Section 9.6 but reference should also be made to the ANC-AVO-Residential-Design-Guide-January-2020-v1.1-1 (Ref. 5)
	lity management	
1	recommends that only certified contractors should be used for the installation of noise insulation products. (Granville: already in place)	The quality of the selected materials as well as the care and experience of installers will have a significant effect on the finished performance. **See Section 9.6: " Quality control and workmanship"**

7 CAP 1588:2018 “Aircraft Noise and Annoyance: Recent findings”

7.1.1 I was surprised that the Applicant did not utilise or reference CAP 1588 in the DCO.

7.1.2 The aim of this report is to provide an overview of the recent research into and state of knowledge on the effects of aircraft noise and annoyance responses. It is a complex area, and this report is split into sections in order to cover each subject.

7.1.3 Chapter 2 addresses the definition of annoyance and how it came to attention as a public issue, the pathways in which annoyance can interact with other health endpoints and external factors, and an explanation of the current thresholds for describing degrees of annoyance.

7.1.4 Chapter 3 describes the methodologies used to measure aircraft noise-induced annoyance, and the most commonly used dose-response relationships to date.

7.1.5 Chapter 4 discusses the recent developments in research findings over the past ten years or so, and suggestions for how methodologies could be improved for future research.

7.1.6 Chapter 5 explains the complexities of how non-acoustic factors can influence the annoyance results and new methods that may be employed to take account of them when designing future annoyance studies.

7.1.7 Note that the third of the three aims of NPSE is to improve the quality of life for residents. Under the DCO proposals there is no quality of life improvement, only a deleterious effect, for those living close to the airport and its flypaths.

7.1.8 The DCO makes specious claims about ‘quality of life improvements’ that could occur when a person currently unemployed gets a job at the airport. This is tenuous at best since any such improvement will only relate to the individual, not an entire community, and the individual may not even live in an affected area anyway.

7.1.9 Note:

a) Figure 17 – correlation of annoyance with the number of events - which would apply to the DCO;
b) Figure 20 = annoyance sensitivity related to trust in Authorities and
c) Figure 21 for Fairness of decisions.

Given that LBC, the Applicant and LLAOL have historically gone ahead with their plans despite there being significant local opposition (e.g. Century Park, 19mppa Variation proposal, non-statutory 32mppa proposal) it could be suggested that all three Figures apply to this DCO.

7.1.10 Page 5 suggests that there is a difference in sensitivity for those living near High Rate of Change (HRC) airports and suggest 5dB lowering of effect levels relative to Low Rate of Change (LRC) airports. LLA can only be described as a HRC airport given the huge increases in passengers over very recent years so it behoves the Applicant to consider reviewing the severity levels.

8 Glossary

ATM	Air Traffic Movement
ICCAN	Independent Commission on Civil Aviation Noise
LBC	Luton Borough Council
LR	Luton Rising
LOAEL	Lowest Observable Adverse Effect Level
LLA	London Luton Airport
LLAOL	London Luton Airport Operations Limited
NIS	Noise Insulation Sub-committee
NOEL	No Observable Effect Level
mppa	million passengers per annum
SOAEL	Significant Observed Adverse Effect Level
UAEL	Upper Adverse Effect Level

9 References

	Title	Author
1	2023 Noise Monitoring Schedule	LLAOL
2	Airport Noise Action Plan 2019-2023	LLAOL
3	BS8233 2014 Guidance on Sound Insulation and Noise Reduction for Buildings	British Standards Institute
4	SEL definition	LLAOL
5	ANC-AVO-Residential-Design-Guide-January-2020-v1.1-1	Acoustics and Noise Consultants (ANC)
6	CAP 1588_Feb18	CAA
7	ICCAN review of airport noise insulation schemes March 2021	ICCAN

.

10 Appendices

Appendix A Relevant Extracts from BS8233_2014

.

Appendix A

Relevant Extracts from BS8233: 2014

4 Measuring equipment and accuracy
The equipment to be used for measuring noise levels should:

a) conform to the accuracy requirements specified in BS EN ISO 140,BS EN ISO 10140 or BS 4142, as applicable; or
b) if not stated, meet Class 2 or better (see BS EN 61672-1, BS EN 61672-2 and BS EN 60942).

……………………

6.3.2 Prediction of noise from aircraft

Prediction of noise from aircraft or airports is complex, though aircraft noise modelling software packages are available. Many airports periodically produce contours showing the noise exposure around the airport. Care is needed in interpreting these contours as they tend to show average exposure, taking account of different modes of airport operation. This means that, on a particular day, the noise exposure at a particular location might be higher than implied by the contours, and consideration should be given to designing the building envelope for those operational days.

These contours show the noise of aircraft departing from and arriving at an airport without the presence of any shielding effects from buildings or topographical features. They also do not include the noise from ground operations such as taxiing, auxiliary or ground power units or engine testing. Where appropriate, these sources need to be considered separately.

Where it appears that sound insulation treatment is necessary, noise exposure data should be obtained by on-site noise measurements, taking account of wind direction and runway usage. The survey duration of on-site measurements should be sufficient to take account of the various permutations of runway use that can occur, as certain flight paths might only be used under certain wind direction conditions. Where treatment of the building envelope is required to achieve internal design standards then site-specific measurements should be recorded, including provision for the frequency content of the noise (predominantly low frequency noise). It should be noted that for a jet aircraft the frequency content of noise when landing is generally different from that when departing. Typically, landing jet aircraft produce relatively higher levels of high-frequency noise and departing jet aircraft produce relatively higher levels of low-frequency noise.

…………………

7.7.2 Internal ambient noise levels for dwellings
In general, for steady external noise sources, it is desirable that the internal ambient noise level does not exceed the guideline values in Table 4.

Table 4 Indoor ambient noise levels for dwellings

Activity	Location	07:00 to 23:00	23:00 to 07:00
Resting	Living room	35 dB *L*Aeq,16hour	—
Dining	Dining room/area	40 dB *L*Aeq,16hour	—
Sleeping (daytime resting)	Bedroom	35 dB *L*Aeq,16hour	30 dB *L*Aeq,8hour

NOTE 1 Table 4 provides recommended levels for overall noise in the design of a building. These are the sum total of structure-borne and airborne noise sources. Groundborne noise is assessed separately and is not included as part of these targets, as human response to groundborne noise varies with many factors such as level, character, timing, occupant expectation and sensitivity.

NOTE 2 The levels shown in Table 4 are based on the existing guidelines issued by the WHO and assume normal diurnal fluctuations in external noise. In cases where local conditions do not follow a typical diurnal pattern, for example on a road serving a port with high levels of traffic at certain times of the night, an appropriate alternative period, e.g. 1 hour, may be used, but the level should be selected to ensure consistency with the levels recommended in Table 4.

NOTE 3 These levels are based on annual average data and do not have to be achieved in all circumstances. For example, it is normal to exclude occasional events, such as fireworks night or New Year's Eve.

NOTE 4 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 LAmax,F, depending on the character and number of events per night. Sporadic noise events could require separate values.

NOTE 5 If relying on closed windows to meet the guide values, there needs to be an appropriate alternative ventilation that does not compromise the façade insulation or the resulting noise level. If applicable, any room should have adequate ventilation (e.g. trickle ventilators should be open) during assessment.

NOTE 6 Attention is drawn to the Building Regulations [30, 31, 32].

NOTE 7 Where development is considered necessary or desirable, despite external noise levels above WHO guidelines, the internal target levels may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

If there is noise from a mechanical ventilation system, the internal ambient noise levels should be reported separately with the system operating and with it switched off. If the room contains items such as fridges, freezers, cookers and water heaters, these should be turned off during measurement. Shorter measurement periods such as *L*Aeq, 1 hour may be used by agreement, provided the selected shorter measurement period is shown to be representative of the entire night or day period.

……….

7.7.3.2 Design criteria for external noise
For traditional external areas that are used for amenity space, such as gardens and patios, it is desirable that the external noise level does not exceed 50 dB *L*Aeq,*T*, with an upper guideline value of 55 dB *L*Aeq,*T* which would be acceptable in noisier environments. However, it is also recognized that these guideline values are not achievable in all circumstances where development might be desirable. In higher noise areas, such as city centres or urban areas adjoining the strategic transport network, a compromise between elevated noise levels and other factors, such as the convenience of living in these locations or making efficient use of land resources to ensure development needs can be met, might be warranted. In such a situation, development should be designed to achieve the lowest practicable levels in these external amenity spaces, but should not be prohibited.
Other locations, such as balconies, roof gardens and terraces, are also important in residential buildings where normal external amenity space might be limited or not available, i.e. in flats, apartment blocks, etc. In these locations, specification of noise limits is not necessarily appropriate. Small balconies may be included for uses such as drying washing or growing pot plants, and noise limits should not be necessary for these uses. However, the general guidance on noise in amenity space is still appropriate for larger balconies, roof gardens and terraces, which might be intended to be used for relaxation. In high-noise areas, consideration should be given to protecting these areas by screening or building design to achieve the lowest practicable levels. Achieving levels of 55 dB *L*Aeq,*T* or less might not be possible at the outer edge of these areas, but should be achievable in some areas of the space.

……………..

8.2 Flanking transmission
The sound insulation between rooms in a building is not only influenced by the sound insulation of the separating element, but also by transmission via adjoining elements and air paths through or round the element, known as flanking transmission (see Annex E)………

…………………….

8.3 Sound Insulation Tests
Standard laboratory measurements of airborne sound insulation in accordance with BS EN ISO 10140-2 and impact sound insulation in accordance with BS EN ISO 10140-3 do not take account of flanking transmission, and so should only be regarded as a guide to the performance of an element in the field. The performance of the completed construction can be checked by tests carried out in accordance with BS EN ISO 140-4 and BS EN ISO 140-7. From these measurements, single-number ratings can be calculated according to BS EN ISO 717-1, for airborne insulation, and BS EN ISO 717-2, for impact insulation (see Annex C).
…………….

8.4.5.4 Ventilation
The Building Regulations' supporting documents on ventilation [48, 49, 50] recommend that habitable rooms in dwellings have background ventilation. Where openable windows cannot be relied upon for this ventilation, trickle ventilators can be used and sound attenuating types are available. However, windows may remain openable for rapid or purge ventilation, or at the occupant's choice. Alternatively, acoustic ventilation units (see 7.7.2) are available for insertion in external walls. These can provide sound reduction comparable with double glazed windows. However, ducted systems with intakes on the quiet side of the building might be required in very noisy situations, or where appearance rules out through-the-wall fans.

…………………………..

9.6 Quality control and workmanship
Experience has shown that effective sound insulation and noise control require careful detailing on the part of the designer and a high standard of workmanship on the part of the contractor. Correct execution of the detailing should be checked on site, and the completed building should be fully commissioned before handover.

Noise control is only one aspect of environmental design and designers should be aware that the solution to a noise problem can cause difficulties elsewhere, e.g. thermal insulation, cold bridging, solar gain, ventilation and condensation. Much information on the environment in and around buildings is available and should be considered at an early stage of the design process.

……………………

Annex C

C.4 Rating sound insulation
Measurements of insulation against both airborne and impact sounds yield values in a number of frequency bands. To make this information more manageable, rating methods such as those in BS EN ISO 717-1 and BS EN ISO 717-2 are used to reduce the frequency band values to single-figure ratings. These single-figure ratings are generally good predictors of subjective assessments of insulation of similar constructions. However, this is not always the case for different constructions, for example the low-frequency performance of a lightweight partition might be significantly different from that of a masonry partition with the same single-number rating, so it is prudent to examine the full measurement data in critical situations.
The more common indices used to describe sound insulation are summarized in Table C.1 and Table C.2.

NOTE 1 Further guidance on rating sound insulation is given in BS EN ISO 717-1 and BS EN ISO 717-2. The terminology shown in Table C.1 is used, but with additional spectrum adaptation terms (C).
EXAMPLE
*R*w (*C*; *C*tr) = 41(0; −5) dB.
Here, *C* (value 0) is the correction needed to convert *R*w to a dB insulation value against a pink noise spectrum; *C*tr (−5) is the correction needed to convert *R*w to a dB insulation value against a standardized road traffic noise spectrum. In this case the dB insulation is 41 − 5 = 36 dB.
NOTE 2 Pink noise has the same sound pressure level in adjacent frequency bands, and is used to represent general activity noise.

It is essential that the difference between the sound insulation value obtained for a single building element in the laboratory and the value for a completed construction in the field environment is understood. A common mistake is to expect to obtain values of a weighted sound reduction index, *R*w, from a completed building. To clarify this, different indices are used to indicate sound insulation performance in the different environments. Table C.1 and Table C.2 show the different indices that apply to the laboratory or field environment respectively.

Due to the flanking transmission paths and a difference in the calculation method, a laboratory test value for sound insulation might not be obtained in the field, even if all elements of the construction have been specified and built correctly.

…………………………

Table C.2 **Common indices used to describe field airborne and impact sound insulation**

Airborne (*A*) or impact (*I*)	**Measured values**		**Single number quantity**	
	Name	Symbol	Name	Symbol
A	Standardized level difference	D_{nT}	Weighted standardized level difference	$D_{nT,w}$
A	Spectrum adaptation term	C	Spectrum adaptation term	C
A	Spectrum adaptation term	C_{tr}	Spectrum adaptation term	C_{tr}
I	Standardized impact sound pressure level	L'_{nT}	Weighted standardized impact sound pressure level	$L'_{nT,w}$
A	Apparent sound reduction index	R	Weighted sound reduction index (dB)	R'_{w}

Annex D

D.5 Aircraft noise

As there are many variables affecting the level of aircraft noise heard on the ground, expert advice is almost always required. Contours of daytime LAeq,T levels are available from most major airports and helipads. Where measurements of facade insulation are necessary a test method is described in BS EN ISO 140-5.

Reference 1

2023 Noise Monitoring Schedule

2023 Noise Monitoring Schedule

Version 1.0

London
Luton
Airport

Noise Monitoring Programme (Portable)

	Jan – Mar	Apr – Jun	Jul – Sept	Oct – Dec
NMT04 (Trailer)	Redbourn	Whitwell	Childwickbury	Dagnall
NMT05 (Tripod)	Calibration	Caddington	Markyate	Stevenage – easterly departures
NMT06 (Tripod)	Wheathampstead	Knebworth	South Luton	Calibration
NMT07 (Tripod)		Pitstone	Harpenden	Kensworth
NMT08 (Tripod)	Stevenage (westerly arrivals)	Leighton Buzzard	St Albans (Jersey Farm)	Croydon
NMT09 (Tripod)	Gamlingay	Potton	Flamstead	Hitchin
NMT10 (Tripod)	Slip End / Pepperstock	Little Gransden / Great Gransden	Breachwood Green	

Easterly

Westerly

Noise Monitoring Programme (Handheld)

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Handheld monitor 1	Breachwood Green	Harpenden	Gamlingay	St Albans

Reference 2

Airport Noise Action Plan 2019-2023

London Luton Airport

Environmental Noise Directive

Noise Action Plan 2019 - 2023

www.london-luton.co.uk/noise

Version 1 – February 2019

Contents

Foreword

2017 was the busiest year on record for London Luton Airport (LLA). 15.8 million passengers travelled with us, and together with our airline partners we enabled 135,000 flights; representing a 37 per cent increase over the last five years.

Our story is similar to all London airports and is a reflection of the record demand for air travel across the UK. According to their latest figures, NATS handled 2.6m flights in 2017, a 24 per cent increase over the last five years.

To meet this increasing demand and open up the full potential of the airport we have invested £160 million since 2015 in a programme to transform LLA.

This major development, the biggest in our 80-year history, will increase annual capacity to 18 million passengers per annum by 2020. As a major employer and economic contributor, the new and expanded airport will contribute £1.4billion per year to the local economy and £2.3billion nationally; supporting over 37,700 jobs by 2031.

However, we're acutely aware of the importance of balancing the benefits of being a thriving business with the operational reality of aircraft noise, which we know can often be an area of concern for our neighbours.

LLA has some of the most stringent noise control measures of any UK airport, and we've already made great progress when it comes to tackling noise. Recent measures include increasing the number of local noise monitors and improving the way that we communicate with local communities via our dedicated noise website and regular noise surgeries. We have also committed £100,000 per year to insulate local properties, including installing high performance glazing.

We're particularly proud of our trial involving delayed landing gear deployment. During the trial, which saw pilots delay the deployment of landing gear as late as possible. We measured noise levels at strategic locations and found that average noise from aircraft reduced by 2.7dB at six nautical miles and 3.4dB at seven nautical miles from the airport. This meant that ground noise was reduced by 50%.

As we continue to grow, we know that we must continue to tackle the issue of noise.

This Noise Action Plan sets out our vision for the next five years, and contains policies and initiatives which have been developed in close collaboration with our local communities.

Some of the new measures contained in this plan include a voluntary commitment that all aircraft using the airport will be at least Chapter 4 or below by 2022. We're introducing a new biennial noise survey to create another voice for local communities to give us feedback on how we're doing.

All of these improvements will be taking place at a time when the UK's airspace is under general review – the current airspace was designed in the 1960s and modernisation is required to ensure that it is fit to handle the growing number of aircraft which use it every day. We are working closely with other industry partners to make this happen, and are always looking for ways to reduce the impact of noise on our communities.

Noise is an unavoidable part of being a busy UK airport, but as this plan demonstrates, we're committed to reducing it wherever we can. It is important to work together with our local communities to build an airport which works for everyone.

Neil Thompson
Operations Director
London Luton airport

[redacted]

Purpose and Scope

This Draft Noise Action Plan has been prepared in response to the Environmental Noise Directive (2002/49/EC) which requires all Member States within the European Union to produce Noise Maps and Action Plans for the main sources of environmental noise, including airports. This Plan addresses the period 2019 – 2023, whilst the previous approved Noise Action Plan addressed the period 2013 – 2018.

The requirements of the Environmental Noise Directive (2002/49/EC) are transposed into the Environmental Noise (England) Regulations 2006 (as amended) and build upon the Government's aim, as set out in the Aviation Policy Framework (March 2013), "to limit and where possible reduce the number of people in the UK significantly affected by aircraft noise".

The Regulations require the preparation of Strategic Noise Maps and this Action Plan has been developed in connection with the 2016 noise mapping and in accordance with the Environmental Noise (England) Regulations 2006 (as amended) and associated guidance updated by DEFRA in July 2017.

London Luton Airport Operations Limited, as operator of London Luton Airport, is the competent authority for developing this Noise Action Plan. This Noise Action Plan will be formally submitted to the Secretary of State for Environment, Food and Rural Affairs and will be published in its final format once formal adoption has been confirmed by DEFRA.

This plan includes updated noise mapping and a new set of noise actions. It has been developed with the London Luton Airport Consultative Committee (LLACC) with an initial four week consultation period taking placein line with the directive. LLA also conducted a second two-week consultation period in order to gather further feedback from stakeholders.

For some residents, aircraft noise is a serious concern and the aviation industry recognises that it needs to better understand specific issues that disturb the public.

London Luton Airport is committed to being a good neighbour and endeavours to minimise the impact of its operations on local communities. Continued and enhanced consultation with the community is essential so that an appropriate balance can be struck between the socio-economic benefits of airport operations and its environmental impacts. This Noise Action Plan, once adopted by DEFRA, will provide a meaningful framework for London Luton Airport and its Consultative Committee to build upon it's established approach to the proactive management of aircraft noise in and around the airport.

London Luton Airport

London Luton Airport is an important international centre for commercial, business and cargo aviation, as well as aircraft maintenance. In 2016 (the assessment year for this Noise Action Plan), London Luton Airport handled 131,435 aircraft movements and 14.5 million passengers.

The main aircraft types operating in 2016 were Airbus A320 and A321 aircraft, operated by easyJet and Wizz Air. These were closely followed by Airbus A319 (also operated by easyJet) and Boeing 737-800, operated mainly by Ryanair. In 2016, our airlines flew to 135 destinations across 35 different countries. The map below shows the destinations flown/on sale to and from London Luton in 2016.

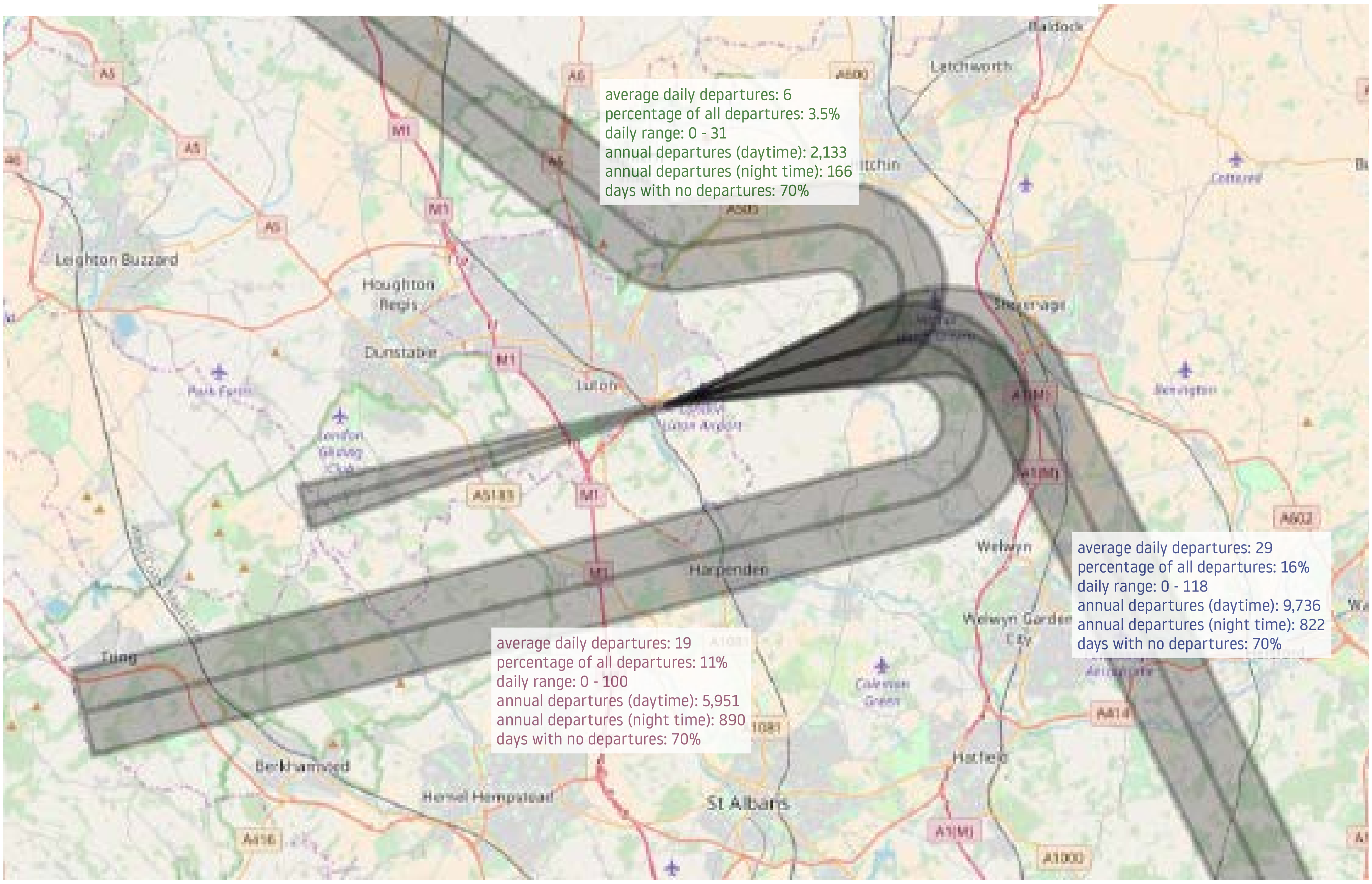
Local Communities

London Luton Airport has one runway which is 2160m in length and six main Noise Preferential Routes (NPRs); three departing in an easterly direction and three departing in a westerly direction. There are two arrival routes, one arriving from a westerly direction and one from the east. The maps on the following pages illustrate the six Noise Preferential Routes and two arrival routes at the airport.

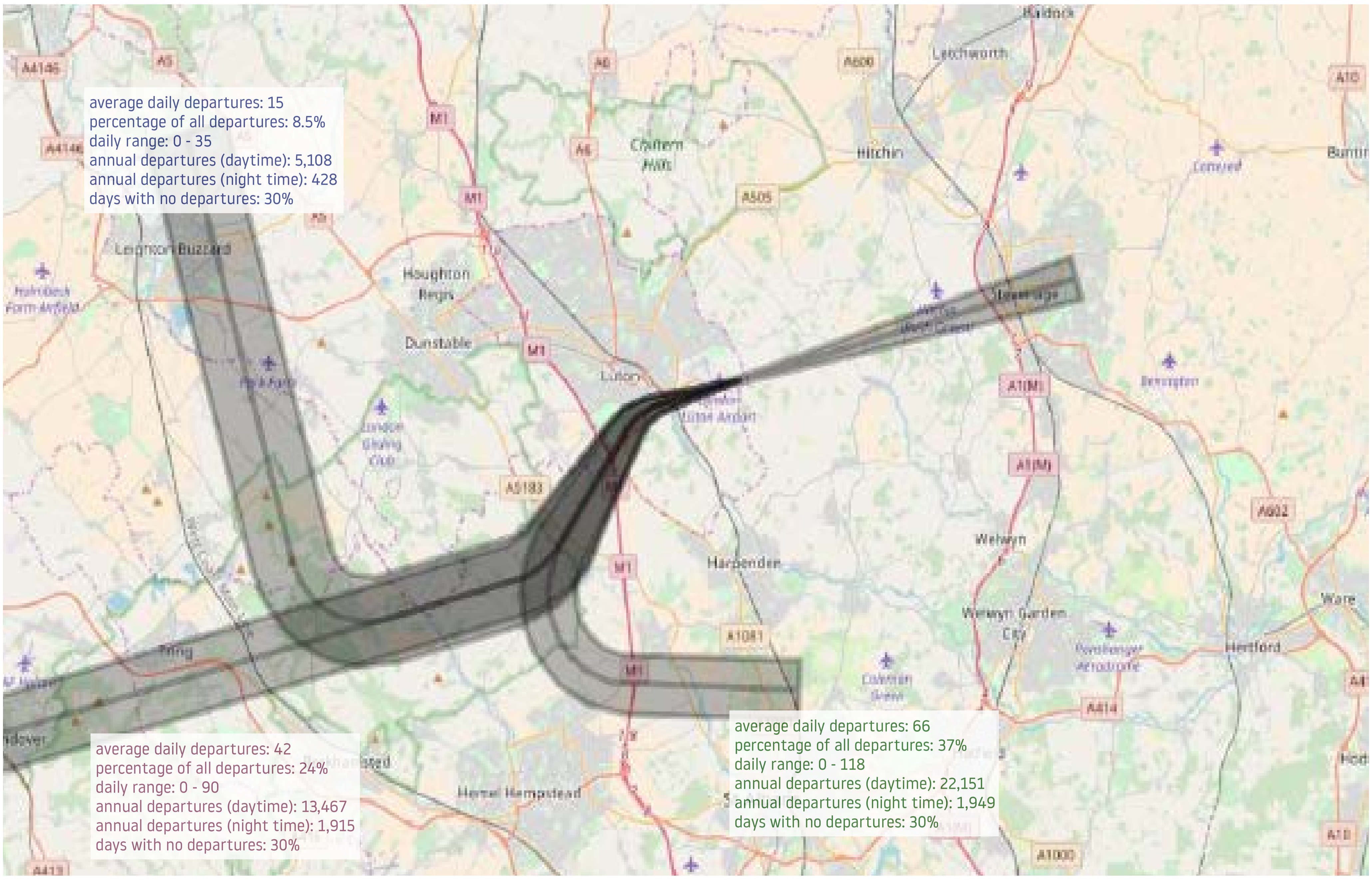
The closest residential areas to the airport are those located to the west and south-west of Luton however the more densely populated areas are to the north. There are a number of small villages within relatively close proximity. Breachwood Green and Whitwell, located to the east, are predominantly affected by easterly departures and westerly arrivals. Residential areas to the west, such as Slip End, Caddington, Flamstead and Markyate are generally affected by easterly arrivals or westerly departures.

In addition to aircraft noise originating from London Luton Airport, the surrounding areas are also affected to varying degrees by road traffic noise, as well as overflights travelling to and from other UK airports.

Plan showing Easterly (08) flight routes and 2016 traffic statistics



Plan showing Westerly (26) flight routes and 2016 traffic statistics



LLA's Contribution to the Local Economy

In February 2015, the airport owner London Luton Airport Limited (LLAL) and the operator London Luton Airport Operations Limited (LLAOL) commissioned Oxford Economics to undertake an analysis of the nature and scale of the economic impact of London Luton Airport on the UK as a whole, and on the surrounding sub-regional and local economies.

The study found that in 2013, the economic activity created by London Luton Airport contributed some £1.3 billion to UK GDP. For every pound London Luton Airport contributes to GDP itself, it creates another £2 elsewhere in the UK economy. Furthermore, for every direct job the airport supports, another 1.9 are supported elsewhere in the UK economy. The airport is estimated to have sustained 27,000 jobs in 2013, comprising 9,400 direct jobs (10% of all employment in Luton Borough), 7,700 indrect jobs within the supply chain of the airport and 10,000 induced jobs as employees of the airport and its supply chain spent their wages.

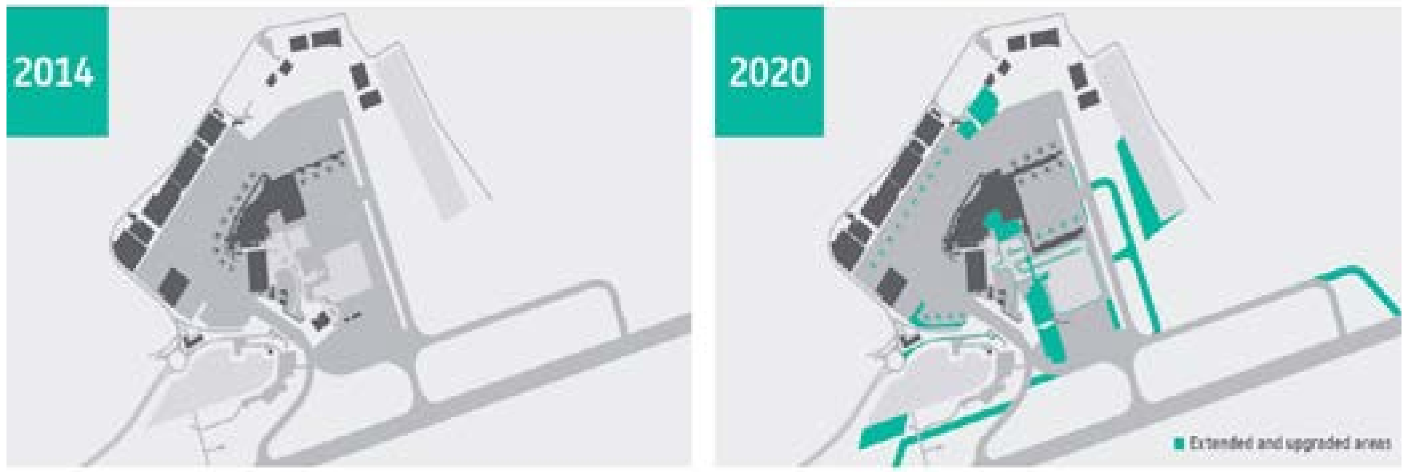
With changes to the capacity of London Luton Airport planned, the study was able to forecast how LLA's economic impact would likely evolve to 2031. By 2031, it is expected that LLA will support 37,700 jobs in the wid economy and the contribution to the Three Counties will almost double from £732m to £1.4bn.

Airport Development

On 3rd December 2012, LLA submitted a full planning application to Luton Borough Council for:

"Dualling of Airport Way/Airport Approach Road and associated junction improvements, extensions and alterations to the terminal buildings, erection of new departures / arrivals pier and walkway, erection of a pedestrian link building from the short-stay car park to the terminal, extensions and alterations to the mid-term and long-term car parks, construction of a new parallel taxiway, extensions to the existing taxiway parallel to the runway, extensions to existing aircraft parking aprons, improvements to ancillary infrastructure including access and drainage, and demolition of existing structures and enabling works. Outline planning application for the construction of a multi-storey car park and pedestrian link building (all matters reserved)"

This application seeked to increase the capacity of London Luton Airport to 18mppa from 12mppa. The planning consent was granted in 2014 and the ambitious project aims to greatly enhance the passenger experience with an extensive terminal upgrade, better road access and a new multi-storey car park. The maps below show the extent of the works and more information can be found at transforminglla.com.



Background to Legal Context

The following section sets out a summary of the relevant international, national and local legislation and policy for aircraft noise management. The diagram at the bottom of the page provides the tiers of aircraft noise regulation for operations at London Luton Airport.

International Regulation

The International Civil Aviation Organisation (ICAO) is the agency of the United Nations which oversees the civil aviation industry. ICAO adopts standards, protocols and recommended practices relating to all aspects of international aviation.

Balanced Approach

Since 2001, ICAO seeks members to adopt a 'balanced approach' to aircraft noise management. This includes reducing noise at source; the use of operational noise abatement procedures, land use policies and management, and restricting and banning the operation of certain aircraft; ICAO has developed policies on each of these elements. This approach has been followed when developing this Noise Action Plan.

Aircraft Noise Certifications

ICAO sets noise emission standards for all aircraft types, these are known as 'chapters'. These standards are progressively strengthened to prohibit aircraft that do not meet certain noise emission standards. Chapter 2 aircraft have been banned from operating in the EU since 1st April 2002, unless granted exemptions.

International

The International Governing body is the United Nations and these regulations are implemented by the International Civil Aviation Organisation (ICAO).

- Aircraft Noise Certifications
- Balanced Approach

European

The European Governing body is the European Union and these regulations are implemented through the European Civil Aviation Conference (ECAC).

- European Directive 2006/93
- European Directive 598/2014
- Enironmental Noise Directive (2002/49/EC)

National

The UK Government creates regulations which are implemented by the Department for Transport, Civil Aviation Authority and the Department for Environment, Food and Rural Affairs.

- Environmental Noise Regulations (2006)
- The Aerodrome Regulations (2003)
- Civil Aviation Act (1982, 2006, 2012)
- Aviation Policy Framework
- Aeroplane Noise Regulations (1999)
- UK Air Navigation Guidance (2017)
- CAP 1616
- Noise Policy Statement for England (NPSE)
- National Planning Policy Framework (NPPF)
- Aeronautical Information Publication (AIP)

Local

The Local Planning Authority creates local regulations which are implemented by London Luton Airport Operations Limited.

- Planning Conditions

European Regulation

Directives relating to the management and control of environmental noise have been issued by the European Commission (EC). These are legislative acts which require Member States to achieve a specified result without necessarily determining a means of how it can be achieved.

European Directive 598/2014

This legislation establishes the rules and procedures with regard to the introduction of noise related operating restrictions at Union Airports within a Balanced Approach. It also sets out the definition of marginally compliant aircraft and the process to be followed in the implementation of an operating restriction.

Environmental Noise Directive (2002/49/EC)

Directive 2002/49/EC is the Environmental Noise Directive (END) which defines a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure of environmental noise. It requires airports over 50,000 movements to develop Noise Action Plans and produced Strategic Noise Maps.

In accordance with the END, London Luton Airport was identified as a major airport and consequently Strategic Noise Maps have been produced and this Noise Action Plan prepared. Annex V of END (Appendix F) specifies those elements that a Noise Action Plan must include.

On 23 June 2016, the EU referendum took place and the people of the United Kingdom voted to leave the European Union. Until exit negotiations are concluded, the UK remains a full member of the European Union and all the rights and obligations of EU membership remain in force. During this period the Government will continue to negotiate, implement and apply EU legislation. Therefore END Noise Action Plans are still necessary.

National Regulation

The UK Government has enacted several policies and regulations relating to the management and control of environmental noise and noise from aircraft and airports. These are summarised below:

The Environmental Noise (England) Regulations 2006 (as amended)

The Environmental Noise (England) Regulations 2006 (as amended), came into force in 2006 and transpose the requirements of the European Noise Directive (2002/49/EC) into English law. The Regulations also name the competent authorities responsible for their delivery. Under the Regulations, the competent authority for preparing Strategic Noise Maps and a Noise Action Plan for London Luton Airport is London Luton Airport Operations Limited, the airport operator. Strategic Noise Maps for London Luton Airport have been produced and submitted to the Secretary of State for Environment, Food and Rural Affairs.

The Regulations state that Noise Action Plans must be prepared, adopted and reviewed when necessary but at least every 5 years and whenever a major development occurs.

Furthermore, in July 2017, DEFRA published updated guidance for airport operators to produce airport Noise Action Plans. This Noise Action Plan has been prepared having regard for this guidance, as required by the Regulations.

Civil Aviation Act 1982 (as amended including the Civil Aviation Act 2006 and 2012)

The Civil Aviation Act 1982 is the principal legislation within the UK for the control of aircraft operations. The Act provides a legislative means of avoiding and limiting the effect of noise from aircraft arriving and departing at UK airports. This includes the enforcement of aircraft noise emission standards and operational procedures as well as the provision to enable airport operators to use charging mechanisms to encourage the use of aircraft that are quieter or with lower emission levels.

Aeroplane Noise Regulations 1999

These regulations provide a set of statutory instruments that describe various methods that are implemented by the Civil Aviation Authority (CAA) that allow noise certified aircraft to use UK airports. The Regulations refer to ICAO noise certification standards and noise limits. The Regulations also provide a list of aircraft that are exempt from noise certification by ICAO.

The Aerodromes (Noise Restrictions) (Rules and Procedures) Regulations 2003

These regulations were transposed from EC Directive 2002/30/EC which builds on ICAO's Balanced Approach. The Regulations apply to all city airports and other civil airports within the UK which have more than 50,000 civil aircraft movements a year and give airport operators the scope to restrict marginally compliant aircraft.

Aviation Policy Framework

The Aviation Policy Framework (APF) was published in March 2013 and fully replaced the 2003 Air Transport White Paper (ATWP) as government's policy on aviation, alongside any decisions government makes following the recommendations of the independent Airports Commission. The Government have advised in the APF that they want to strike a fair balance between the negative impacts of noise and the positive economic impacts of aviation. The Government's overall policy on aviation noise is "to limit and, where possible, reduce the number of people in the UK significantly affected by aircraft noise." 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 impacts on health and quality of life. The noise commitments are similar to those given in the ATWP.

In 2017, following a consultation, the Department for Transport introduced some changes to airspace policy, including the creation of a new Independent Commission on Civil Aviation Noise (ICCAN), amendments to compensation policy, and new metrics to consider noise and health impacts further away from the airport than at present; LLA will ensure these policy requirements are met wherever applicable.

UK Air Navigation Guidance (2017)

This guidance is intended to provide direction to the CAA and airports when conducting an airspace change. It includes detailed guidance on the potential environmental impacts of airspace change as well as highlighting the need for engagement and transparency during an airspace change. The guidance also provides clarity of the Secretary of State's call-in function during the Airspace Change Process.

Planning Policy

In 2010 the Noise Policy Statement for England (NPSE) was brought in for noise to be considered in all planning applications, this includes noise from aircraft. The policy aims to promote good health and a good quality of life through the effective management of noise within the context of Government Policy on sustainable development.

In March 2012, the Government discarded the advice on planning and noise, recorded in PPG24, and issued the National Planning Policy Framework (NPPF). It is important that aircraft noise is considered when considering new developments close to the airport boundary or flight paths. In order to address this the NPPF advised that planning policies and decisions should aim to:

- Avoid noise from giving rise to significant adverse impacts on health and quality of life as a result of new development;
- Mitigate and reduce to a minimum other adverse impacts on health and quality of life arising from noise from new development. Including through the use of conditions
- Recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put on them because of changes in land uses since they were established; and
- Identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason.

CAP 1616

CAP 1616 is a CAA document which explains the regulatory process to change current airspace. It is a seven stage process which includes developing and assessing airspace change options, engagement with stakeholders, consultation requirements and the decision process. Any airspace change must follow this process.

Local Regulation

A range of policy instruments are available at a local level to manage and minimise the effects of aircraft operations.

Aeronautical Information Publication (AIP)

As a result of the National regulations listed, each UK airport created a document which provides the specific noise controls when operating at each airport. It includes Noise Preferential Routes (NPR's), Continuous Descent Approaches (CDAs) and night noise restrictions. LLA's AIP can be found here.

Planning Conditions

As well as government legislation, extra noise controls have been defined by LLA's local planning authority (Luton Borough Council) as part of the recent redevelopment plans granted in 2014. These conditions are some of the most stringent in the country and relate to the specific aircraft types operating, number of aircraft operating during the night time period, as well as the introduction of a Noise Insulation Scheme. A full list of planning conditions relating to noise can be found in Appendix F.

Framework for Noise Management

Demand for air travel across the UK is increasing rapidly. In response to increased demand, we are making the biggest investment in LLA's history to transform the airport. The redevelopment of our terminal will bring huge benefits for passengers, but it is vitally important to us that the local community also shares in the success of the airport.

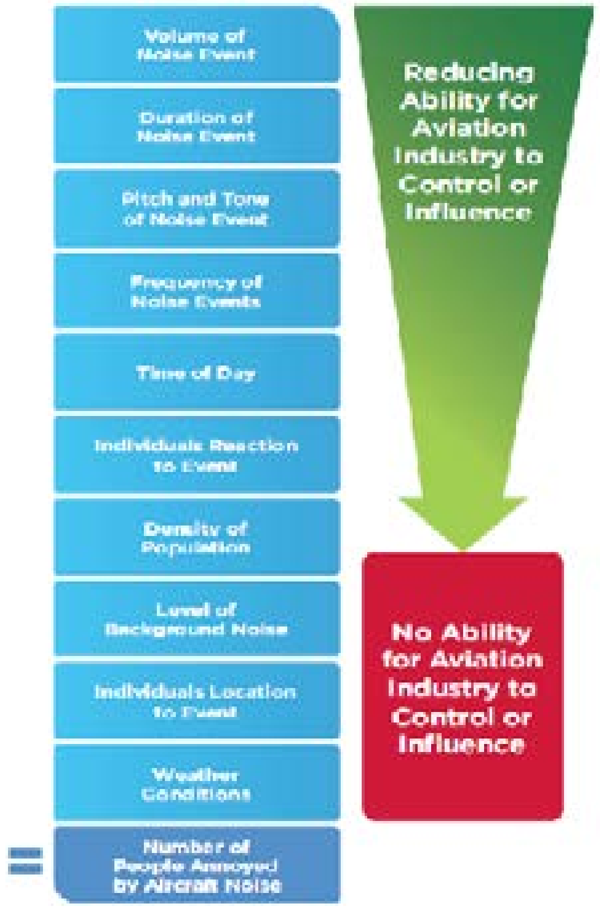
At LLA, our aim is always to work constructively with the local community and our partners to strike the right balance between maximising the positive social and economic benefits to the local area and the UK as a whole while minimising the impact of aircraft noise.

Once the current development is complete, LLA will contribute £1.4billion per year to the local economy and £2.3billion nationally. By 2031 we expect to support over 37,700 jobs, which on average pay £11,000 per year more than the national average wage.

But we recognise that the airport's growth may give rise to questions about noise levels. LLA already operates under the most stringent noise restrictions of any major UK airport. But we are continually looking to do more. As the airport continues its growth and development, we are evolving our approach to noise management and this can be seen through the development of our Noise Action Plan.

LLA's Noise Strategy

The main objective of managing noise is to limit and where possible reduce the number of people significantly affected. Aircraft noise is subjective and peoples level of tolerance may vary. The diagram shown to the right* details the factors which can cause an individual to become annoyed at aircraft noise. Some of these variables can be minimised by the aviation industry, whereas others may need a multi-stakeholder approach. There are also some factors which cannot be controlled by the aviation industry and therefore these will not be addressed in this plan.



*Source: Sustainable Aviation Noise Road-Map
https://www.sustainableaviation.co.uk/goals/noise/

Our strategy has been developed in line with the International Civil Aviation Organisation's (ICAO's) Balanced Approach to Aircraft Noise Management, which comprises of four key elements, such that they achieve maximum environmental benefit in the most cost effective manner. We have combined this approach with Sustainable Aviation's Noise Road-Map as we believe that working with the local community and industry partners should also form part of our Noise Strategy. Our 5 main work areas are explained in the table on the following page.

Approach	Description
Operational Procedures	We will constantly review our operating procedures to ensure the most environmentally friendly procedures are in place, as part of this we will challenge best practice to provide continuous improvement. If more fundamental changes to airspace are required we will proactively engage with stakeholders, in line with CAP 1616, to effectively manage aircraft noise impacts.
Quieter Aircraft	Modern aircraft of today are less noisy than previous generations, however as traffic continues to grow where demand for air travel increases, this reduction can often be counteracted by the number of aircraft overflying an area. At LLA we are encouraging operators to use the quietest aircraft practicable to the Luton operation, particularly during early morning and night time periods.
Land-use Planning and Mitigation	Through communication with local planning authorities we will continue to discourage developments near the airport which would give rise to the number of people significantly effected by noise. Furthermore, we will proactively review the Noise Insulation Scheme to ensure that it remains an effective means of noise mitigation.
Operational Restrictions	Restrictions should not be the first option when it comes to noise management however, we have a range of operating restrictions including movement limits and noise quota limits. Where restrictions are in place we are focused on ensuring that they are adhered to fully.
Working with the local community & industry partners	In order to reduce the impact of noise we recognise the importance of working with our communities and industry partners to understand any concerns and take action where possible, keeping communities up to date.

Operational Procedures

At London Luton Airport we monitor adherence to noise procedures through our Aircraft Noise and Track System. This system captures aircraft flight information operating within a 25 mile radius of the airport and generally up to an altitude of 12,000ft. The public can access this system here.

It receives data from our fixed and portable noise monitoring terminals, located within the neighbouring communities. This enables us to:
- identify noise infringements and to subsequently impose penalties where relevant;
- monitor track-keeping and work with operators to improve performance;
- monitor noise in all our local communities;
- Investigate complaints of disturbance and enquiries.

Off-track Violation Scheme

Aircraft taking off normally generate more noise than landing, as such aircraft are required to follow specific paths called Noise Preferential Routes (NPRs) unless otherwise directed by air traffic control.

Each NPR corridor extends 1.5 km either side of the NPR centre-line and to a release altitude typically 3,000 feet in the day and 4,000 feet at night. Aircraft flying inside this corridor are considered to be flying on-track, those flying outside are considered to be off track and may be subject to a penalty. All of the fines are put into the Community Trust Fund, which provides grants to community groups and charities in Bedfordshire, Hertfordshire and Buckinghamshire. In 2016, there were 91 off-track violations which contributed £72,000 to the Community Trust Fund.

Once an aircraft reaches the NPR release altitude an air traffic controller can instruct it to turn onto a more direct heading to its destination, which may take the aircraft outside the NPR corridor - this is called vectoring. There may be occasions where it is necessary for safety reasons (e.g. to avoid severe weather conditions) to vector aircraft off NPRs below the release altitude.

The approved Noise Preferential Routes for departures from LLA are shown on pages 6 and 7. These areas have been established in consultation with the Civil Aviation Authority and LLACC.

Noise Violation Scheme

Noise levels of departing aircraft are monitored at three locations 6.5km from start of roll on the runway, this is the international standard set by ICAO. Any aircraft departure exceeding the noise violation limits at these monitors will be charged accordingly. The noise limits are:

82dB(A) during the daytime (07:00hrs – 23:00hrs)
80dB(A) at night (23:00hrs – 07:00hrs)

Further reductions to the noise violation levels are planned for 2020, down to 80dB(A) during the daytime and 79dB(A) at night.

Since April 2018, if an aircraft exceeds these noise limits during the day time they will be fined £1000, an aircraft exceeding in the night time will be fined £2000. All fines are put into the Community Trust Fund, which is independently administered by the Bedfordshire and Luton Community Foundation.

Continuous Descent Approach

We encourage all operators to use a Continuous Descent Approach (CDA), this technique means an aircraft stays higher for longer and descends at a continuous rate to the runway threshold therefore reducing periods of prolonged level flight at lower altitudes. With CDA less fuel is burnt, less emissions are produced but most importantly it reduces the noise by avoiding the use of engine thrust required for level flight.

At LLA we regularly achieve our target of 90% compliance and work with operators to increase CDA performance where possible.

Delayed Landing Gear

In 2017, LLA conducted a trial aimed at reducing the noise generated by arriving aircraft. The trial consisted of aircraft delaying the deployment of landing gear. As an aircraft makes its final approach most noise is caused by the flow of air over the fuselage as drag is created to slow the aircraft down.

Noise was measured along the arrivals flightpath to understand what, if any, reduction could be achieved. Stevenage, Dagnall and Whipsnade were among those communities who saw the greatest benefit of between 2.7db and 3.4db. Overall the results showed a 50% reduction in aircraft noise for communities between 5 and 7 nautical miles from the runway. The detailed report of this trial is available on our website here.

Following the successful trial, the majority of operators (77%) have changed their operating procedures to make this standard practice. LLA continues to work with all operators to encourage them to follow suit.

Airspace modernisation

London's Airspace is a particularly busy area and is in need of modernisation, the current airspace was designed in the 1960's for fewer aircraft and it has not been re-designed since, despite the increase in flights from all airports and advances in aircraft technological capabilities.

As part of a National airspace change programme, London Luton Airport is required to update all of its departure procedures in a move towards satellite based technology. LLA is using this opportunity to identify the most environmentally efficient way of managing our airspace with the main focus being on reducing the noise impact associated with aircraft operations.

Any proposed designs will look to replicate as closely as possible the routes being used today but we will also look at how we can move flights away from areas of population to reduce the noise in those communities.

Single engine taxi (Ground noise procedures)
Aircraft ground noise can be generated by aircraft whilst on the ground during taxiing. We encourage all operators to taxi using just one engine, in order to reduce the noise for our communities closest to the airport.

Landing Charges
Night-time noise can be particularly disturbing and can lead to sleep deprivation and sleep pattern disruption. Furthermore, noise generated during the night-time is often perceived to be louder in the absence of other daytime background noise.

We encourage aircraft to operate during daytime hours through financial incentives. For example, airline landing fees are increased during the night-time period. These are outlined in our Charges and Conditions of use, available to view on our website here.

Quieter Aircraft

Quota Count
In line with other UK airports, LLA operates a Quota Count system during the night time period (23:30hrs – 06:00hrs). Aircraft operating at night are given a quota count rating determined from the aircraft manufacturer's noise certification test results. Quieter aircraft have a lower quota count (QC) value, with some particularly quiet aircraft being exempt. The table below shows Quota Count noise classification.

Noise Classification	Quota Count Value
Below 84 EPNdb1	Exempt
84-86.9 EPNdb	0.25
87-89.9 EPNdb	0.5
90-92.9EPNdb	1
93-95.9EPNdb	2
96-98.9EPNdb	4

Since 2010 aircraft movements with a QC value of greater than 2 have been excluded during the night-time period.

In October 2015 a QC limit was put in place and LLA is currently subject to a 3,500 night noise QC point limit, the QC value therefore indicating points per corresponding aircraft movement (e.g. 1,750 QC2 movements, or 3,500 QC 1 movements, or 7,000 QC0.5 movements). As part of the 2015 planning conditions the 3,500 night noise QC limit is to be reduced until it does not exceed 2,800 by 2028.

Operational Restrictions

Movement Limits
As part of our commitment to minimise disturbance during the night time period, we operate a rolling 12-month limit on the number of movements permitted to operate during the night time period (23:00hrs – 06:00hrs) and the early morning shoulder period (06:00hrs – 07:00hrs). These limits are listed in the table to the right.

Time Period	Total number of movements permitted per 12 month period
Night-time (23:30-06:00hrs)	9,650
Early Morning Shoulder Period (06:00-07:00hrs)	7,000

Chapter 2 Aircraft
Chapters are a categorisation method for aircraft, based on their noise. It was introduced by ICAO in 1972 and has been developed through time as manufacturers reduce the noise of aircraft through new technologies. The exact categorisation is listed in ICAO Annex 16 Volume 1.

In line with the European Directive 2006/93 and Aeroplane Noise Regulations 1999, aircraft operating within the UK must be Chapter 3 or above. Aircraft hush-kitted or modified to Chapter 3 standards comply with this requirement. LLA operates in line with this requirement.

Aircraft Engine Testing
After maintenance an aircraft's engines must be tested before a flight is permitted. At LLA we have a certain area to conduct this testing a distance away from local properties. This area is only to be used during day time periods, in order to reduce the night time noise disturbance for our local community. If an aircraft needs to conduct engine testing during the night time period, the operator must apply for the permission of LLA and this permission is only granted in exceptional circumstances.

Auxiliary Power Unit's
An Auxiliary Power Unit (APU), is a device on an aircraft which provides energy on board the aircraft whilst not in the air. When an aircraft is running an APU, usually when boarding passengers, this can create additional noise. An alternative to using an APU is a Ground Power Unit (GPU) which provides the aircraft which power and uses less energy and is much quieter. At LLA we encourage operators to use GPU's, in order to minimise the noise emitted from aircraft on the ground. Furthermore, we also restrict the length of time an APU is permitted to be used.

Land-Use Planning and Mitigation

Noise Insulation Scheme

Together with an Independent Noise analyst and our London Luton Airport Consultative Committee (LLACC) Noise Insulation Sub-Committee, we offer noise insulation to eligible properties. Our Annual Noise Contours determine the eligible properties each year.

The scheme covers both residential and non-residential properties in Bedfordshire and Hertfordshire. Depending on any existing insulation in the property, double glazing, secondary glazing and ventilation units can be provided. Rooms eligible for insulation include living rooms, dining rooms, kitchen-diners and bedrooms. More information is available on our website here.

Noise Contours

In the UK, noise measurements are evaluated using the average noise level during the day (a 16-hour day) during the summer period. The measure of noise is given in decibels (dB) and presented as noise contours.

This averaged decibel measurement 'LAeq', is the most common international measure of aircraft noise, it means 'equivalent continuous noise level'. LLA's planning conditions refer to the 57dB LAeq (16 hour) as the area enclosed by this contour should not exceed 19.4 sq km for daytime noise. The planning conditions also state a limit on the area enclosed by the 48db LAeq 8hr (2300-0700) contour, this should not exceed 37.2 sq km for night-time noise.

By 2021, LLA will develop a strategy to define methods to reduce the area of the noise contours by 2028 for daytime noise to 15.2sq km for the area exposed to 57dB(A) Leq16hr (0700-2300) and above and for night-time noise to 31.6 sq km for the area exposed to 48dB(A) Leq8hr (2300-0700) and above.

Local Development Control

London Luton Airport works closely with local planning authorities to ensure that careful consideration is given to planning decisions in noise sensitive areas. LLACC also monitors wider development planning matters to discourage local planning authorities from permitting inappropriate development in noise sensitive areas.

Working with the Local Community and Industry Partners

Complaints Handling

London Luton Airport investigates, logs and responds to all concerns relating to aircraft activity. General information is available on the London Luton Airport website and complaints can be submitted by telephone, email, or through our online Flight Tracking system (TraVis).

Complaint statistics are reported quarterly and annually to LLACC and trends are identified. The noise complaints handling system is kept under continual review to ensure the local community receives timely feedback in relation to concerns raised.

London Luton Airport Consultative Committee (LLACC)

LLACC is the formal mechanism for the airport to interact and exchange information with communities. Its membership includes representatives from local authorities, community groups, airport users and other interested parties. The Committee meets quarterly and is supported by the Noise and Track Sub Committee and Passenger Services Sub Committee. Both the Consultative Committee and sub-committee's are well attended, with current members listed in Appendix C.

The LLACC and its membership have assisted in the development of this Noise Action Plan and will play a full role in monitoring the implementation and effectiveness of the actions.

Flight Operations Committee (FLOPC)

The FLOPC is made up of operators at LLA, the committee discusses noise infringements, track keeping statistics, data from any ongoing trials and CDA compliance. The committee is focussed on improving operations at LLA, whilst ensuring this minimises the noise to our local community.

Public Surgeries

LLA holds approximately 6 Public Surgeries each year which provides an opportunity for local residents and councillors to meet with the Flight Operations team to personally answer any queries on airspace and aircraft noise. At LLA we believe that these are an effective way to understand the concerns of local residents. In addition to this, we offer invitations for local parish councils to visit the Flight Operations team at the airport.

Community Updates - Inform

Inform is LLA's Flight Operations team bi-monthly newsletter to keep stakeholders and members of our local community up to date with the latest information, this is directly sent to all interested parties. All issues are also uploaded to our website here.

Community Trust Fund

At London Luton Airport, we are proud to say that all of our Noise and Off-track fines are added to our Community Trust Fund. During 2016, £75,700 was transferred into the community trust fund from violations, this is in addition to the £50,000 the airport already commits each year.

Our Community Trust Fund allows communities to apply for grants between £250 to £7,500, to help fund or support projects and charities within the local area. The graph to the right shows the activities supported in 2016.

Sustainable Aviation

Sustainable Aviation is a UK aviation industry group, made up of UK airlines, manufacturers, airports and air-traffic control. LLA is part of the Noise Working Group and actively engages with this committee to limit and where possible reduce the impact of aviation noise.

Noise Mapping

In the UK, the noise impact of an airport is primarily described in terms of the LAeq averaged over the 16 hour period from 0700 – 2300, for an average day between the 16th June and 15th September. London Luton Airport annually produces these contours as well as the 8 hour night period between 2300 and 0700 for an average summer night, over the same period as the day time period, using the LAeq,8h indicator. These are published in our Annual Monitoring Reports.

Furthermore, since 2002, London Luton Airport has produced noise contour information for an average night each quarter, together with comparative values from the previous quarter and the equivalent period the previous year. This data is presented to LLACC (via NTSC) within the Quarterly Monitoring Reports.

As LLA, already conducts regular noise mapping assessments, the results of the noise mapping in 2016 did not raise any new concerns. Typically our approach has been to reduce noise for location both inside and outside of these contours, as we understand the noise disturbance from our operations is not constrained to these areas.

Noise Mapping Results

For the purpose of the Noise Action Plan, the noise maps have been produced in terms of the five noise metrics (Lden, Lnight, LAeq,16h, Lday, and Levening) for aircraft movements in 2016, as required by the Regulations. The Noise Mapping data has been taken from the Airport Noise Action Planning Data Pack published by DEFRA. The Strategic Noise Maps can be found at Appendix B.

The shape of the contours are illustrative and show the noise from LLA operations in the context of the local area. Due to the alignment of the runway, both South Luton (to the west of the airfield) and Breachwood Green (to the east of the airfield) are incorporated within the noise contours.

The contours stretch further to the east, with the 55 Lden contour extending to the A1(M) at Stevenage to the east of the airport, incorporating Bendish, St Paul's Walden and the Breachwood Green. The eastern side of the contour extends further when compared to the west as all easterly departure and westerly arrivals follow the extended centreline of the runway up to Stevenage.

To the west of the airport, the contours show two distinctive spurs, the first is caused by the easterly arrivals path, in line with the runway, and includes parts of Caddington. The second spur is larger and stretches towards Markyate and Flamstead caused by the initial turn in the main westerly departure corridor.

The noise mapping results continue to indicate that no residential properties are located within the 69dB(A) LAeq 16h contour area.

Contour Population Results

The estimated total number of people and dwellings exposed above various noise levels from aircraft using London Luton Airport are shown in the tables below and on the following page.

In order to derive the statistics, analysis has been undertaken to count the population and number of dwellings within the specified noise contours. This assessment was carried out utilising a strategic residential population location dataset, provided by DEFRA.

Population and dwelling counts have been rounded as follows:
• The number of dwellings has been rounded to the nearest 50, except when the number of dwellings is greater than zero but less than 50, in which case the total has been shown as "< 50".
• The associated population has been rounded to the nearest 100, except when the associated population is greater than zero but less than 100, in which case the total has been shown as "< 100".

L_{den}	2006		2011		2016	
Noise Level (dB)	**Number of Dwellings**	**Number of People**	**Number of Dwellings**	**Number of People**	**Number of Dwellings**	**Number of People**
≥ **55**	3,800	8,600	6,450	14,300	8,250	17,000
≥ **60**	850	2,100	1,800	4,700	2,150	5,600
≥ **65**	< 50	100	350	1,000	400	1,100
≥ **70**	0	0	0	0	0	0
≥ **75**	0	0	0	0	0	0

Estimated total number of people and dwellings above various noise levels (L_{den}) between 2006 - 2016.

L_{day}	2006		2011		2016	
Noise Level (dB)	**Number of Dwellings**	**Number of People**	**Number of Dwellings**	**Number of People**	**Number of Dwellings**	**Number of People**
≥ **54**	2,800	6,500	5,050	11,300	6,000	13,200
≥ **57**	1,050	2,600	2,550	6,200	3,000	7,500
≥ **60**	450	1,100	950	2,500	1,050	2,800
≥ **63**	< 50	< 100	300	800	400	1,000
≥ **66**	< 50	< 100	< 50	< 100	< 50	< 100
≥ **69**	0	0	0	0	0	0

Estimated total number of people and dwellings above various noise levels (L_{day}) between 2006 - 2016.

$L_{evening}$	2006		2011		2016	
Noise Level (dB)	Number of Dwellings	Number of People	Number of Dwellings	Number of People	Number of Dwellings	Number of People
≥ 54	1,900	4,500	2,950	7,000	4,600	10,800
≥ 57	800	1,900	1,150	3,000	2,050	5,300
≥ 60	250	600	450	1,200	750	2,000
≥ 63	< 50	< 100	< 50	< 100	150	400
≥ 66	< 50	< 100	0	0	< 50	< 100
≥ 69	0	0	0	0	0	0

Estimated total number of people and dwellings above various noise levels ($L_{evening}$) between 2006 - 2016.

$L_{Aeq\ 16h}$	2006		2011		2016	
Noise Level (dB)	Number of Dwellings	Number of People	Number of Dwellings	Number of People	Number of Dwellings	Number of People
≥ 54	2,550	6,000	4,550	10,300	5,700	12,600
≥ 57	1,000	2,400	2,150	5,400	2,800	7,000
≥ 60	400	900	800	2,100	950	2,500
≥ 63	< 50	< 100	150	400	350	900
≥ 66	< 50	< 100	< 50	< 100	< 50	< 100
≥ 69	0	0	0	0	0	0

Estimated total number of people and dwellings above various noise levels ($L_{Aeq\ 16h}$) between 2006 - 2016.

L_{night}	2006		2011		2016	
Noise Level (dB)	Number of Dwellings	Number of People	Number of Dwellings	Number of People	Number of Dwellings	Number of People
≥ 48	-	-	5,000	11,400	5,300	11,800
≥ 51	-	-	2,400	6,000	2,300	5,900
≥ 54	2,450	5,800	900	2,400	850	2,220
≥ 57	950	2,300	300	900	200	600
≥ 60	400	900	< 50	< 100	< 50	< 100
≥ 63	< 50	< 100	0	0	0	0
≥ 66	< 50	< 100	0	0	0	0

Estimated total number of people and dwellings above various noise levels (L_{night}) between 2006 - 2016.

LLA's Noise Action Plan

This Noise Action Plan has been developed with the support of LLACC, NATS (our air traffic control provider) and airline partners.

During the drafting of the initial Noise Action Plan in 2009, London Luton Airport held a 16 week consultation exercise to seek the views of key stakeholders and the local community, from 28th September 2009 to 17th January 2010. During the consultation period representatives from London Luton Airport attended meetings with Planning and Environmental Health Officers from neighbouring local authorities and other key stakeholders and community groups on request.

According to guidance updated by DEFRA in June 2017, the airport involved LLACC and FLOPC members in two further consultations. The first was a four-week consultation from the 4th-29th June 2018. There were few responses to this consultation and therefore LLA conducted a further two-week consultation between 3rd - 17th August 2018. In addition, LLA hosted a drop-in event providing an opportunity for any stakeholders to ask questions about the Noise Action Plan, this was held on the 14th June 2018.

A schedule of all those individuals and organisations that were notified of the consultation in 2018 can be found in Appendix C.

A copy of the final Noise Action Plan (2019 -2023) will be sent to key stakeholders and those who participated in the consultation process once it has been formally adopted by DEFRA. It will also be published on the airport community website here.

London Luton Airport, through its Consultative Committee, remains committed to public engagement and communication with respect to noise management. This consultative approach will be sustained throughout the life of this Noise Action Plan.

Section 1: Operational Procedures

We will constantly review our operating procedures to ensure the most environmentally friendly procedures are in place, as part of this we will challenge best practice to provide continuous improvement. If more fundamental changes to airspace are required we will proactively engage with stakeholders, in line with CAP 1616, to effectively manage aircraft noise impacts.

Ref:	Action	Impact	Timescale	Performance Indicator	Numbers Affected	Target
1.1	Reduce the Maximum Noise Violation Limits (NVL) for departing aircraft and bi-annually review the penalties to ensure it remains effective in seeking to reduce departure noise.	Departure Noise	2020	Reduction of NVL's.	Residents within and beyond 55dB L_{den}	Reduce NVL's to 80dB during the day time and 79dB during the night-time by 2020.
1.2	We will work with our airline partners to improve performance relating to Continuous Descent Approach (CDA) with the aim of reducing the noise impact to the communities below.	Arrival Noise	Ongoing	CDA Compliance.	Residents within and beyond 55dB L_{den}	92% compliance by 2020. 95% compliance by 2022.
1.3	We will identify and act on opportunities to minimise noise through modernisation of the airspace structure working with both community and industry partners.	Departure/ Arrival Noise	Ongoing	Progress through CAP 1616 process.	Residents within and beyond 55dB L_{den}	Submit Airspace Change Proposal to the CAA by 2022.
1.4	Work with Air Traffic Control, airlines and local communities stakeholders to explore opportunities to facilitate more continuous climb operations (CCO).	Departure Noise	2019-2023	Evidence of work.	Residents within and beyond 55dB L_{den}	Explore opportunities and make appropriate changes to facilitate more CCO's.
1.5	Undertake a review of Noise Abatement Departure Procedures used at London Luton Airport to evaluate their effectiveness and work with our airline partners to identify and implement improvements.	Departure Noise	2019	Evidence of the review.	Residents within 55dB L_{den}	To assess the effectiveness and establish targets for noise reduction.
1.6	Review and promote the Arrivals Code of Practice and Departures code of Practice and work with our airline partners to set minimum performance criteria and a method for measuring performance.	Arrivals/ Departure/ Ground Noise	2019-2023	Evidence of review and new performance criteria.	Residents within and beyond 55dB L_{den}	Set minimum performance criteria by Q2 2019.
1.7	Continue to promote and encourage the use of single engine taxi procedures at London Luton Airport.	Ground Noise	Ongoing	Minutes of FLOPC meetings.	Residents within 65dB L_{den}	Increase the number of aircraft using single engine taxi procedures.
1.8	Work with our airline partners to promote and encourage the adoption of low power, low drag procedures such as delayed landing gear deployment in order reduce noise from arriving aircraft.	Arrival Noise	Ongoing	% of aircraft using low power, low drag procedures.	Residents within and beyond 55dB L_{den}	Increase the number of operators using low power, low drag procedures.
1.9	Working with our partners at Sustainable Aviation we will challenge current operational procedures to ensure continuous improvement to best practice.	Departure/ Arrival Noise	Ongoing	Minutes of Sustainable Aviation meetings.	Residents within and beyond 55dB L_{den}	Annually review and improve the departures and arrivals code of practice.

Section 2: Quieter Aircraft

Modern aircraft of today are less noisy than previous generations, however as traffic continues to grow where demand for air travel increases, this reduction can often be counteracted by the number of aircraft overflying an area. At LLA we are encouraging operators to use the quietest aircraft practicable to the Luton operation particularly during early morning and night time periods.

Ref:	Action	Impact	Timescale	Performance Indicator	Numbers Affected	Target
2.1	We will work with our Airline Partners to achieve the voluntary phase out of aircraft that are Chapter 3 or below, to encourage the introduction of quieter aircraft.	Departure/ Arrival/ Ground Noise	2019-2023	% of Chapter 4 aircraft.	Residents within and beyond 55dB L_{den}	100% Chapter 3 aircraft by 2020 and 100% Chapter 4 aircraft by 2022.
2.2	We will review our landing charges annually to encourage the use of quieter aircraft at London Luton Airport.	Departure/ Arrival/ Ground Noise	Annually	Publication of Charge's and Conditions of use.	Residents within and beyond 55dB L_{den}	Reduce the size of the noise contours.
2.3	Introduce incentives for airlines to adopt the quietest aircraft e.g. Airbus NEO and Boeing Max.	Departure/ Arrival/ Ground Noise	2019	Publication of Charge's and Conditions of use.	Residents within and beyond 65dB L_{den}	Introduce new charges in 2019.

Section 3: Operational Restrictions

Restrictions should not be the first option when it comes to noise management however, we have a range of operating restrictions including movement limits and noise quota limits. Where restrictions are in place we are focused on ensuring that they are adhered to fully.

Ref:	Action	Impact	Timescale	Performance Indicator	Numbers Affected	Target
3.1	We will operate within our agreed Total Annual Movement caps.	Night Noise	Ongoing	Movement reports in AMR and QMR.	Residents within and beyond 48dB L_{night}	A maximum of 9,650 movements between 23:00hrs-06:00hrs and a maximum of 7000 movements between 06:00hrs-07:00hrs for a rolling 12-month period.
3.2	We will continue to operate within our agreed Total Annual Quota Count (QC) caps.	Night Noise	Ongoing	QC reports in AMR and QMR.	Residents within and beyond 48dB L_{night}	3,500 QC points for a rolling 12-month period between (23:30hrs-06:00hrs).
3.3	To review and reduce the Total Annual Quota Count (QC) cap.	Night Noise	2020	Reduction of annual QC cap.	Residents within and beyond 48dB L_{night}	To review the Quota Count (QC) cap in 2020 to minimise night time noise disturbance.
3.4	We will operate within our agreed contour area limits.	Arrivals/ Departure/ Ground Noise	Ongoing	Area of noise contours	Residents within 57dB $L_{aeq\ 16\ h}$ and within 48dB L_{night}	57dB(A) Leq16hr (0700-2300) - 19.4 sq km. 48dB(A) Leq8hr (2300-0700) - 37.2 sq km.
3.5	Develop a noise contour reduction strategy to define methods to reduce the area of the noise contours.	Arrivals/ Departure/ Ground Noise	2021	Evidence of work.	Residents within 57dB $L_{aeq\ 16\ hr}$ and within 48dB L_{night}	Submit strategy to Local Planning Authority in 2021.
3.5	In order to minimise ground noise we will monitor and enforce restrictions around the use of Aircraft Auxiliary Power Unit's (APU).	Ground Noise	Ongoing	Minutes of FLOPC meetings.	Residents within 65dB L_{den}	Ensure operators are aware of the APU procedures at Flight Operations Committee meetings.
3.6	In order to minimise ground noise, particularly at night, we will restrict the permitted hours for engine testing to daytime periods only.	Ground Noise	Ongoing	Log of engine testing.	Residents within 48dB L_{night}	Restrict engine testing for aircraft in the daytime period only.

Section 4: Land-use Planning and Mitigation

Through communication with local town councils we will continue to discourage developments that would increase the number of properties within noise sensitive areas around the airport. Furthermore, we will proactively review the Noise Insulation Scheme to ensure that it remains an effective means of noise mitigation.

Ref:	Action	Impact	Timescale	Performance Indicator	Numbers Affected	Target
4.1	We will install acoustic insulation in eligible properties as part of our residential and non-residential Noise Insulation schemes.	Ground/ Departure/ Arrival Noise	Ongoing	Noise Insulation Scheme update in QMR and AMR.	Residents within 63dB L_{day} or 55dB L_{night} or any property in which airborne noise level in excess of 90dB SEL occurs.	Continue to spend the full NIS budget annually.
4.2	We will conduct an annual survey of those properties who have received noise insulation to measure the levels of satisfaction with the current Noise Insulation Scheme.	Ground/ Departure/ Arrival Noise	2019- 2023	Annual Survey Results.	N/A	Conduct annual survey of insulated properties by the following February. Report results of survey to Noise and Track Sub-Committee.
4.3	We will offer households exposed to levels of noise of 69dB $L_{Aeq\ 16h}$ or more assistance with the cost of moving.	Ground/ Departure/ Arrival Noise	Ongoing	Evidence in AMR.	Residents within 69dB L_{AEQ}	Continue to offer assistance.
4.4	We will work with community stakeholders to develop a plan to protect quiet areas as defined by UK government policy.	Ground/ Departure/ Arrival Noise	2020	Evidence of Plan.	Residents within and beyond 55dB L_{den}	Develop a plan by 2020 and ensure this is protecting quiet areas.
4.5	Through the Airspace Change Process we will ensure areas identified as 'quiet areas' are preserved as far as possible. 'Quiet Areas' will be defined and assessed as per government legislation.	Ground/ Departure/ Arrival Noise	Ongoing	Stages in CAP 1616 process.	Residents within and beyond 55dB L_{den}	Preserve quiet areas through Airspace Change Process as far as possible.
4.6	We will work with local authorities to raise awareness of the impacts of siting new developments that may be affected by aircraft noise.	Ground/ Departure/ Arrival Noise	Ongoing	Local Planning Group meeting minutes.	N/A	Increase awareness for local authorities through our Local Planning Group.

Section 5: Working with the Local Community and Industry Partners

In order to reduce the impact of noise we recognise the importance of working with our communities and industry partners to understand their concerns and ensure our actions address the issues.

Ref:	Action	Impact	Timescale	Performance Indicator	Numbers Affected	Target
5.1	Carry out biennial surveys of local communities to seek feedback on our approach to noise management and our complaints service for continual improvement and to offer the ability for local communities to help shape the future of noise controls.	Community relationship	2019 / 2020	Results of Survey.	N/A	Carry out first survey in 2019 to define baseline and set improvements in 2020.
5.2	We will improve communications through regular updates to our website, noise blog, community newsletters (Inform) and reports.	Community relationship	Ongoing	Evidence of comms. on website.	N/A	Review website annually and publish newsletter bi-monthly.
5.3	We will positively respond to requests for meetings with airport representatives regarding aircraft noise, airspace modernisation and expansion plans*.	Community relationship	Ongoing	Minutes of meetings.	N/A	Engage proactively with any visitors to the airport, as well as visiting local residents.
5.4	We will regularly organise public drop in sessions in locations surrounding the airport for community members to visit and speak to airport employees about noise management.	Community relationship	Ongoing	Evidence in QMR and AMR.	N/A	Organise and attend at least 6 Public Surgery drop-In events each year.
5.5	We will log all enquiries and complaints relating to airport operations and publish complaint statistics in our QMR & AMR.	Community relationship	Ongoing	Evidence in QMR and AMR.	N/A	Regularly publish statistics in monitoring reports on quarterly and annual basis.
5.6	We will annually monitor the Noise Action Plan (NAP) actions with LLACC and where we recognise that further improvements can potentially be achieved; we will look to address it.	Community relationship	Ongoing	Evidence in AMR.	N/A	Publish NAP update in the AMR annually.
5.7	We will give the public access to our online noise and track monitoring system (TraVis) and work with the supplier to enhance future functionality.	Community relationship	Ongoing	Evidence of TraVis website.	N/A	Maintain and enhance functionality of TraVis system.
5.8	We will divert all money raised from noise and track violations penalty schemes into the Community Trust Fund (CTF).	Community relationship	Ongoing	Evidence in annual Community Strategy and AMR.	N/A	Annually publish the amount of money diverted to the CTF.

*expansion of the airport is currently being sought by the airport owners, more detail will be provided as and when it becomes available. Any increase in noise will be addressed through this application process.

Ref:	Action	Impact	Timescale	Performance Indicator	Numbers Affected	Target
5.9	We will produce and publish Quarterly Monitoring reports to inform Stakeholders of performance trends and noise management at London Luton Airport.	Community relationship	Ongoing	QMR published on website.	N/A	Publish reports on our website at earliest opportunity each quarter.
5.10	We will continue to present summer and annual noise contours within our Annual Monitoring Report.	Community relationship	Ongoing	Evidence in AMR.	N/A	Publish contour statistics in Annual Monitoring Reports.
5.11	We will continue to produce and publish an Annual Monitoring Report to inform stakeholders of performance trends and noise management at London Luton Airport.	Community relationship	Ongoing	AMR published on website.	N/A	Publish AMR on our website by 31st May each year.
5.12	We will engage proactively with LLACC and NTSC to identify initiatives which will help minimise noise in our local community.	Community relationship	Ongoing	Minutes of Meetings.	N/A	Meet with LLACC and NTSC every 3 months.
5.13	We will collaborate with our Flight Operations Committee (FLOPC) to determine new initiatives to reduce noise.	Community relationship	Ongoing	Minutes of FLOPC meetings.	N/A	Engage proactively with FLOPC at meetings held twice a year.

Evaluating the Noise Action Plan

LLA is committed to working openly with the local community in order to balance the benefits of a successful airport, while minimising the impact of aircraft noise. Therefore, in order to evaluate the effectiveness of our Noise Action Plan we have created a set of 10 Key Performance Indicators and associated targets. The full list of indicators and targets are listed on pages 25-29 of the Noise Action Plan.

Our definition of a Key Performance Indicator is a long term, quantifiable measure that can be easily understood and monitored. Alongside the Key Performance Indicators, we have created accompanying targets to review and measure progress over the length of the plan.

We want to ensure that we are always transparent when reporting progress on our Noise Action Plan, so we will publish these statistics within our Annual Monitoring Report's. These reports are currently presented to our consultative committee and published on our website - this will continue.

During the 5-year period of the Noise Action Plan, it may be necessary to add or amend the performance indicators to enable effective management and continuous improvement of our aircraft noise impacts. Occasionally we may also set annual targets after discussion with our London Luton Airport Consultative Committee.

Ref:	Key Performance Indicator (KPI)	Target
KP1	Percentage of aircraft on-track	Maintain on-track performance of no less than 99%.
KP2	Population inside 51dB LAeq (16hr) Daytime Contour	Limit and where possible reduce the population within the contour over the course of the action plan.
KP3	Population inside 45dB LAeq (8hr) Night time contour	Limit and where possible reduce the population within the contour over the course of the action plan.
KP4	Percentage of Chapter 4 aircraft	100% Chapter 4 by 2022.
KP5	QC and Movement limits	Ensure compliance within the set limits.
KP6	Percentage of aircraft conducting a CDA	To improve CDA compliance to 95% by 2022.
KP7	Overall Satisfaction with NIS	To ensure an overall satisfaction of the Noise Insulation scheme of 80%.
KP8	Public perception as rated by survey	To increase the percentage of local community that consider that we are doing all we reasonably can to manage the noise impacts of our operations over the course of our action plan.
KP9	Departure Noise Infringement (Day)	To reduce the number of infringements over the course of the action plan.
KP10	Departure Noise Infringement (Night)	To reduce the number of infringements over the course of the action plan.

Conclusion

This Noise Action Plan has been produced with regard to the European Noise Directive and the DEFRA guidance and builds on London Luton Airport's established approach to noise management.

It includes 37 actions that will further improve noise management at London Luton Airport, representing a robust and acceptable approach to addressing noise matters. A large proportion of these measures are voluntary in nature, demonstrating our commitment to take a proactive approach to noise management and seek to minimise the adverse effects of our operations.

The strategy includes a range of instruments, including operational controls, financial penalties and mitigation, where appropriate. It highlights the need to monitor our operations carefully and to report this information transparently and in a way it can be easily understood. It also stresses our commitment to engage in an open and honest way.

In line with the Environmental Noise Directive (END) 2002 and associated regulations, we will formally review our Noise Action Plan every five years. This will follow the END five year cycle starting from 2019 - 2023. We are however committed to continue to review and deliver improvements where possible and necessary.

The successful delivery of this Noise Action Plan requires the cooperation and support of our air traffic control provider, NATS, airlines and other operators. However, it also requires support from the local community and other key stakeholders, to ensure that noise management is considered in the context of the ICAO Balanced Approach.

We will continue to listen and engage. With the support of LLACC we will seek to deliver improvements in the noise performance at London Luton Airport whilst maximising the wider benefits that a major international airport can bring to the local region.

Appendix A

Glossary of Terms

AIP	Aeronautical Information Publication
APU	Auxiliary Power Unit. A power unit located on the aircraft.
ATC	Air Traffic Control
CAA	Civil Aviation Authority
CDA	Continuous Descent Approach
dB (A)	A unit of sound pressure level, adjusted in accordance with the A weighting scale, which takes into account the increased sensitivity of the human ear at some frequencies.
Decibel (dB)	The unit used to measure noise (typically 70dB is equivalent to a normal conversation level).
DEFRA	Department for Environment Food and Rural Affairs
DfT	Department for Transport
END	Environment Noise Directive
EPNdB	Effective Perceived Noise Decibels. It refers to the metric 'EPNL' (Effective Perceived Noise Level) which is used for noise certification and takes account of tones and duration.
FLOPC	Flight Operations Committee
GPU	Ground Power Unit. A power unit located on the ground.
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
LAeq, 16hr	The A-weighted average sound level over the 16 hour period of 07:00 – 23:00
Lday	The A-weighted average sound level over the 12 hour day period of 0700 - 1900 hours.
Lden	The day, evening, night level. It is a logarithmic composite of the Lday, Levening, and Lnight levels but with 5 dB(A) being added to the Levening value and 10 dB(A) being added to the Lnight value.
Leq	Equivalent sound level of aircraft noise in dBA, often called equivalent continuous sound level. For conventional historical contours this is based on the daily average movements that take place in the 16 hour period (0700- 2300 LT) during the 92 day period 16 June to 15 September inclusive.
Levening	The A-weighted average sound level over the 4 hour evening period of 1900 - 2300 hours
LLACC	London Luton Airport Consultative Committee
Lmax	The maximum noise level from a single aircraft passing.
LPA	Local Planning Authority
Lnight	The A-weighted average sound level over the 8 hour night period of 2300 - 0700 hours.

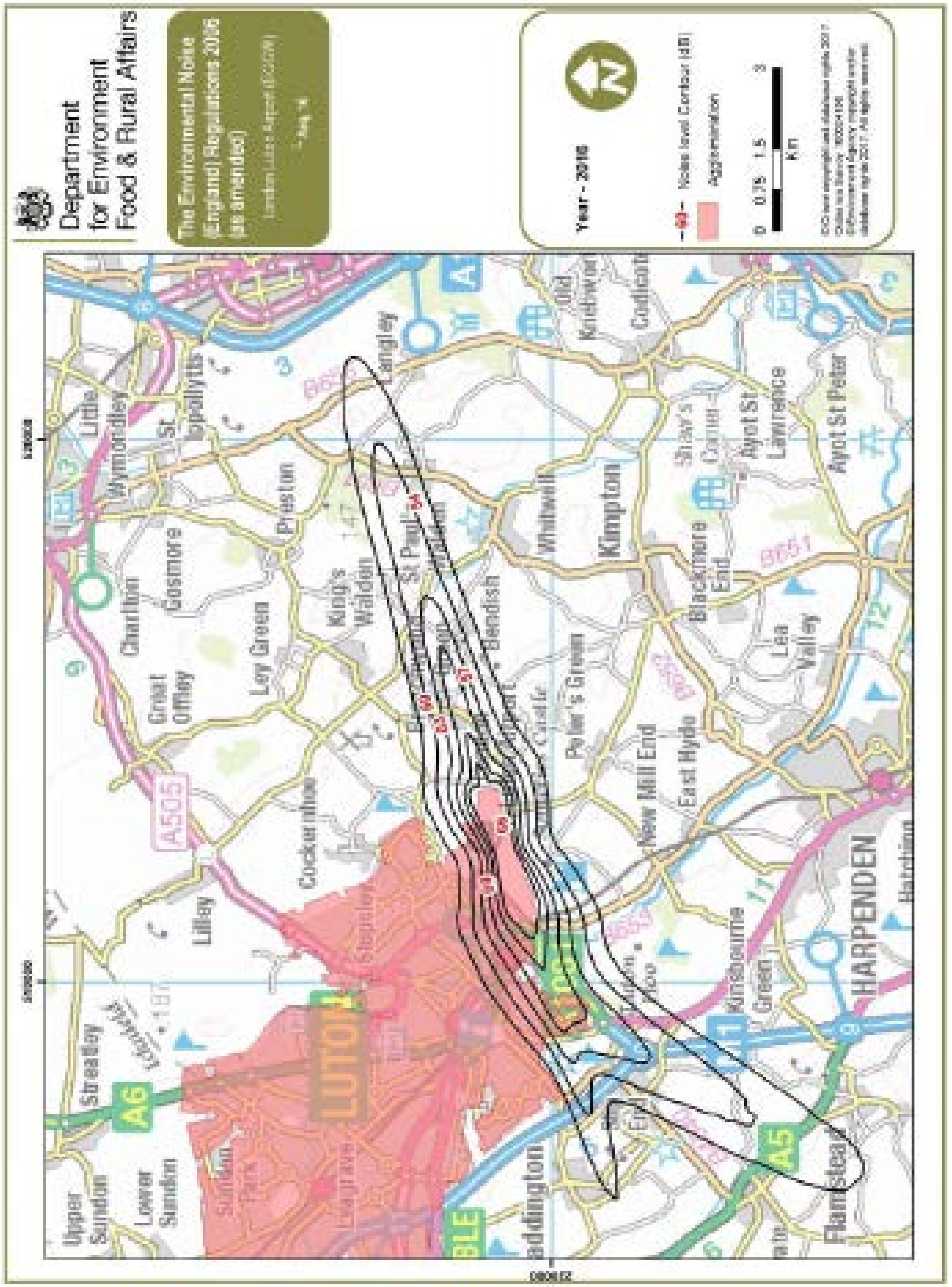
Appendix A (continued)

Glossary of Terms

NATS	Formerly known as National Air Traffic Services Ltd. NATS provides en-route air traffic control for the UK, including local air traffic services at Luton.
Noise Contour	Map contour line indicating noise exposure in dB for the area that it encloses
NTSC	London Luton Airports Noise and Track Sub-Committee
NPR	Noise Preferential Route
QC	Quota Count
SEL	Sound Exposure Level. The level generated by a single aircraft at the monitoring point. This normalised to a 1 second burst of sound and takes account of the duration of the sound as well as its intensity.
SID	Standard Instrument Departure, the published route that an aircraft must follow on departure.
SoS	Secretary of State
Sustainable Aviation	A UK aviation industry initiative aiming to set out a long term strategy for the industry to address sustainability issues.

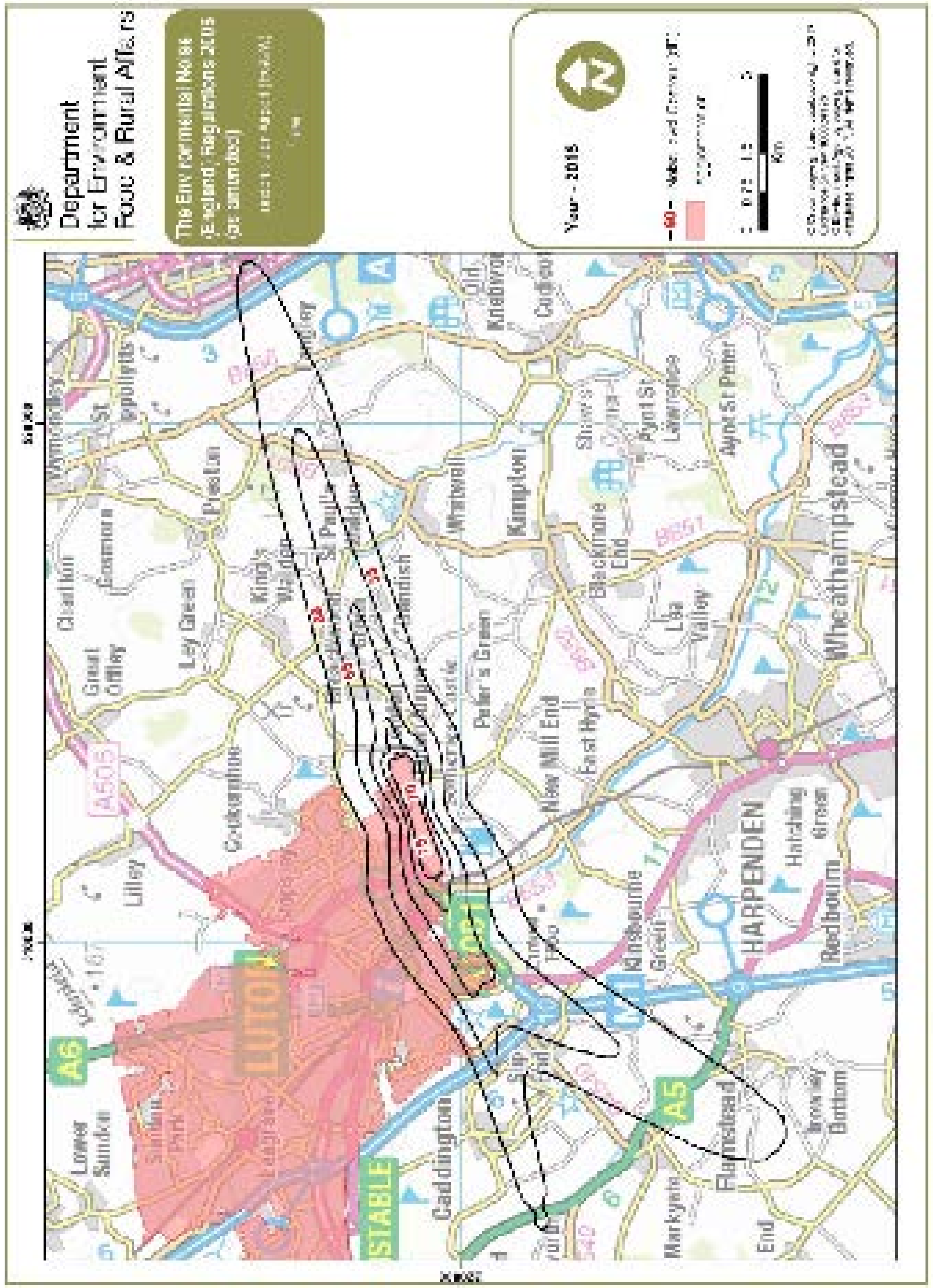
Appendix B

Noise Map - LAeq (16hr)



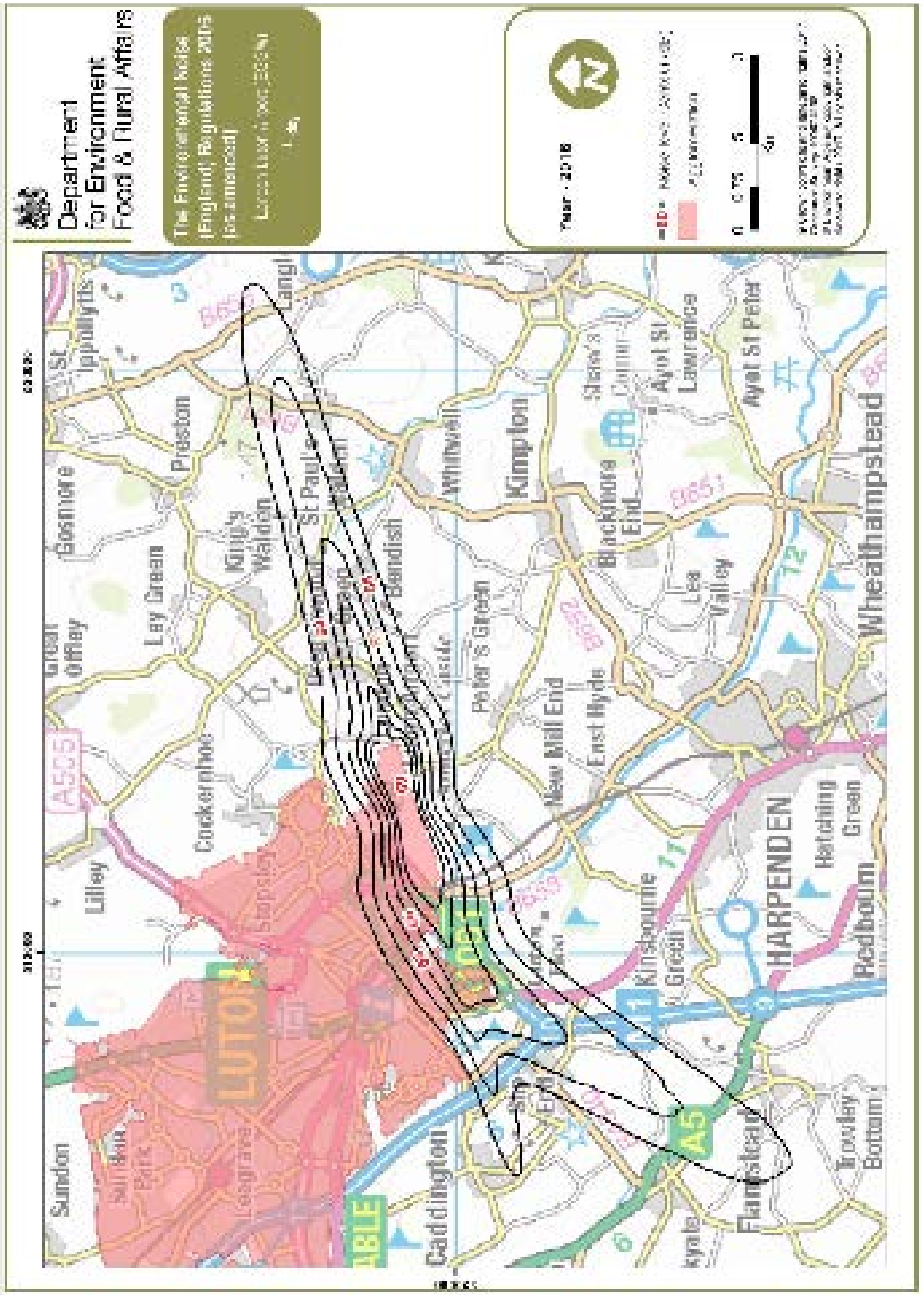
Appendix B (continued)

Noise Map - Lden



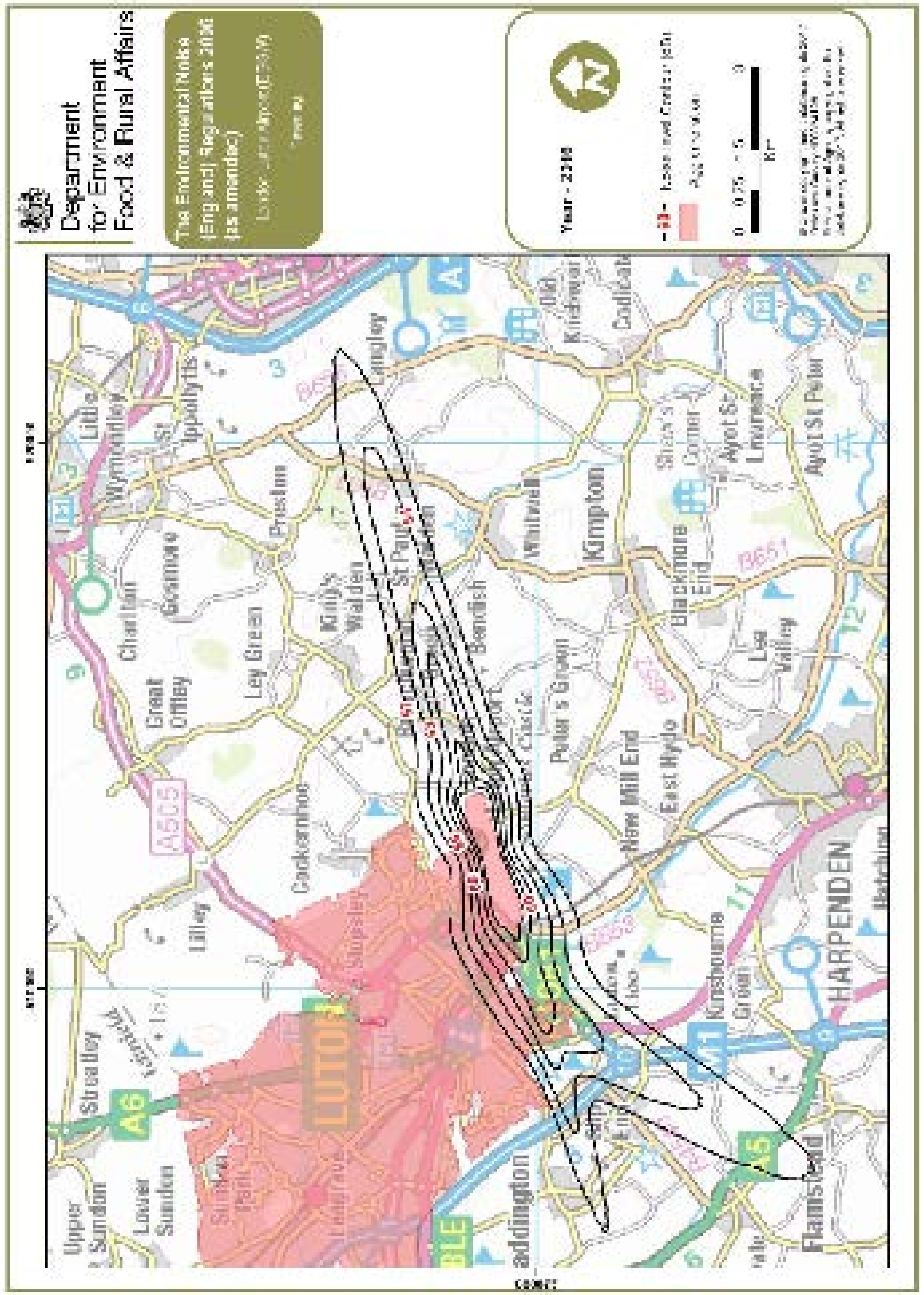
Appendix B (continued)

Noise Map - Lday



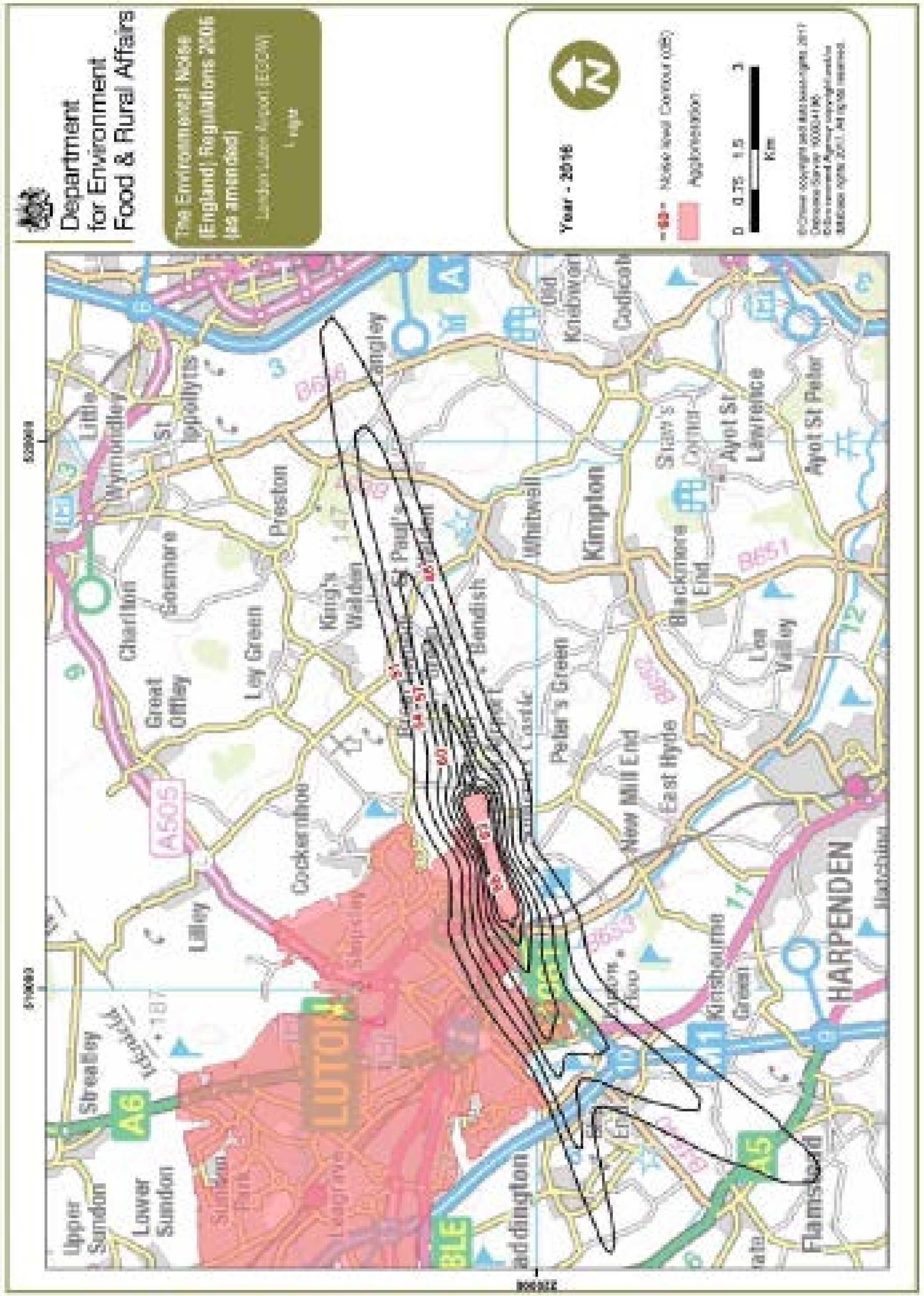
Appendix B (continued)

Noise Map - Levening



Appendix B (continued)

Noise Map - Lnight



Appendix C

Key Stakeholders

London Luton Airport held two consultation periods to seek the views of key stakeholders. The following were organisations were notified of the consultations.

London Luton Airport Consultative Committee (LLACC)

LLACC Independent Chairman
Aylesbury Vale District Council
Bedfordshire & Luton Chamber of Commerce
Bedfordshire Association of Town and Parish Councils
Breachwood Green Society
British Business General Aviation Operators
Buckinghamshire County Council
Buckinghamshire & Milton Keynes Association of Local Councils
Central Bedfordshire Council
Dacorum Borough Council
easyJet Airline Company Limited
Freight Airline Representative
Hertfordshire Association of Town & Parish Councils
Hertfordshire County Council
London Luton Airport Trade Union
Luton and District Association for the Control of Aircraft Noise (LADACAN)
London Luton Airport Town & Villages Communities Committee (LLATVCC)
Luton Borough Council
NATS – London Luton Air Traffic Control
People Against Aircraft Intrusive Noise (PAIN)
St Albans City & District Council
St Albans Quieter Skies
Stevenage Borough Council

London Luton Airport Flight Operations Committee (FLOPC)

Wizz Air
easyJet
Ryanair
Vueling
Blue Air
London Executive Aviation
TUI
Harrods Aviation
Signature Aviation
NetJets
VistaJet
DHL
BALPA
NATS (Swanwick)
Lux Aviation
MNG Airlines
El Al Airlines
Saxon Air
Air Charter Scotland
West Atlantic
Penavia

Other interested parties

London Luton Airport Limited
HarpendenSky
Chiltern Conservation Board
St Albans Save Our Skies

Appendix D

Consultation

In line with the requirements for Noise Action Plans, as set out in DEFRA's Guidance for Airport Operators to produce airport noise action plans under the terms of the Environmental Noise (England) Regulations 2006 (as amended), the information contained in this appendix provides a summary of the consultation responses received from 4th June to 17th August 2019.

The Airport launched its initial consultation on the Draft Noise Action Plan 2019-2023 (DNAP) on the 4th June 2018 and notified 48 organisations that the consultation was open for comment, it also held a consultation event on the 14th June 2018 where representatives from the airport were on hand to answer questions about the DNAP to ensure that consultees could enquire about the proposed actions, as well as providing an email point of contact for any questions in case attendance at the consultation event was not possible.

For the initial consultation period only 9 responses were received, no-one attended the consultation event nor did the Airport receive any questions relating to any of the proposed actions in the DNAP via email.

Following this, the Airport changed the DNAP to incorporate responses from the initial consultation period and chose to extend it to the 17th August 2018 in an attempt to gain further responses to the proposed action plan.

In total the Airport received 14 responses to the DNAP a summary of the common themes is detailed in the table overleaf and a reasoned justification for the response to the issues raised.

Please note that this is not an exhaustive list of all responses received, but all responses were considered and incorporated where possible.

Consultation Questions

Below are the questions used during the draft Noise Action Plan consultation. The responses we receive will be used to influence the detail of the final action plan.

1. Do you think the draft Noise Action Plan will help to strike the right balance between minimising the impact of aircraft noise whilst making best use of the positive social and economic benefits of a successful airport?
Yes/No
Comments

2. To what extent do you think that the draft noise action plan provides a suitable framework to manage aircraft noise?
Excellent - Above Average – Average - Below Average - Very Poor

3. To what extent do you believe that LLA's draft Noise Action Plan meets the requirements of The Noise Action Plan Guidance?
Excellent - Above Average – Average - Below Average - Very Poor

4. Do you think there are any additional actions that LLA should be including in the Noise Action Plan?
Yes/No.
If yes, examples:

5. The draft noise action plan proposes a number of performance indicators to measure progress in implementing the action plan. To what extent do you think that these performance indicators are sufficient?
Extremely – Very - Moderately – Slightly - Not at all

6. Do you have any further comments on the London Luton Airport Draft Noise Action Plan?
Comments

7. Are you happy to have you details recorded/reported?
Yes/No

Summary of Consultation Responses

Description of comments received	London Luton Airport Response	Change to the DNAP
Many of the NAP's actions are without quantitative targets to reduce noise.	Quantitative targets are included in the Airports planning conditions and detailed in the Noise Control Scheme most of which can be found in section 3. The NAP also includes actions to establish baselines and set reduction targets which will be done in collaboration with the Airport's Consultative Committee.	Y
There are no actions that relate to the LLAL vision2050 to expand the airport.	This noise action plan covers the actions proposed for the next 5 years. The proposal to expand the airport beyond 18m passengers per annum has not yet be submitted, The proposal, which will be submitted by the airport owner, will be subject to its own noise management plan, if approved the NAP will be reviewed and will include those additional actions where required.	N
Suggestions that EPNL should be used to show the true position of noise intrusion	Effective Perceived Noise Level (EPNL) is a measure of the relative loudness of an individual aircraft event, usually at the point of noise certification, and cannot be used to measure the impact over multiple aircraft over time. The recent CAA survey of noise attitudes (CAP1506 – SoNA) indicates that the LAeq 16h measurement is still the best to use for evidence based decisions.	N
Omission of the noise contour limits from the Operational Restrictions Section	This was an administrative error, DNAP now contains this action	Y
Lack of detail on how the Airport intends to reduce the noise impact for communities outside the 55dBLAeq	The action plan contains a number of actions that will benefit communities within and beyond the 55dBLAeq including incentivising the use of quieter aircraft and to identify and act on opportunities for modernising airspace structures to facilitate more continuous climb procedures as well as actions to further improve Continuous Descent Approach procedure adherence	N
"quiet areas" need to include rural villages which are beyond the 55dBLAeq contour	"Quiet areas" will be defined as per Government policy	N
LLAOL need to include measures which it is taking to address the mental health impacts of flights and aircraft noise and specifically the impact of sleep disturbance of residents who are most significantly impacted by aircraft noise events outside of the 57dBLAeq	The Noise Policy Statement for England makes the distinction between those significantly adversely affected, and those adversely affected, and requires the focus of noise control to be on those people significantly adversely affected because those are the people most at risk of health impacts. Recent government research indicates that the 63 dBLAeq is the Significant Observed Adverse Effect Level. Many of the actions detailed in the NAP seek to address this requirement.	N

Appendix E

Financial Information

London Luton Airport has estimated the annual financial spend on noise management activities, this is detailed below.

Activity	Estimated Cost (£)
Staff Costs	£150,000
Equipment (including maintenance and licenses)	£110,000
Consultancy	£100,000
Noise Insulation Scheme	£100,000
Community Trust Fund	£125,000

Appendix F

Planning Conditions relating to noise

8. At no time shall the commercial passenger throughput of the airport exceed 18 million passengers in any twelve month period. From the date of this permission the applicant shall every quarter report in writing to the Local Planning Authority the moving annual total numbers of passengers through the airport (arrivals plus departures). The report shall be made no later than 28 days after the end of each quarter to which the data relates.

9 The development shall be operated in accordance with the Noise Control Scheme approved on 2 March 2015 (ref: 14/01519/DOC).

For the avoidance of doubt the controls within that scheme include:
i) Measures with the purpose of phasing out of night time (2300 to 0700) operations by aircraft with a QC value of greater than 1 on either departure or arrival.
ii) Monitoring and review of the scheme not later than the 1st and 4th year after its introduction and every subsequent five years.
iii) Limits during the night time period (2330 to 0600) of:
a) Total annual movements by aircraft (per 12 month period) of no more than 9,650 movements; and
b) Total annual noise quota movements of no more than 3,500 which, using all reasonable endeavours, shall be reduced at each review until it reaches a point where it does not exceed 2,800 by 2028.
iv) Limits for the Early Morning Shoulder Period (0600 to 0700) of not more than 7,000 movements in any 12 month period.
v) Reporting of the actual and forecast total number of aircraft movements for the preceding and next 12 months to the Local Planning Authority every three months.
vi) Within six months of the commencement of the development, a progressive reduction in the night-time (2300-0700) maximum Noise Violation Limits (NVL) by the noisiest aircraft shall be implemented, as follows:
- o 80dB(A) the date hereof
- o 79dB(A) from 1st January 2020
- o 77dB(A) from 1st January 2028

vii) Within six months of the commencement of the development, a progressive reduction in the daytime (0700 - 2300) maximum NVL by the noisiest aircraft shall be implemented, as follows:
- o 82 dB(A) the date hereof
- o 80 dB(A) from 1st January 2020

10 The development shall be operated in accordance with the Noise report approved on 2 March 2015 (ref: 14/01519/DOC), including providing details of forecast aircraft movements and consequential noise contours as set out in that report.

The area enclosed by the 57dB(A) Leq16hr (0700-2300) contour shall not exceed 19.4 sq km for daytime noise, and the area enclosed by the 48dB(A) Leq8hr (2300-0700) contour shall not exceed 37.2 sq km for night-time noise, when calculated by the Federal Aviation Authority Integrated Noise Model version 7.0-d (or as may be updated or amended).

Within five years of the commencement of development a strategy shall be submitted to the Local Planning Authority for their approval which defines the methods to be used by LLAOL or any successor or airport operator to reduce the area of the noise contours by 2028 for daytime noise to 15.2sq km for the area exposed to 57dB(A) Leq16hr (0700-2300) and above and for night-time noise to 31.6 sq km for the area exposed to 48dB(A) Leq8hr (2300-0700) and above.

Appendix F (continued)

11 The development shall be operated in accordance with the Noise Control Monitoring Scheme as approved on 2 March 2015 (ref: 14/01519/DOC).
For the avoidance of doubt the controls include:
i) Fixed noise monitoring terminals and track keeping system (vertical and horizontal)
ii) Complaint handling system
iii) Sanctions to be imposed on infringement by aircraft in respect of track keeping and noise violation limits in accordance with condition 9 (parts vi and vii) of this permission
iv) Arrangements for the verification of the submitted information
A review shall take place not later than the 1st and 4th year after introduction and every subsequent 5 years.

12 The development shall be operated in accordance with the scheme to control ground noise approved on 2 March 2015 (ref: 14/01519/DOC).

Reference 3

BS8233 2014 Guidance on Sound Insulation and Noise Reduction for Buildings

BS 8233:2014

BSI Standards Publication

Guidance on sound insulation and noise reduction for buildings

bsi.

...making excellence a habit.™

Publishing and copyright information

Published by BSI Standards Limited 2014

ISBN 978 0 580 74378 8

ICS 91.120.20

The following BSI references relate to the work on this document:
Committee reference B/564
Draft for comment 12/30241578 DC

Publication history

First published 1948
Second edition 1960
Third edition 1987
Fourth edition 1999
Fifth (present) edition, February 2014

Amendments issued since publication

Date	Text affected

Contents

List of figures

List of tables

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 78, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 28 February 2014. It was prepared by Technical Committee B/564, *Noise control on building sites*, and Subcommittee EH/1/6, *Building acoustics*. A list of organizations represented on these committees can be obtained on request to their secretaries.

Supersession

This British Standard supersedes BS 8233:1999, which is withdrawn.

Information about this document

This British Standard draws on the results of research and experience to provide information on the design of buildings that have internal acoustic environments appropriate to their functions. It deals with control of noise from outside the building, noise from plant and services within it, and room acoustics for non-critical situations. This document is intended for use by non-specialist designers and constructors of buildings and those concerned with building control, planning and environmental health.

This is a full revision of the standard. The principal changes have been made to reflect:

- changes to the legislative framework since publication of the 1999 edition;
- revisions to Building Regulations Approved Document E [1];
- the publication of specialist documents for specific sectors, such as healthcare and education;
- the publication in England of the National Planning Policy Framework [2] in March 2012, with the concurrent withdrawal of numerous individual planning guidance and policy statement documents, including those specifically relating to noise;
- a reappraisal of the tabular content with respect to setting targets for various classes of living space in the light of research findings; and
- the need to transfer some of the more detailed information from the main text to annexes.

BS 8233:1999 was, like its predecessor CP3 Chapter III:1972, published as a code of practice. However, it was decided to publish this edition as a guide because the text largely comprises guidance that does not support claims of compliance.

Use of this document

As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

0 Introduction

Noise control in and around buildings is discussed in this British Standard guide on an objective and quantifiable basis as far as is currently possible. For many common situations, this guide suggests criteria, such as suitable sleeping/resting conditions, and proposes noise levels that normally satisfy these criteria for most people. However, it is necessary to remember that people vary widely in their sensitivity to noise, and the levels suggested might need to be adjusted to suit local circumstances. Moreover, noise levels refer only to the physical characteristics of sound and cannot differentiate between pleasant and unpleasant sounds. Important though psychological factors are, it is not practicable to consider them in this guide.

NOTE The standard is intended to be used routinely where noise sources are brought to existing noise-sensitive buildings.

Attention is drawn to the fact that measures taken to control sound might also impinge on fire precautions and other health and safety requirements. All such requirements need to be considered together at an early stage of the design.

1 Scope

This British Standard provides guidance for the control of noise in and around buildings. It is applicable to the design of new buildings, or refurbished buildings undergoing a change of use, but does not provide guidance on assessing the effects of changes in the external noise levels to occupants of an existing building.

This British Standard does not cover:

a) specialist applications, such as auditoria and cinemas (for cinemas, see BS ISO 9568);

b) vibration control, except where it is evident in the form of radiated sound; or

c) noise that breaks out from the building that might affect external receptors.

NOTE Annex A describes some of the simpler types of noise calculation. A method of rating noise is described in Annex B. Methods of measurement of sound insulation are described in Annex C. Annex D outlines some special problems requiring expert advice. Annex E describes airborne and impact sound insulation. Annex F sets out the legislative framework applicable to noise producing developments. Annex G provides example calculations for resolving a typical design problem. Examples of design criteria adopted by various hotel groups are included for reference in Annex H.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 4142, *Methods for rating and assessing industrial and commercial sound* [1)]

BS 5502-32, *Buildings and structures for agriculture – Part 32: Guide to noise attenuation*

BS EN 20354, *Acoustics – Measurement of sound absorption in a reverberation room*

[1)] Revision in preparation.

BS EN 60942, *Electroacoustics – Sound calibrators*

BS EN 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

BS EN 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*

BS EN ISO 140, *Acoustics – Measurement of sound insulation in buildings and of building elements*

BS EN ISO 140-4, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 4: Field measurements of airborne sound insulation between rooms*

BS EN ISO 140-7, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 7: Field measurements of impact sound insulation of floors*

BS EN ISO 10140-1, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 1: Application rules for specific products*

BS EN ISO 10140-2, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation*

BS EN ISO 10140-3, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 3: Measurement of impact sound insulation*

BS EN ISO 10140-4, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 4: Measurement procedures and requirements*

BS EN ISO 10140-5, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1.1 A-weighted sound pressure

p_A

value of overall sound pressure, measured in pascals (Pa), after the electrical signal derived from a microphone has been passed through an A-weighting network

NOTE The A-weighting network modifies the electrical response of a sound level meter with frequency in approximately the same way as the sensitivity of the human hearing system.

3.1.2 A-weighted sound pressure level

L_{pA}

quantity of A-weighted sound pressure given by the following formula in decibels (dBA)

$$L_{pA} = 10 \log_{10} (p_A/p_0)^2$$

where:

p_A is the A-weighted sound pressure in pascals (Pa);

p_0 is the reference sound pressure (20 μPa)

*NOTE Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with subjective assessments of loudness. They are usually made to assist in judging the effects of noise on people. The size of A-weighting, in 1/3 octave bands, is shown in Annex A (see **A.5**). An increase or decrease in level of 10 dBA corresponds roughly to a doubling or halving of loudness.*

3.1.3 background sound

underlying level of sound over a period, *T*, which might in part be an indication of relative quietness at a given location

3.1.4 break-in

noise transmission into a structure from outside

3.1.5 break-out

noise transmission from inside a structure to the outside

3.1.6 cross-talk

noise transmission between one room and another room or space via a duct or other path

3.1.7 C_{tr}

correction term applied against the sound insulation single-number values (R_w, D_w, and $D_{nT,w}$) to provide a weighting against low frequency performance

NOTE The reference values used within the C_{tr} calculation are based on urban traffic noise.

3.1.8 equivalent continuous A-weighted sound pressure level

$L_{Aeq,T}$

value of the A-weighted sound pressure level in decibels (dB) of a continuous, steady sound that, within a specified time interval, *T*, has the same mean-squared sound pressure as the sound under consideration that varies with time

NOTE 1 This is given by the following formula.

$$L_{\mathrm{Aeq},T} = 10\log_{10}\left[\frac{1}{T}\int_0^T \frac{p_{\mathrm{A}}^2(t)}{p_0^2}\mathrm{d}t\right]$$

where:

$p_A(t)$ *is the instantaneous A-weighted sound pressure in pascals (Pa);*

p_0 *is the reference sound pressure (20 μPa).*

NOTE 2 Equivalent continuous A-weighted sound pressure level is mainly used for the assessment of environmental noise and occupational noise exposure.

3.1.9 equivalent sound absorption area of a room

A

hypothetical area of a totally absorbing surface without diffraction effects, expressed in square metres (m^2), which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration

3.1.10 facade level

sound pressure level 1 m in front of the facade

NOTE Facade level measurements of L_{pA} are typically 1 dB to 2 dB higher than corresponding free-field measurements because of the reflection from the facade.

3.1.11 free-field level
sound pressure level away from reflecting surfaces

NOTE Measurements made 1.2 m to 1.5 m above the ground and at least 3.5 m away from other reflecting surfaces are usually regarded as free-field. To minimize the effect of reflections the measuring position has to be at least 3.5 m to the side of the reflecting surface (i.e. not 3.5 m from the reflecting surface in the direction of the source). Estimates of noise from aircraft overhead usually include a correction of 2 dB to allow for reflections from the ground.

3.1.12 impact sound pressure level
L_i

average sound pressure level in a specific frequency band in a room below a floor when it is excited by a standard tapping machine or equivalent

NOTE For additional information on impact sound pressure level and the standard tapping machine see Annex C and BS EN ISO 140-7.

3.1.13 indoor ambient noise
noise in a given situation at a given time, usually composed of noise from many sources, inside and outside the building, but excluding noise from activities of the occupants

NOTE The location(s) within the room at which the ambient indoor noise is to be measured or calculated ought to be considered.

3.1.14 noise criteria
numerical indices used to define design goals in a given space

3.1.15 noise rating
NR

graphical method for rating a noise by comparing the noise spectrum with a family of noise rating curves

NOTE Noise rating is described in Annex B.

3.1.16 normalized impact sound pressure level
L_n

impact sound pressure level normalized for a standard absorption area in the receiving room

NOTE Normalized impact sound pressure level is usually used to characterize the insulation of a floor in a laboratory against impact sound in a stated frequency band (see Annex C and BS EN ISO 140-7).

3.1.17 octave band
band of frequencies in which the upper limit of the band is twice the frequency of the lower limit

3.1.18 percentile level
$L_{AN,T}$

A-weighted sound pressure level obtained using time-weighting “F”, which is exceeded for *N*% of a specified time interval

EXAMPLE

$L_{A90,1h}$ is the A-weighted level exceeded for 90% of 1 h.

NOTE Percentile levels determined over a certain time interval cannot accurately be extrapolated to other time intervals. Time-weighting "F" or "S" can be selected on most modern measuring instruments and used to determine the speed at which the instrument responds to changes in the amplitude of the signal. Time-weighting "F" is shorter than "S" and so its use can lead to different values when rapidly changing signals are measured.

3.1.19 rating level

$L_{Ar,Tr}$

equivalent continuous A-weighted sound pressure level of the noise, plus any adjustment for the characteristic features of the noise

NOTE This is used in BS 7445 and BS 4142 for rating industrial noise, where the noise is the specific noise from the source under investigation.

3.1.20 reverberation time

T

time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped

NOTE Reverberation time is usually measured in octave or third octave bands. It is not necessary to measure the decay over the full 60 dB range. The decay measured over the range 5 dB to 35 dB below the initial level is denoted by T_{30}, and over the range 5 dB to 25 dB below the initial level by T_{20}.

3.1.21 sound exposure level

L_{AE}

level of a sound, of 1 s duration, that has the same sound energy as the actual noise event considered

NOTE 1 The L_{AE} of a discrete noise event is given by the formula:

$$L_{AE} = 10 \log_{10} \left[\frac{1}{t_0} \int_{t_1}^{t_2} \frac{p_A^{\,2}(t)}{p_0^{\,2}} \, dt \right]$$

where:

$p_A(t)$ *is the instantaneous A-weighted sound pressure in pascals (Pa);*

$t_2 - t_1$ *is a stated time interval in seconds (s) long enough to encompass all significant sound energy of the event;*

p_0 *is the reference sound pressure (20 μPa);*

t_0 *is the reference time interval (1 s).*

NOTE 2 L_{AE} is also known as L_{AX} (single-event noise exposure level).

3.1.22 sound level difference

D

difference between the sound pressure level in the source room and the sound pressure level in the receiving room

NOTE D is given by the following formula.

$$D = L1 - L2$$

where:

L1 is the average sound pressure level in the source room;

L2 is the average sound pressure level in the receiving room.

3.1.23 sound pressure
p

root-mean-square value of the variation in air pressure, measured in pascals (Pa) above and below atmospheric pressure, caused by the sound

3.1.24 sound pressure level
L_p

quantity of sound pressure, in decibels (dB), given by the formula:

$$L_p = 10\log_{10}\left(p / p_0\right)^2$$

where:

p is the root-mean-square sound pressure in pascals (Pa);

p_0 is the reference sound pressure (20 μPa)

NOTE The range of sound pressures for ordinary sounds is very wide. The use of decibels gives a smaller, more convenient range of numbers. For example, sound pressure levels ranging from 40 dB to 94 dB correspond to sound pressures ranging from 0.002 Pa to 1 Pa. A doubling of sound energy corresponds to an increase in level of 3 dB.

3.1.25 sound reduction index
R

laboratory measure of the sound insulating properties of a material or building element in a stated frequency band

NOTE For further information, see Annex C and BS EN ISO 10140-2.

3.1.26 standardized impact sound pressure level
L'_{nT}

impact sound pressure level normalized to a reverberation time in the receiving room of 0.5 s

NOTE Standardized impact sound pressure level is used to characterize the insulation of floors in buildings against impact sounds in a stated frequency band (see Annex C and BS EN ISO 140-7).

3.1.27 standardized level difference
D_{nT}

difference in sound level between a pair of rooms, in a stated frequency band, normalized to a reference reverberation time of 0.5 s for dwellings

NOTE Standardized level difference takes account of all sound transmission paths between the rooms (see Annex C and BS EN ISO 140-4).

3.1.28 Groundborne and structure-borne noise

NOTE When elements of a structure vibrate they radiate noise and, if the vibration is high enough, this noise can be audible. Groundborne and structure-borne noise are rarely an issue outside buildings or structures.

3.1.28.1 groundborne noise

audible noise caused by the vibration of elements of a structure, for which the vibration propagation path from the source is partially or wholly through the ground

NOTE Common sources of groundborne noise include railways and heavy construction work on adjacent construction sites.

3.1.28.2 structure-borne noise
audible noise caused by the vibration of elements of a structure, the source of which is within a building or structure with common elements

NOTE Common sources of structure-borne noise include building services plant, manufacturing machinery and construction or demolition of the structure.

3.1.29 third octave band
band of frequencies in which the upper limit of the band is $2^{1/3}$ times the frequency of the lower limit

3.1.30 weighted level difference
D_w

single-number quantity that characterizes airborne sound insulation between rooms, but which is not adjusted to reference conditions

NOTE Weighted level difference is used to characterize the insulation between rooms in a building as they are. Values cannot normally be compared with measurements made under other conditions (see BS EN ISO 717-1).

3.1.31 weighted normalized impact sound pressure level
$L'_{n,w}$

single-number quantity used to characterize the impact sound insulation of floors over a range of frequencies

NOTE Weighted normalized impact sound pressure level is usually used to characterize the insulation of floors tested in a laboratory (see Annex C and BS EN ISO 717-2).

3.1.32 weighted sound reduction index
R_w

single-number quantity which characterizes the airborne sound insulating properties of a material or building element over a range of frequencies

NOTE The weighted sound reduction index is used to characterize the insulation of a material or product that has been measured in a laboratory (see Annex C and BS EN ISO 717-1).

3.1.33 weighted standardized impact sound pressure level
$L'_{nT,w}$

single-number quantity used to characterize the impact sound insulation of floors over a range of frequencies

NOTE Weighted standardized impact sound pressure level is used to characterize the insulation of floors in buildings (see Annex C and BS EN ISO 717-2).

3.1.34 weighted standardized level difference
$D_{nT,w}$

single-number quantity that characterizes the airborne sound insulation between rooms

NOTE Weighted standardized level difference is used to characterize the insulation between rooms in a building (see Annex C and BS EN ISO 717-1).

3.2 Symbols

For the purposes of this British Standard the following symbols apply.

A Equivalent sound absorption area (m^2)

D Sound level difference (dB)

D_w Weighted level difference (dB)

D_{nT}	Standardized level difference (dB)
$D_{nT,w}$	Weighted standardized level difference (dB)
L_{Amax}	Maximum noise level (dB)
$L_{Ar,Tr}$	Rating level (dB)
L_{i}	Impact sound pressure level (dB)
L_{n}	Normalized impact sound pressure level (dB)
L'_{nT}	Standardized impact sound pressure level (dB)
$L'_{nT,w}$	Weighted standardized impact sound pressure level (dB)
$L'_{n,w}$	Weighted normalized impact sound pressure level (dB)
L_{p}	Sound pressure level (dB)
L_{pA}	A-weighted sound pressure level (dB)
$L_{AN,T}$	Percentile level (dB)
L_{AE}	Sound exposure level (dB)
$L_{Aeq,T}$	Equivalent continuous A-weighted sound pressure level (dB)
p	Sound pressure (Pa)
p_{A}	A-weighted sound pressure (dB)
$p_{A}(t)$	Instantaneous A-weighted sound pressure (Pa)
p_{0}	Reference sound pressure (Pa)
R	Sound reduction index (dB)
R_{w}	Weighted sound reduction index (dB)
T	Time interval (also used for reverberation time) (s)
t_{0}	Reference time interval (s)

4 Measuring equipment and accuracy

The equipment to be used for measuring noise levels should:

a) conform to the accuracy requirements specified in BS EN ISO 140, BS EN ISO 10140 or BS 4142, as applicable; or

b) if not stated, meet Class 2 or better (see BS EN 61672-1, BS EN 61672-2 and BS EN 60942).

In critical situations, for example, where the measurements are to confirm that a specification has been met or for the resolution of a dispute, the appropriate guidelines for the building use should also be followed.

*NOTE 1 Quantification of measurement uncertainty is generally described in the relevant British or International standard and specific guidance, such as that supporting the Building Regulations (see, for example, **7.7.3.1**), healthcare design technical manuals and schools building bulletins (see, for example, **7.7.8**).*

NOTE 2 Where there are no specific measurement requirements for a building use, the guidelines published by the Association of Noise Consultants [3] or other professional bodies may be followed.

5 Planning and design

5.1 Sequence of stages

The recommended sequence of stages in the planning and early design stages of a development is as follows.

a) Assess the site, identify significant existing and potential noise sources, measure or estimate noise levels (see Clause **6**), and evaluate layout options (see **5.2**).

b) Determine design noise levels for spaces in and around the building(s) (see **5.3** and Clause **7**).

c) Determine sound insulation of the building envelope, including the ventilation strategy (see **5.4.5** and Clause **6**).

d) Identify internal sound insulation requirements (see **5.3** and Clause **8**).

e) Identify and design appropriate noise control measures (see **5.4**).

f) Establish quality control and ensure good quality workmanship (see **5.5**).

Although this British Standard does not cover the impacts on external receptors of noise that breaks out from the building, it might be necessary to address this within the overall design and planning process.

The same sequence [a) to f)] can be applied where a new noise-making development is to be introduced near an existing noise-sensitive development, such as housing.

5.2 Assessing the building or site

5.2.1 Need for noise assessment

When planning permission is sought for a new building or for a change of use to an existing building, the local planning authority may:

a) refuse permission if the site is too noisy for the proposed use and local or national noise policies will not be met; or

b) refuse permission if the proposed use is likely to cause noise disturbance to the occupants of existing buildings such that local or national noise policies will not be met; or

c) grant permission, with or without conditions regarding noise levels, so that local or national noise policies are met.

NOTE 1 The local planning authority needs to take account of the following government publications:

- *in England: the National Planning Policy Framework published by the Department for Communities and Local Government (March 2012) [2], relevant National Policy Statements and the Noise Policy Statement for England [4];*
- *in Wales: the Welsh Government publications "Planning Policy Wales" [5] and Technical Advice Note (TAN) 11: Noise [6];*
- *in Scotland: the Scottish Government's Planning Advice Note 1/2011: Planning and Noise [7] and the accompanying Technical Advice Note [8];*
- *in Northern Ireland: where appropriate, the relevant Planning Policy Statement [9] or relevant Development Control Advice Note [10]; and*
- *any noise action plans published under the relevant Environmental Noise Regulations [11, 12, 13, 14].*

It is therefore important that, even when a full environmental assessment is not mandatory, proposals for developments on noisy sites, or sites which generate noise, should take account of noise, and an assessment should be made of the possible effects of:

1) noise generated outside the site that might enter any building on site;
2) noise generated inside the site or a building on site that could affect people outside the site/building;

   NOTE 2 The noise in item 2) is outside the scope of this British Standard.

3) the effect of the proposed development on the existing ambient noise outside the site.

Some noise sources (e.g. airports) might not always be active, or might change their mode of operation under different weather conditions and/or at certain times of day or night. Furthermore, buildings might not necessarily be occupied when the outside environment is noisy. It is therefore essential to make a full assessment of the site before considering the need for, and extent of, noise control.

5.2.2 Noise generated inside or outside the building

5.2.2.1 Noise generated inside the building

For noise generated and heard within the building, the design guidance in Clause **8** for sound insulation within the building should be followed.

The existing and expected noise source(s) should first be identified and the designer should apply the following procedures.

a) Select metrics to use for measuring or predicting noise levels (e.g. $L_{\text{Aeq},T}$, or L_p in octave or third octave bands).
b) Assess effects of topography and other features, such as noise screens or reflecting surfaces.
c) Measure or predict noise levels at strategic points. In some complex situations it might be worth drawing a contour map of external noise levels.
d) If appropriate, assess noise levels due to user activities around the buildings and site.

The levels of existing noise and noise expected in the foreseeable future should be based on measurement where practicable, or may be predicted if there is reliable information.

5.2.2.2 Noise generated outside the building

For noise sources outside the building, the initial appraisal should take account of the options for:

a) location of the site in relation to the noise source(s);
b) reduction of noise at source;
c) positioning of buildings on site;
d) orientation of buildings on site;
e) provision of barriers;
f) increasing the sound insulation of the building envelope; and
g) re-planning the interior layout of the building.

These options might also be applicable to protecting neighbouring buildings that are likely to be disturbed by noise generated within the building.

5.3 Design and noise criteria: noise levels

The designer should establish the intended use, including noise activity, noise sensitivity and privacy, of the proposed rooms and other spaces.

To achieve satisfactory sound insulation inside the building, it is necessary to know how each space is to be used so that appropriate noise criteria can be chosen. The designer can then decide which noise criteria are appropriate for the relevant parts of the proposed building, and select appropriate noise levels (see **7.2** and **7.3**).

NOTE Advice on indoor ambient noise criteria for various building types is given in ***7.3****.*

The designer should also:

a) compare external noise levels with internal design criteria;

b) calculate the noise reduction required between the exterior and interior;

c) if appropriate, assess internal noise sources;

d) calculate the noise reduction required between internal user areas and, if necessary, the noise reduction required to reduce noise from internal sources to the level required outside the building; and

e) identify which noise control measures would be appropriate to deliver this noise reduction (see **5.4**).

5.4 Noise control measures

5.4.1 General approach

All reasonable noise control measures should be designed and implemented to ensure that the noise levels are met, along with local or national noise management policies, as appropriate.

NOTE Effective design for noise control requires a good understanding of the behaviour of sound. While the general approach is explained in this subclause, practical information on the transmission of sound within buildings and propagation across the ground is given in the Building Research Establishment document BR 238/CIRIA report 127 [15]. Specialist advice is required for more complex situations, such as those listed in Annex D.

In determining the appropriate noise control measures, the designer should take the following steps, which may be iterative.

a) Check the feasibility of reducing noise levels and/or relocating noise sources.

b) Consider options for planning the site or building layout.

c) Consider the orientation of proposed building(s).

d) Select construction types and methods for meeting building performance requirements (see **5.4.4**).

e) Examine the effects of noise control measures on the requirements for ventilation, fire regulation, health and safety, cost, CDM (construction, design and management), etc.

f) Assess the viability of alternative solutions.

The designer should then decide which of the following options can be applied to reduce noise levels.

1) Quietening or removing the source of noise (**5.4.2**).

2) Attenuating the sound on its path to the receiver (**5.4.3**).

3) Obstructing the sound path between source and receiver (**5.4.4**).

4) Improving the sound insulation of the building envelope (**5.4.5**).

5) Using agreements to manage noise (**5.4.6**).

5.4.2 Quietening the source

Reducing the noise at source should always be considered because the number of people benefiting might be large and it can be the most cost-effective method.

5.4.3 Attenuating the noise

Noise is attenuated as it travels through the air because it:

a) spreads out;

b) is affected by nearby surfaces, such as grass-covered ground; and

c) is partly absorbed by the air itself.

These mechanisms for attenuating noise become more effective as the distance between the source and the receiver increases. Spreading is usually the most important effect. For small sources, the reduction is up to approximately 6 dB for each doubling of distance between source and receiver. For extended sources, there is a smaller reduction with distance. For example, the noise level from dense road traffic diminishes at approximately 3 dB for each doubling of distance.

In some circumstances, the noise might not attenuate at expected rates, with poor attenuation occurring with traffic in city streets with high buildings on both sides. In this situation, the noise level diminishes vertically very slowly as the storey height increases because of multiple reflections between the facades (canyon effect).

Ground attenuation is negligible for hard ground and water surfaces. For grassland and other types of ground considered “soft”, the attenuation varies with frequency.

5.4.4 Obstructing the sound

Complete enclosure of the noise source or receiver is the most effective form of barrier, provided it is impervious and sufficiently heavy. The walls and roof of a building usually perform this function (see Clause **8**). Their effectiveness as a sound insulator is reduced by weaknesses in the envelope (e.g. ventilation openings, thin glazing and doorways), especially when windows are opened. It is therefore important that the effectiveness of measures for obstructing sound is determined.

Barriers that are not complete enclosures (e.g. screens) are normally most effective when tall, long, sound-absorbent, and close to either the source or the receiver.

Solid fences, walls, earth bunds or buildings should extend to the ground.

Whilst neither of the national methods for calculating noise from road traffic or from railways provides for any reduction in noise due to the presence of vegetation, other available guidance suggests that appreciable attenuation can be expected under certain conditions. ISO 9613-2 includes procedures for estimating the attenuation from foliage (trees and shrubs) in each octave band as a function of the total propagation distance that the sound travels through the foliage.

In the context of promoting sustainable methods for reducing road traffic noise, the HOSANNA (Holistic and Sustainable Abatement of Noise by Optimised Combinations of Natural and Artificial Means) Research Project (see Note), funded by the European Union Seventh Framework Programme, was tasked with investigating the theoretical performance of different forms and configurations of vegetation-based noise mitigation, including trees (rows and belts), shrubs and bushes. The study reports that, through an optimized combination of scattering, dispersion, absorption and diffraction effects, appreciable reductions in traffic noise can be expected from compositions of vegetation elements (such as twigs, leaves, stems and trunks).

*NOTE To calculate the attenuation for road and rail traffic noise and construction noise, see the references given in Clause **6**. Attenuation values of approximately 10 dB are common, but a barrier can reduce the benefit of any ground absorption.*

5.4.5 Sound insulation of the building envelope

5.4.5.1 General

Where the designer proposes a form of construction that is intended to obstruct noise, and which might take into account cost and other constraints, the proposed design should be examined and calculations carried out to determine whether the target noise reduction is likely to be achieved. The results indicate whether a higher standard of noise reduction might be necessary or whether a lower standard is adequate. If the need for a change in the design is indicated, further calculations should be carried out and the process repeated until a satisfactory result is obtained. In a situation where a low standard suffices it might be prudent to consider future uses of the building.

When the sound insulation of the building envelope is not known, this may be calculated using one of the methods given in **5.4.5.2** (see also BS EN 12354).

5.4.5.2 Calculations

5.4.5.2.1 General

The required sound insulation should be determined on the basis of the assessment of:

a) the level and characteristics of the noise outside the building (see **5.2** and Clause **6**);

b) the design noise levels in the rooms and other spaces of the building (see **5.3** and Clause **7**).

The sound insulation required can then be determined.

5.4.5.2.2 Initial estimates

Initial estimates may be obtained using calculations based on single-figure data such as the following.

a) The level of the noise at a key position, such as the equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$) at the location of the nearest facade of the proposed building. The time period, T, should be chosen to cover the normal operation of the source, or particular occupational requirements of the building if more appropriate. If the source level varies, the maximum level having an appreciable duration should be chosen.

b) The sound reduction of appropriate parts of the building envelope, e.g. estimated from values of R_w (see Clause **8** and Annex E).

   NOTE Annex A contains a method for estimating the sound insulation of a non-uniform facade comprising windows, ventilation openings and cladding.

c) The design sound level at the receiver (e.g. $L_{Aeq,T}$). If the source operates at night, it might be appropriate to have separate design noise levels for day and night periods.

It is important to understand that there is no simple relationship connecting these single-figure data and that the results are approximate (see Clause **6**).

5.4.5.2.3 Detailed calculations

For detailed calculations, knowledge of the following is required.

a) Frequency characteristics of the noise source(s).

b) Frequency characteristics of the sound reducing elements.

c) Surface area of the common construction separating the two areas.

d) Reverberation time of the receiving space.

Generally, frequency data should be for contiguous octave bands.

5.4.6 Agreements

For certain types of building, it might be possible to assist the management of noise by express provisions in agreements. For example, a contract specification might set noise limits, a tenancy agreement can restrict the use of musical instruments, providing the restriction is sufficiently specific to be enforceable, or a noise management plan might require monitoring of noise levels and actions if limits are exceeded.

5.5 Quality control and workmanship

Quality control and workmanship should always be considered very carefully. Noise control measures can fail to perform adequately if they are not built as the designer intended. Such variations might appear to be unimportant, but often have serious implications for noise control, e.g. a slight warp in a window frame can reduce the effectiveness of the seals. To establish good quality control and workmanship the following aspects should be considered by the designer and discussed with the builder.

a) Detailed specifications.

b) The standards of materials and workmanship.

c) Performance specification in the contract documentation.

d) Checking and testing procedures that are to be used to demonstrate the standard of workmanship during construction.

e) Checking and testing procedures that are to be used to assess the building performance.

6 External noise sources

6.1 Introduction

Noise from common sources in the environment is dealt with in **6.2** to **6.7**. In each case, information is given on the characteristics of the noise and guidance is given as to how levels can be determined and controlled for each specific source. Example calculations for resolving a typical design problem are given in Annex G.

6.2 Noise from road traffic

6.2.1 General

Road traffic noise generation depends upon a number of factors, including:

a) traffic flow, which can vary considerably within and between days of the week;

b) type of vehicles, i.e. proportion of heavy or light;

c) mode of operation, i.e. on level or inclined road;

d) surface texture of the road; and

e) traffic speed and whether flow is continuous or interrupted.

NOTE Weather conditions, e.g. surface water on road, can also affect noise generation.

As with other types of noise the propagation depends upon meteorological conditions, topographical features and ground cover characteristics.

For a typical urban situation where road speed is below 60 km/h, sound energy is concentrated in the low frequency end of the spectrum because of high levels of exhaust noise, particularly from diesel commercial vehicles. At greater speeds (i.e. 80 km/h or higher), more energy is present at higher frequencies due to the road/tyre surface interaction and aerodynamic noise. This difference in spectral characteristics can affect the nature of the noise heard within a building, and should be considered when different noise control measures are being examined.

For initial design purposes, typical noise levels for three common situations are given in Table 1.

Table 1 **Typical traffic noise levels measured approximately 1 m from the facade**

Situation	**dB** $L_{Aeq,16h}$
At 20 m from the edge of a busy motorway carrying many heavy vehicles; average traffic speed 100 km/h; intervening ground turfed	78
At 20 m from the edge of a busy main road through a residential area; average traffic speed 50 km/h; intervening ground paved	68
On a residential road parallel to a busy main road and screened by the houses from the main road traffic; free flowing traffic	58

NOTE Values are for dry road.

A typical noise spectrum for assessing sound reduction near roads is given in BS EN 1793-3. For more complex situations, detailed calculations or measurements should be undertaken.

6.2.2 Modelling traffic noise

The noise from road traffic can be calculated for a specified range of situations using the method in *Calculation of Road Traffic Noise* (CRTN) [16]. This method predicts the $L_{A10,18h}$ for the period 06:00 to 24:00 or the $L_{A10,1h}$ for roads carrying more than 1 000 vehicles per 18 h day or 50 vehicles per hour. It is the recognized national method for calculating road traffic noise levels, but has been augmented by additional guidance published by the Highways Agency (*Design Manual for Roads and Bridges*, Volume 11, Section 3, Part 7, HD 213/11 – Revision 1) [17]. This additional guidance includes updated advice on calculating night-time noise levels, determining the extent of the study area, vehicle classification, corrections for contemporary road surfaces, speed data, and other approaches to modelling certain specific situations. It is usual to make flow rate forecasts 15 years ahead.

The method takes the following factors into account.

a) Hourly or 18-hourly traffic flow rate.

b) Mean traffic speed.

c) Percentage of heavy vehicles.

Other information required for the calculation includes:

1) road surface and gradient;

2) ground type;

3) height of receiver;

4) shielding by barriers and cuttings;

5) reflections at facades and from nearby buildings; and

6) angle of view of the road.

The method can be used to draw noise contours on a site plan, and this is now usually implemented through a number of proprietary noise prediction models which implement the calculation procedure in CRTN [16]. However, where traffic conditions are complex or unusual it might be necessary to measure noise levels on site, and procedures for measurements are contained within CRTN [16].

A Defra-commissioned study, prepared by TRL and entitled "*Method for Converting the UK Road Traffic Noise Index $L_{A10,18h}$ to the EU Noise Indices for Road Noise Mapping*" [18], is the source of the method promulgated in Highways Agency document HD 213/11 [17] for estimating night-time noise levels from the calculated or measured $L_{A10,18h}$.

This study, however, also provides methods for the conversion of $L_{A10,18h}$ index to other indices, including various period $L_{Aeq,T}$ values. Whilst these conversions have been developed primarily for compliance with strategic EU noise mapping requirements, they provide one potential approach to estimating the range of noise indicators which are relevant to modelling traffic noise.

Otherwise, conversion of L_{A10} to L_{Aeq} can be achieved by the (approximate) relationship: $L_{Aeq,16h} = L_{A10,18h} - 2$ dB. This is generally correct with a 95% confidence interval of ±2 dB for moderate and heavy traffic flows.

6.3 Noise from aircraft

6.3.1 General

For most airports, the airport operator is responsible for the noise management, which has to be designed to align with Government policy. The exceptions are Heathrow, Gatwick and Stansted, for which the Department of Transport has noise management responsibility. Airports covered by Directive 2002/49/EC [19] have published Noise Action Plans which describe their noise management, including information about flight paths, hours of operation, the planning conditions under which they operate and other noise mitigation practices.

Aircraft noise can be controlled by voluntary noise abatement procedures, which can include:

a) the adoption of noise preferential routes; and

b) restrictions on the number of movements and/or classes of aircraft.

Aerodromes used for commercial air transport of passengers and for training in aircraft above certain total maximum total weights are licensed by the Civil Aviation Authority (CAA). Many aerodromes, including general aviation (private and recreational flying and aviation work), do not require a licence for their operation, but the CAA remains responsible for all matters affecting the safety of aircraft and provides guidance on noise consideration at general aviation aerodromes [20].

Planning conditions and legally binding agreements between local planning authorities and landowners can also impose restrictions on aircraft types and operating times, and number of movements, to control noise.

Military aircraft operate under the control of the Military Aviation Authority (MAA).

6.3.2 Prediction of noise from aircraft

Prediction of noise from aircraft or airports is complex, though aircraft noise modelling software packages are available. Many airports periodically produce contours showing the noise exposure around the airport. Care is needed in interpreting these contours as they tend to show average exposure, taking account of different modes of airport operation. This means that, on a particular day, the noise exposure at a particular location might be higher than implied by the contours, and consideration should be given to designing the building envelope for those operational days.

These contours show the noise of aircraft departing from and arriving at an airport without the presence of any shielding effects from buildings or topographical features. They also do not include the noise from ground operations such as taxiing, auxiliary or ground power units or engine testing. Where appropriate, these sources need to be considered separately.

Where it appears that sound insulation treatment is necessary, noise exposure data should be obtained by on-site noise measurements, taking account of wind direction and runway usage. The survey duration of on-site measurements should be sufficient to take account of the various permutations of runway use that can occur, as certain flight paths might only be used under certain wind direction conditions. Where treatment of the building envelope is required to achieve internal design standards then site-specific measurements should be recorded, including provision for the frequency content of the noise (predominantly low frequency noise). It should be noted that for a jet aircraft the frequency content of noise when landing is generally different from that when departing. Typically, landing jet aircraft produce relatively higher levels of high-frequency noise and departing jet aircraft produce relatively higher levels of low-frequency noise.

6.4 Noise from railways

6.4.1 General

Noise from passing trains is characterized in two ways.

a) The passage of trains over the day and night periods, which is dependent upon timetabling. Passenger trains follow strict daily timetables; freight train passage is less predictable and often occurs at night when passenger services have ceased.

b) The specific characteristic associated with the passage of each train type, but this is generally characterized by short periods of high noise levels dependent upon speed, locomotive type, power type (electric/diesel), etc.

6.4.2 Prediction of airborne noise from railways

The recognized national calculation method for airborne noise from railways is given in *Calculation of Railway Noise (CRN)* [21], with additional source terms given in *Additional railway noise source terms for "Calculation of Railway Noise 1995"* [22]. The method begins with the calculation of a reference sound exposure level (SEL or L_{AE}) for rolling noise at 25 m, which is speed-based. The calculated value is then corrected for vehicle type/description which takes into account number of axles and brake type. The procedure enables calculation of two $L_{Aeq,T}$ values:

a) day $L_{Aeq,16h}$ (07.00 to 23.00); and

b) night $L_{Aeq,8h}$ (23.00 to 07.00).

This method takes into consideration the following factors for each type of train.

1) SEL (or L_{AE}) of the train(s).
2) Number and times of train movements.
3) Distance from track.
4) Air absorption.
5) Ground type.
6) Track bed type.
7) Screening.
8) Angle of view.
9) Reflection and facade effects.

6.5 Noise from industry

6.5.1 General

Industrial noise can originate from specific processes, either internal or external to buildings, or from related transport operations, such as loading/unloading vehicles or activities involving other plant such as fork lift trucks.

*NOTE Normal traffic movements on site may be assessed using the measures in **6.2**.*

6.5.2 Assessment of industrial noise

Where industrial noise affects residential or mixed residential areas, the methods for rating the noise in BS 4142 should be applied. BS 4142 describes methods for determining, at the outside of a building:

a) noise levels from factories, industrial premises or fixed installations, or sources of an industrial nature in commercial premises; and

b) background noise level.

6.6 Noise from construction and open sites

6.6.1 General

Noise from construction and open sites can disturb occupants of nearby buildings, whether in residential or other uses. Noise at night can cause sleep disturbance. On this basis, it is commonly accepted that controls are necessary for many construction and open sites, unless they are sufficiently remote from occupied buildings. BS 5228-1 gives recommendations for basic methods of noise control for construction and open sites where work/activities/operations, including demolition, generate significant noise levels. Industry-specific guidance is also included. The legislative background to noise control is described and recommendations are given for establishing effective liaison between developers, site operators and local authorities. Guidance is also given on methods of predicting and measuring noise and assessing its impact on those exposed to it.

6.6.2 Noise effects and community reaction

The main factors that affect the acceptability of noise arising from construction sites are:

a) site location;

b) existing ambient noise levels;

c) duration of site operations;

d) hours of work;

e) attitude of the site operator, e.g. if the site operator communicates with affected residents on a regular basis as to when and for how long noisy events are planned to occur, the expected noise is perceived as less annoying than unexpected noise of an unknown duration;

f) noise characteristics; and

g) whether additional mitigation has been provided in the form of sound insulation or temporary or permanent rehousing.

BS 5228-1 describes methods for noise control and for determining the significance of noise effects. Several example assessment methods are provided from various significant projects. However, one of the key elements is the provision in BS 5228-1:2009, Annex F, of methods for estimating noise from sites, which is assisted by the inclusion of a large data set of source terms for plant and activities.

6.6.3 Prediction of construction site noise

Noise from construction sites arises from a wide range of plant and activities with many different characteristics. BS 5228-1:2009, Annex F, provides methods for estimating the $L_{\text{Aeq},T}$ levels, taking into account:

a) sound power outputs of processes and plant;

b) periods of operation of processes and plant;

c) distances from sources to receivers;

d) presence of screening by barriers;

e) reflection of sound; and

f) soft ground attenuation.

The levels from the range of equipment used are combined to give an overall $L_{\text{Aeq},T}$ level.

NOTE Slightly different procedures exist for stationary and mobile plant, and these are described in a flowchart in BS 5228-1:2009, Figure F.1.

6.7 Noise from wind farms

6.7.1 General

Wind turbines vary in size and power output, from those just a few metres in diameter to large turbines of around 90 m in diameter. As the turbine blades rotate, aerodynamic noise is generated, which sounds like a swishing noise. Many modern pitch-regulated turbines achieve a maximum level of noise emission at or around the wind speed at which they reach their maximum power generation capacity, which then remains constant, or in some cases declines, as wind speed increases. Mechanical noise from the gearbox (when fitted) and, to a lesser extent, the generator is not usually significant, except in small or older turbine designs. The hub is isolated from the tower and the blade assembly to prevent significant structure-borne noise occurring, which in turn prevents any significant vibrations being transmitted to the ground.

6.7.2 Assessment of wind farm noise

The design, size and rotational speed of a turbine influences the character of the noise generated. The quantification of the noise emissions of medium to large wind turbines is set out in BS EN 61400-11. A particular feature of aerodynamic noise, which is often cited as an adverse feature of medium to large wind turbines, is that of amplitude modulation (AM), which is the modulation or rhythmic swish. Excess AM can sometimes occur. However, it cannot be predicted at the planning stage with the current state of the art. Within the UK, ETSU-R-97 [23] may be used to assess and rate the noise from wind farms. ETSU requires wind farms to achieve defined noise limits in order to preserve day time outdoor amenity and sleep quality at night.

In comparison, small turbines generally have a lower noise emission level, but generate higher frequencies since the blades rotate at greater speeds. Thus the noise impact from these turbines is relatively localized. Offshore turbines might only influence the design and construction of buildings when there is nearby onshore infrastructure, such as electrical substations and converter stations.

6.7.3 Prediction of wind turbine noise

Reliable estimates of wind turbine noise can be made using the procedures in the Institute of Acoustics' *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* [24], which provides accepted methods of noise prediction. Following these procedures permits calculation of reliable noise levels at varying distances and locations for a range of operational wind speeds (typically 4 m/s to12 m/s).

6.8 External noise sources: Meteorological effects

Whether noise levels are measured or predicted, wind gradients, temperature gradients and turbulence affect the level of received sound and audibility over short periods. The magnitude of these effects, i.e. variations in noise level and audibility, increases with increasing distance between source and receptor. The effects are asymmetrical and, for distances of 500 m to 1 000 m, typically range from increasing the level by typically 2 dB downwind to reducing it by typically 10 dB upwind. It is not usually practicable to use these factors in design, but the prevailing wind direction should be considered when planning building orientation.

Noise from wind and precipitation, including the wind-generated noise from trees, can also affect noise measurements.

6.9 Other sources of noise

Other noise sources exist, many of which originate from leisure activities, e.g. model aircraft, sports and entertainment.

Codes of practice give guidance on likely noise levels, assessment and frequency of occurrences for most of these noise sources [for example, 25, 26, 27]. Specialist advice might be required.

NOTE Codes produced by the Government can normally be obtained from The Stationery Office, and additional advice might be available from local authority environmental health departments.

Noise from natural sources, such as rivers, streams, waves, birdsong, wind in trees or rain, also contributes to the acoustic environment and could affect noise assessments.

7 Specific types of building

7.1 General

Guidance is given in **7.2** to **7.6** on acoustic criteria and noise levels appropriate for various types of space that have different functions. In addition, attention is drawn to special features requiring consideration. Where the acoustic performance of spaces or systems is critical [e.g. auditoria or complex heating, ventilating and air conditioning (HVAC) systems], specialist advice should be sought (see Annex D).

It is not practical to give detailed guidance on all types of building. Many types of building include spaces having different functions. For example, a factory may include workshops, offices and meeting rooms. Appropriate guidance is given in **7.7**.

7.2 Design considerations

To control internal ambient noise from sources such as traffic and mechanical services, the designer should, at the outset, decide which of the following are appropriate for all or different parts of the proposed building.

a) Industrial working conditions.

b) Speech and telephone communications.

c) Acoustic privacy.

d) Conditions for study and work requiring concentration.

e) Listening conditions.

f) Resting/sleeping conditions.

The designer should establish noise activity levels, noise sensitivity and privacy levels for the relevant spaces.

7.3 Indoor ambient noise criteria

For each space there might be a range of noise levels that are considered acceptable. The designer should select a level appropriate for the particular circumstances. In noise-making workshops, etc., the activity noise is dominant and so the internal ambient noise level is not critical. In most other situations internal ambient noise is important.

NOTE Guidance on indoor ambient noise levels is given in Table 2, Table 3, Table 4, Table 5 and Table 6 for various types of room.

Normally, only the maximum desirable noise level needs to be decided (see Table 4 and Table 5). In some cases, such as open-plan offices and restaurants, a moderate noise level might provide masking for acoustic privacy in shared spaces without causing disturbance, so upper and lower noise levels should be considered (see Table 2).

Table 2 **Indoor ambient noise levels in spaces when they are unoccupied and privacy is also important**

Objective	Typical situations	Design range $L_{Aeq,T}$ dB
Typical noise levels for acoustic privacy in shared spaces	Restaurant	40 – 55
	Open plan office	45 – 50
	Night club, public house	40 – 45
	Ballroom, banqueting hall	35 – 40
	Living room	35 – 40

NOTE See Noise control in building services [28] and BS EN ISO 3382.

Noise levels generally apply to steady sources, such as those due to road traffic, mechanical services or continuously running plant, and should be the noise level in the space during normal hours of occupation but excluding any noise produced by the occupants and their activities. The time period, *T*, should be appropriate for the activity involved (e.g. 23.00 to 07.00 for bedrooms, 30 min for schools). If the noise is fairly steady, it might not be necessary to measure for the whole of the relevant time period to establish the typical outdoor level.

*NOTE Guidelines for the measurement of noise in buildings can be obtained from The Association of Noise Consultants (http://www.association-of-noise-consultants.co.uk/index.php?*p=pubguide).*

7.4 Noise indices

The noise rating (NR) system, a graphical method described in Annex B, is in common use for rating noise from ventilation systems. Although there is no direct relationship between dBA and NR, the following approximate relation applies in the absence of strong low frequency noise.

$$NR \approx dBA - 6$$

Although the NR system is currently a widely used method for rating noise from mechanical ventilation systems in the UK, other methods are also available that are more sensitive to noise at low frequencies [29]. Low frequency noise can be disturbing or fatiguing to occupants, but might have little effect on the dBA or NR value.

7.5 Internal sound insulation

In addition to controlling exterior noise and internal services noise, sound from adjacent spaces can affect the intended use, depending on the noise activity, noise sensitivity and privacy requirement. A matrix may be used to determine the sound insulation requirement of separating partitions once the noise activity, noise sensitivity and privacy requirements for each room and space are established (see **7.2**). An example matrix, which can be adapted according to the specific building use, is given in Table 3. Each room may be both a source and a receiving room. Where adjacent rooms have different uses, the worst case sound insulation should be specified.

Table 3 **Example on-site sound insulation matrix (dB $D_{nT,w}$)**

Privacy requirement	Activity noise of source room	Noise sensitivity of receiving rooms		
		Low sensitivity	Medium sensitivity	Sensitive
Confidential	Very high	47	52	57 A)
	High	47	47	52
	Typical	47	47	47
	Low	42	42	47
Moderate	Very high	47	52	57 A)
	High	37	42	47
	Typical	37	37	42
	Low	No rating	No rating	37
Not private	Very high	47	52	57 A)
	High	37	42	47
	Typical	No rating	37	42
	Low	No rating	No rating	37

NOTE Background noise can also influence privacy. See also ***7.7.6.3****.*

A) $D_{nT,w}$ 55 dB or greater is difficult to obtain on site and room adjacencies requiring these levels should be avoided wherever practical.

7.6 Limits for reverberation time

As well as internal ambient noise level, the reverberation time, *T*, measured in seconds (s), should also be considered because it affects the noise level in the space, and also affects the clarity of speech and the warmth of music. Even where good speech conditions are not paramount, an excessively long reverberation time accentuates the background noise and can reduce the clarity of public address announcements.

General guidance on designing rooms for speech (e.g. meeting rooms) is given in **7.7.10**, although the acoustic design of auditoria is a specialized subject and is beyond the scope of this British Standard.

NOTE BS EN ISO 3382 covers the measurement of reverberation time in various room types.

7.7 Specific types of building

7.7.1 Dwelling houses, flats and rooms in residential use (when unoccupied)

This subclause applies to external noise as it affects the internal acoustic environment from sources without a specific character, previously termed "anonymous noise". Occupants are usually more tolerant of noise without a specific character than, for example, that from neighbours which can trigger complex emotional reactions. For simplicity, only noise without character is considered in Table 4. For dwellings, the main considerations are:

a) for bedrooms, the acoustic effect on sleep; and

b) for other rooms, the acoustic effect on resting, listening and communicating.

NOTE Noise has a specific character if it contains features such as a distinguishable, discrete and continuous tone, is irregular enough to attract attention, or has strong low-frequency content, in which case lower noise limits might be appropriate.

7.7.2 Internal ambient noise levels for dwellings

In general, for steady external noise sources, it is desirable that the internal ambient noise level does not exceed the guideline values in Table 4.

Table 4 **Indoor ambient noise levels for dwellings**

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

NOTE 1 Table 4 provides recommended levels for overall noise in the design of a building. These are the sum total of structure-borne and airborne noise sources. Groundborne noise is assessed separately and is not included as part of these targets, as human response to groundborne noise varies with many factors such as level, character, timing, occupant expectation and sensitivity.

NOTE 2 The levels shown in Table 4 are based on the existing guidelines issued by the WHO and assume normal diurnal fluctuations in external noise. In cases where local conditions do not follow a typical diurnal pattern, for example on a road serving a port with high levels of traffic at certain times of the night, an appropriate alternative period, e.g. 1 hour, may be used, but the level should be selected to ensure consistency with the levels recommended in Table 4.

NOTE 3 These levels are based on annual average data and do not have to be achieved in all circumstances. For example, it is normal to exclude occasional events, such as fireworks night or New Year's Eve.

NOTE 4 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 $L_{Amax,F}$, depending on the character and number of events per night. Sporadic noise events could require separate values.

NOTE 5 If relying on closed windows to meet the guide values, there needs to be an appropriate alternative ventilation that does not compromise the facade insulation or the resulting noise level.

If applicable, any room should have adequate ventilation (e.g. trickle ventilators should be open) during assessment.

NOTE 6 Attention is drawn to the Building Regulations [30, 31, 32].

NOTE 7 Where development is considered necessary or desirable, despite external noise levels above WHO guidelines, the internal target levels may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

If there is noise from a mechanical ventilation system, the internal ambient noise levels should be reported separately with the system operating and with it switched off. If the room contains items such as fridges, freezers, cookers and water heaters, these should be turned off during measurement. Shorter measurement periods such as $L_{\text{Aeq, 1 hour}}$ may be used by agreement, provided the selected shorter measurement period is shown to be representative of the entire night or day period.

7.7.3 Living accommodation

7.7.3.1 Regulatory framework

The sound insulation between adjoining dwellings is controlled by the Building Regulations [30, 31, 32], which require reasonable standards of insulation for certain walls, floors, and stairs. As the Building Regulations have been devolved in Scotland, Wales and Northern Ireland, the appropriate national regulations should be consulted, together with their supporting documents:

- England: Approved Document E [1];
- Wales: Approved Document E [1];
- Scotland: Section 5 of the Technical Handbook [33];
- Northern Ireland: Technical Booklets G and G1 [34].

7.7.3.2 Design criteria for external noise

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

Other locations, such as balconies, roof gardens and terraces, are also important in residential buildings where normal external amenity space might be limited or not available, i.e. in flats, apartment blocks, etc. In these locations, specification of noise limits is not necessarily appropriate. Small balconies may be included for uses such as drying washing or growing pot plants, and noise limits should not be necessary for these uses. However, the general guidance on noise in amenity space is still appropriate for larger balconies, roof gardens and terraces, which might be intended to be used for relaxation. In high-noise areas, consideration should be given to protecting these areas by screening or building design to achieve the lowest practicable levels. Achieving levels of 55 dB $L_{\mathrm{Aeq},T}$ or less might not be possible at the outer edge of these areas, but should be achievable in some areas of the space.

7.7.3.3 Internal planning

To minimize disturbance from internally generated noise:

a) services should be kept away from bedrooms;

b) special attention should be given when locating stairs next to noise-sensitive rooms, such as bedrooms, to prevent disturbance by footsteps;

c) special attention should be given when locating bedrooms near the lift and circulation areas, with less sensitive rooms being used as buffers.

NOTE Compatibility between rooms of adjacent dwellings can be assisted by handing and stacking identical dwelling plans.

Where it is necessary to locate bedrooms adjacent to stairs (other than stairs used for fire escape) or lifts, precautions should be taken where practical to minimize noise transfer.

7.7.3.4 Noise levels from lifts in living accommodation

7.7.3.4.1 General

The maximum recommended noise levels within the living accommodation due to lift operation should not exceed the values given in Table 5. These criteria relate to the highest noise levels during any part of the lift cycle and with any occupancy level between zero and the recommended maximum number of people in a car.

The values in Table 5 should be regarded as upper guideline values and every effort should be made in the design of the lift systems and components to minimize noise and vibration at source such that lower levels result in practice.

Table 5 **Noise levels from lifts in living accommodation**

Room	Maximum noise level (dB $L_{\mathrm{Amax,F}}$)
Bedroom	25
Living room	30
Other areas	35

NOTE These figures relate solely to lift noise levels and do not account for any other noise sources. These values include noise from the lifts irrespective of the transmission mechanism, i.e. they include both airborne and structure-borne noise.

The lift motor and associated equipment should be installed on suitable anti-vibration mountings to prevent the transmission of excessive vibration and/or structure-borne noise to any parts of the living accommodation.

Lifts should be positioned such as to minimize noise disturbance from the operation of the control gear. Lift doors should operate quietly, and acoustic signals to herald lift arrival should not be audible within dwellings.

7.7.3.4.2 Lift lobbies

Lift operation noise during any part of the lift cycle, including announcements, and with any occupancy level should not normally exceed 55 dB $L_{Amax,F}$ when measured in the lift lobby.

7.7.3.5 Other precautions

Any partition separating a WC from a noise-sensitive room should have an airborne sound insulation of at least 40 dB R_w.

In an apartment building, sound-absorbing materials should be applied to the ceiling surfaces of communal corridors and stairwells to reduce propagation of noise through the building. Such materials need to be applied carefully, only where necessary and as agreed with building control.

Resilient floor coverings, such as carpet with underlay, can be used to minimize noise from footsteps on stair treads, corridors and landings. Noise is reduced at the same floor level and to rooms below the floor or stair. The quietest types of sanitary, heating and plumbing equipment (e.g. WCs, ball valves, refuse chutes) should be used, though their location is more important than their detailed design.

Structure-borne noise should be controlled by isolating the heating pipework from the building structure, at least near the pump. This may be achieved using flexible pipe connectors and resilient fixings on pipe runs. Where pipework penetrates walls and floors, air gaps should be sealed to reduce airborne noise transmission in such a way that structure-borne noise is not transmitted. This may be achieved by packing the gap with mineral wool, and sealing the faces with non-hardening mastic. Building Regulations guidance for fire safety [35, 36, 37] needs to be taken into account. Ventilation fans and similar equipment should be installed on resilient mountings where structure-borne noise would otherwise be a problem.

NOTE For additional guidance see [15].

7.7.4 Spaces in non-domestic buildings when they are unoccupied

The ambient noise levels in non-domestic buildings should not normally exceed the design ranges given in Table 6.

It is advisable to consult a specialist acoustician for guidance on the design of specialist spaces such as recording studios, cinemas, concert halls and opera houses.

*NOTE For schools and hospitals, see **7.7.8**.*

Table 6 **Typical noise levels in non-domestic buildings**

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

7.7.5 Hotels and rooms for residential purposes

7.7.5.1 Design criteria for intrusive external noise

7.7.5.1.1 General

The recommendations for ambient noise in hotel bedrooms are similar to those for living accommodation (see **7.7.2**).

NOTE 1 In addition to hotels, rooms for residential purposes include, among others, student halls of residence, school boarding houses, hostels, hospices and residential care homes. Approved Document E to the Building Regulations [1] might not be applicable to such premises as they are to dwellings. Occupants of rooms for residential purposes, although transitory rather than permanent, might typically reside for longer periods than hotel guests.

In hotels and other multi-occupancy premises containing rooms for residential purposes, it is desirable to avoid intrusive noise, both airborne and impact, in bedrooms, especially when occupants are sleeping (typically assumed to be at night-time).

Intrusive noise can arise from other rooms or uses within the building, from external sources through facades and from internal building services, including heating, ventilation and air conditioning plant.

Consideration should be given to adjacencies, both horizontal and vertical, between bedrooms, and between bedrooms and rooms used for other purposes. Particular attention should be paid to noise from corridors, door closers, adjoining bathrooms, stairwells, lifts and lift lobbies.

NOTE 2 Several large chains of hotels have developed their own criteria for insulating rooms against intrusive noise. Examples of design criteria adopted by various hotel groups are included for reference in Annex H. These examples reflect commercial judgements dependent on the nature of the accommodation provided, e.g. budget or luxury. They are included in this British Standard not as recommendations but as preliminary guidance and, where appropriate, specialist advice ought to be sought.

7.7.6 Offices

7.7.6.1 General

General acoustic guidance for offices is available from the British Council for Offices [38, 39] and the Association of Interior Specialists [40].

Complaints from office workers can arise from the intrusion of external noise, high internal noise levels from services, low background noise and excessive reflections from room surfaces. Inadequate sound insulation between offices is also a frequent source of complaint from those who require privacy for telephone conversations and interviews.

Privacy between offices and between an office and an occupied space requires effective insulation and moderate background noise to mask intruding speech. In order to achieve unintelligible speech from another office, the minimum sound insulation between two offices needs to be approximately D_w = 38 dB. Where privacy is important the minimum sound insulation should be D_w = 48 dB. It is possible that voices can be heard, but the conversation is not usually understood. Where the internal ambient noise level is low it might be necessary to design for higher insulation values (see Table 3 and **7.7.6.3**).

NOTE If a partition does not run from true slab to soffit, it is unlikely that a high level of privacy can be achieved, due to flanking transmission.

7.7.6.2 Controlling noise in open-plan offices

In open-plan offices, the maximum reduction that can be expected between screened workstations separated by 2.5 m to 3.0 m is 15 dB to 25 dB, but the cumulative noise of equipment and people might provide a masking background level which makes this adequate for general needs. The screening should be absorbent-faced and at least 1.5 m high. Low ceilings and absorbent ceilings can assist in reducing sound transmission between workstations. Where ceilings are higher than 3 m, it is more difficult to provide acceptable acoustic conditions in open-plan offices with absorption coverage lower than Class A. Where exposed soffits are used additional absorption might be required. Carpet having good sound-absorbent properties is a desirable floor finish. It should be noted that if the width of the room is small, reflections from the side walls might reduce the effectiveness of the arrangement.

NOTE BS EN ISO 3382-3 specifies methods for the measurement of room acoustic properties in open-plan offices with furnishing.

As some office equipment (e.g. photocopying machines) is noisy, large installations should be contained in a well-screened area or separate room. This could also simplify control of ventilation noise in mechanically-ventilated buildings. Additional speech privacy can be gained by considering spatial planning and the internal ergonomics of the users.

7.7.6.3 Speech privacy in offices

The guidance in this subclause does not apply to amplified speech (e.g. two adjacent video conference rooms), which requires special consideration.

When considering the sound insulation of a partition between two areas, the following factors should be taken into account.

a) The required function of the two rooms. Is conversation required to be inaudible in one room or is some audible speech acceptable, not intrusive or intelligible?

b) The background sound level present in the critical area due to the air conditioning systems and other sources. The intelligibility of speech and the perception of extraneous noise are controlled by the masking created by this background sound level. The higher the background sound level, the more effective it is in masking unwanted sounds. However, the background noise should not become intrusive in itself, so a balance should be achieved between the background sound level and the partition sound reduction.

7.7.7 Industrial buildings

7.7.7.1 Selecting design criteria

The design criteria for inside the building should include provision of reasonable industrial working conditions and reasonable speech and telephone communications. Other acoustic requirements often include limiting the noise emitted from the building and controlling noise from activities outside the building (e.g. vehicle movements) to minimize disturbance to neighbours.

7.7.7.2 Noise inside workshops

As hearing damage is covered by the Control of Noise at Work Regulations [41], special precautions should be taken and management procedures implemented where it is known that noisy processes are taking place.

Table 7 contains maximum noise levels for reliable speech communication. Even where speech communication is not important, it is important that audible warnings and information announcements can be heard clearly (see, for example, BS 5839-8).

The noise control measures discussed in **7.7.6** should be applied to offices outside production areas.

Table 7 **Maximum steady noise levels for reliable speech communication**

Distances between talker and listener m	**Noise level** dBA	
	Normal voice	**Raised voice**
1	57	62
2	51	56
4	45	50
8	39	44

7.7.7.3 Noise emitted by factories

Where a proposed factory development is to be situated in the vicinity of noise-sensitive buildings, the local planning authority usually sets planning conditions that take account of any predicted increase in noise due to the factory (see Clause **5**). Extensive noise control measures might be required, especially if the noise is impulsive, has a strong tonal character, or is otherwise of a distinguishable nature.

On an industrial estate, the noisier factories should be sited furthest from houses, with warehouses and quieter production areas used as buffers between the noisier factories and dwellings outside the industrial estate. Careful site planning can give some protection to noise-sensitive activities on the estate.

Common causes of complaint, which should be taken into consideration, are noise from:

a) industrial processes;

b) external generators, etc.;

c) calling systems;

d) end-of-shift indicators;

e) vehicle movements; and

f) night-time working.

7.7.7.4 Controlling noise in production areas

A factory divided into a number of smaller workshops is likely to provide a better working environment than one that consists of a single uninterrupted area. As permanent and solid divisions to the full height of the workshop are often not possible, partial enclosures or screens in conjunction with absorbent treatments are useful, both between departments and around individual machines. However, these enclosures or screens should be located so as not to obstruct the flow of work or they could be removed.

Acoustically absorbent materials should be used to reduce the amount of reflected sound within a space. These reduce the noise exposure of people not exposed to the direct sound from a noisy machine or activity, although the absorbent material has little or no effect on the noise level in the immediate vicinity of the noisy machines, etc. These materials can be applied to wall and ceiling surfaces or hung freely in the space (functional absorbers).

NOTE The Health and Safety Executive has published practical examples of noise control measures [42].

7.7.8 Schools and hospitals

Detailed guidance on the design of schools is available from the Department for Education in England [43] and the corresponding departments in the devolved administrations, and detailed guidance on the design of hospitals is available from the Department for Health in England [44] and the corresponding departments in the devolved administrations.

7.7.9 Agricultural buildings

For buildings and structures for agricultural use noise attenuation should be in accordance with BS 5502-32.

7.7.10 Rooms for speech

7.7.10.1 General

Lecture theatres, classrooms and meeting/conference rooms require good acoustic conditions for speakers and listeners. This should be recognized at an early stage of the design as room size and shape influence the acoustic conditions, as much as the selection and distribution of finishes. Although room acoustics is a specialized subject beyond the scope of this British Standard, general guidance on common situations is given in **7.7.10.5** to **7.7.10.7**.

7.7.10.2 Design criteria for intrusive external noise

The design objective for internal ambient noise level is reasonable listening conditions (see Table 4). This requires a low level of background noise and a fairly short reverberation time (see Annex A). However, other requirements should also be fulfilled to ensure the acoustic conditions are good. The main parameters are discussed in **7.7.10.3** and **7.7.10.4**.

7.7.10.3 Design for good speech communication

The sound that arrives at the listener's ears can be considered to have the following three components.

a) Direct sound. This is sound carried by waves that travel directly from the source (e.g. the speaker) to the listener. It should be the strongest component, and all listeners should have an unobstructed view of the source. The distance between the source and the most distant listener should be kept to a minimum. If this distance exceeds approximately 20 m an electro-acoustic sound reinforcement system might be required.

b) Early reflected sound. Shortly after the direct sound arrives, the listener hears a series of wave fronts, which have been reflected once or a small number of times from the walls, ceiling or other hard surfaces. As these have taken a longer path than the direct sound, they arrive later. Sound travels at approximately 340 m/s so, for the simpler paths, the delay can be estimated. Reflections that arrive within approximately 35 ms of the direct sound reinforce it, and so are beneficial. Longer delays generally reduce intelligibility, and delays greater than approximately 50 ms should be avoided. Longer delays can be perceived as echoes.

c) Reverberant sound. Sound waves emitted by a source in a room are repeatedly reflected by the room surfaces, and grow weaker because of absorption by the surfaces at each reflection. The reverberation time, *T*, is a measure of how long a sound takes to decay after the source has stopped. *T* affects the level of sound in a space and gives an indication of the clarity of speech and the warmth of music. It is proportional to the room volume, and inversely proportional to the total absorption, and so can be estimated if the absorption coefficients of the main surfaces and features in the room are known (see Annex A). The optimum *T* for a space depends on whether it is to be used mainly for speech or music, the type of music and the volume of the space.

The optimum values for reverberation time also vary with frequency (pitch) of the sound. Guide values of *T* for rooms of different volume can be found in standard texts, e.g. *Noise control in building services* [28]. Guidance on the calculation of reverberation time in enclosed spaces generally is given in BS EN 12354-6, while BS EN ISO 3382-2 gives guidance for calculation in ordinary rooms and BS EN ISO 3382-1 gives guidance for calculation in larger (performance) spaces.

7.7.10.4 Sound-absorbing materials

Sound-absorbing materials and devices dissipate sound energy as heat, instead of reflecting sound energy back into the source room. Most types of absorber do not provide high values of sound insulation. Porous materials provide absorption over a reasonably wide range of frequencies, depending mainly on their structure and thickness, and they usually perform better at middle and high frequencies. Tuned devices are available which absorb over a limited range of frequencies.

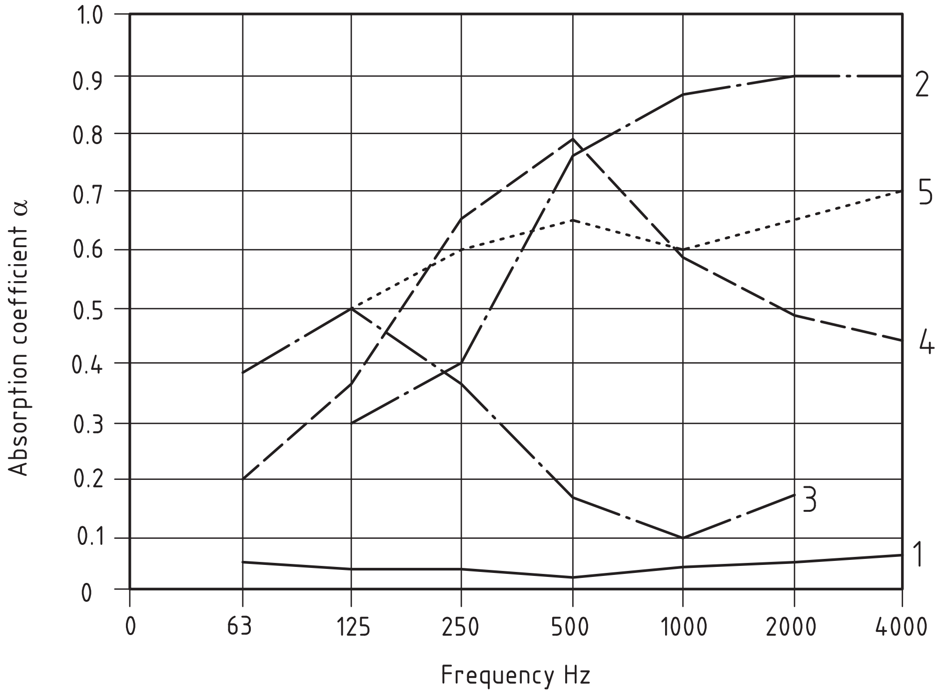
NOTE 1 Typical characteristics of different types of absorber are shown in Figure 1.

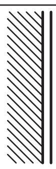
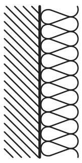
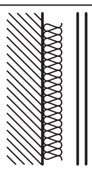
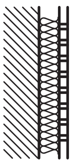
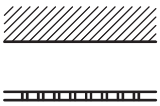
Sound absorbers are used to make acoustic corrections to rooms and spaces by changing the reverberation time (see Annex A). They are commonly used in rooms designed for music or speech, for general noise reduction in rooms (but with minimal benefit close to the source), and for preventing the spread of noise over large rooms or along corridors, ventilation ducts, etc. The type chosen should be influenced by a number of factors, such as acoustic characteristics, appearance, wearing qualities, maintenance, fire spread and other health and safety considerations.

The performance of a porous sound-absorbing material is given by the sound absorption coefficient α. The coefficient varies with the frequency of the sound and is commonly quoted for frequencies at the following octave intervals: 125 Hz, 250 Hz, 500 Hz, 1 000 Hz, 2 000 Hz and 4 000 Hz. Tests should be carried out in accordance with BS EN 20354 to obtain the coefficient in each frequency band.

NOTE 2 A method for assigning a single-number rating for porous absorbers is given in BS EN ISO 11654.

Figure 1 **Characteristics of sound-absorbing materials**



1		Hard finish: Plaster on solid backing
2		Porous absorber: 50 mm mineral fibre 50 kg/m³ Performance is not significantly affected if protected by a perforated panel with at least 30% open area
3		Panel absorber: 9 mm ply, 50 mm cavity containing 25 mm mineral fibre
4		Perforated panel: 14% perforations, 25 mm cavity containing mineral fibre
5		Perforated gypsum ceiling tile/board: 13 mm gypsum tile/board, 16% perforations, suspended with 200 mm plenum

7.7.10.5 Committee/meeting rooms

Seats may be arranged in a circle or oval, rather than in parallel rows facing each other. The ceiling may be acoustically hard and low (not more than 3 m), at least over the table area, to reflect speech. A resilient floor covering minimizes noise from chair and foot movements, and reverberation should be controlled by absorbent materials on the walls. Noise from chair/table movement can also be controlled by rubber feet/castors. Appropriate wall treatments should be used to control the effects of flutter echo. Folding partitions can be provided in large rooms so the size is reduced when it is not fully occupied. The sound insulation of partitions is considered separately in **7.7.6.3**.

7.7.10.6 Lecture theatres

Human speakers project sound predominantly in the forward direction, so all listeners should have a reasonable view of the speaker's face. To facilitate this, the seating may be splayed in a fan shape around the lecturer's dais, extending approximately 70° either side of the centre line. The direct sound reaching the rear of the audience is weakened if the speaker-listener path passes over the heads of intervening listeners at a shallow angle. The effect can be minimized by raising the speaker on a podium or, better, by raking the audience seating at an angle of at least 20°. To reflect the speaker's voice the wall behind the speaker may be reflective. For the same reason, the ceiling may be reflective and horizontal for simplicity. Carpets should be used, and in large rooms the seats should be absorbent to control reverberation when unoccupied. Absorbent material on the rear wall and on the rear side walls should be considered if further measures to control reverberation are required.

Door lobbies can be used where it is necessary to minimize noise from people outside the theatre (see **8.4.4**).

7.7.10.7 Community halls

Although community halls are used for events that involve speech and music, they should normally be designed for speech. The reverberation time could be increased a little above 500 Hz if there are expected to be frequent unamplified musical events (see *Noise control in building services* [28]).

The need for a level floor means that direct sound from the stage is attenuated as it passes over rows of the audience. A reflective wall behind the stage and an angled reflector over it helps to project sound to the back of the room. Making the hall as wide as sight lines allow, rather than long and thin, also helps. In large halls, high-level loudspeakers by the stage might be required to reinforce the sound. The rear wall (i.e. behind the last row of the audience) and the rear side walls may be covered in sound-absorbing material, if necessary, to control reverberation and slap back. If the hall has to be long and thin, smooth, flat side walls should be avoided to prevent sound undergoing repeated reflections between them, giving rise to a flutter echo. Flutter can be controlled by having random indents and projections and/or patches of absorption on the side walls.

As musical events such as discos involve high noise levels, noise emanating from the building should be controlled to prevent this causing a nuisance to local residents, as well as to prevent external noise affecting events in the hall.

Although the designer has no control over the level at which music is played in the room, it would be prudent to inform the client that exposure to high noise levels can be harmful to hearing.

Electronic sound limiting equipment can be used to control the level of amplified music.

8 Sound insulation in a building

8.1 Factors affecting sound insulation

The main factors determining the sound insulation of a building element (wall, floor or facade) are mass, air-tightness and the isolation between elements (e.g. between the leaves of a cavity wall). Other factors which influence the sound transmission through a building are the characteristics of materials used for construction, the standard of workmanship, and the layout and detailing of the building. Sound transmission in buildings occurs through direct and flanking transmission paths, for which the resulting sound insulation can be predicted using theory, measurements or a combination of both [45].

NOTE Some of these factors are discussed in Annex E, which also lists typical sound insulation values of common constructions.

8.2 Flanking transmission

The sound insulation between rooms in a building is not only influenced by the sound insulation of the separating element, but also by transmission via adjoining elements and air paths through or round the element, known as flanking transmission (see Annex E). To control flanking transmission, careful design and high standards of site supervision and workmanship are essential. In addition to obvious air paths, hidden paths might be contained in materials themselves due to porosity and permeability: materials having a high permeability provide sound insulation considerably lower than an impervious material of similar mass per unit area. Applying a sealing finish, such as plaster or cementitious paint, can make a substantial improvement to the performance of a permeable material.

The degree of flanking transmission depends on the overall design of a building, and in some cases flanking transmission can exceed direct sound transmission. It is often a limiting factor where high performance is required. Some factors which should be considered are:

a) junction detail between the separating wall/floor and the flanking wall;

b) mass of flanking elements;

c) transmission through floor voids, loft spaces, service ducts, mullions and similar paths.

It is not practicable to consider the sound insulation of all possible combinations of the elements that might form a building. In the initial stages of a design, individual elements are often considered as though they behaved independently of each other, but later in the design process possible interactions between the elements should be considered and the design modified or refined as necessary.

NOTE The characteristics of common types of building element are discussed in ***8.4***.

8.3 Sound insulation tests

Standard laboratory measurements of airborne sound insulation in accordance with BS EN ISO 10140-2 and impact sound insulation in accordance with BS EN ISO 10140-3 do not take account of flanking transmission, and so should only be regarded as a guide to the performance of an element in the field. The performance of the completed construction can be checked by tests carried out in accordance with BS EN ISO 140-4 and BS EN ISO 140-7. From these measurements, single-number ratings can be calculated according to BS EN ISO 717-1, for airborne insulation, and BS EN ISO 717-2, for impact insulation (see Annex C).

8.4 Sound insulation characteristics of common building elements

8.4.1 Masonry partitions

8.4.1.1 Single-leaf masonry walls

The main parameter which determines sound insulation is mass, and a rough guide to performance can be obtained from the mass law (see Annex E). Different materials sometimes have different empirical mass laws because the mass law approach does not account for stiffness, damping and airflow resistivity. However, all materials have a characteristic reduction in sound insulation due to the coincidence effect at their critical frequency (see Annex E), the position of which is mainly dependent on the mass and stiffness of the wall. The reduction in sound insulation in this frequency region depends on the amount of damping present, and for common materials the insulation at the critical frequency is often 5 dB to 10 dB below the trend at lower frequencies and remains low for an octave above the critical frequency. A typical 225 mm solid, dense masonry wall might show coincidence effects in the 125 Hz octave band, while 100 mm solid lightweight concrete might show the effects in the 500 Hz octave band.

8.4.1.2 Double-leaf masonry cavity walls

With masonry double-leaf walls, sound energy is transmitted from one leaf to the other through the air in the cavity which separates them, and in the form of mechanical vibrations through any ties or structural links between the two leaves. A wide cavity assists in providing good sound insulation. A high degree of structural isolation between the two leaves also assists in reducing structure-borne sound transmission. To this end, ties between the two leaves should be as few as possible and be flexible whilst maintaining structural stability. Butterfly pattern ties are better in this respect than most other types, which degrade acoustic performance. Type A ties need to have a measured dynamic stiffness of <4.8 MN/m^3 for the specified minimum cavity, at a standard density.

Because of unavoidable structural links, masonry cavity walls seldom attain their potential acoustic performance. Each leaf of double-leaf walls is subject to coincidence effects and, in addition, double-leaf constructions exhibit a mass-air-mass resonance (see Annex E) which reduces the insulation at low frequencies.

8.4.2 Lightweight partitions

8.4.2.1 Double-leaf stud walls

Single-frame and twin-frame lightweight partitions are often used to divide a large floor area into separate rooms, for example, in large office blocks. The effects described in **8.4.1.2** are particularly marked where sheet materials such as plasterboard are used. However, the reduction in insulation can be minimized if there is a high degree of mechanical discontinuity between the leaves.

The frames of the lightweight partitions can be made from timber or metal studs. For single-frame partitions the improvement in mechanical discontinuity can be made by use of resilient bar on one or both sides of either timber or metal frames. Mechanical discontinuity can also be improved by use of acoustic versions of the metal studs. Single-frame lightweight partitions can achieve R_w performances ranging from 30 dB to 65 dB.

A higher degree of mechanical discontinuity can be achieved with a twin-frame construction using separate support frames for each leaf, again made from metal or timber studs. Mechanical discontinuity of twin frames can also be improved by use of acoustic versions of studs or by increasing the cavity width. Twin-frame lightweight partitions can achieve R_w performances ranging from 55 dB to 75+ dB.

For both single-frame and twin-frame constructions, sound-absorbing infill such as mineral wool batts or quilt is beneficial. Well-designed, lightweight, double-leaf partitions can provide good performance with much lower mass than a masonry construction of comparable acoustic performance.

NOTE Low frequency performance can be different between lightweight and masonry partition walls.

Particular care should be taken to avoid any significant loss of sound insulation through indirect sound transmission routes. For example, where a partition wall is butted to a suspended ceiling, a continuous barrier should be provided in the space above it.

8.4.2.2 Pre-fabricated walls

To permit flexible room planning and quick installation there are numerous proprietary systems of prefabricated, lightweight, demountable partitions that are easily assembled using dry methods. These partitions seldom exceed approximately 40 kg/m^2 and employ room height units approximately 1 m wide, usually constructed with skins approximately 50 mm apart and with mineral wool or other lightweight cavity filling materials. Various methods are used to fix the panels to the structure and to fasten them together. However, for maximum sound insulation the partition should be fitted to the soffit of the structural slab and sealed around all edges.

Because of their lightness, and the inevitable small gaps around them, the insulation of prefabricated office partitions usually lies in the range 30 dB R_w to 40 dB R_w, occasionally extending up to 45 dB R_w.

8.4.2.3 Operable walls and moveable partitions

Folding and sliding partitions generally provide approximately 30 dB R_w, but better performance can be achieved with careful design and installation. Operable walls and moveable partitions can provide flexibility, for example, to allow meeting or training rooms to be separated or combined. However, where a high degree of acoustic privacy is required between separated spaces, the partitions can be expensive and require specialist maintenance to maintain the acoustic performance. Careful design is also required to avoid flanking paths and to provide structural support for the partition.

8.4.3 Construction details

The following recommendations should be closely followed to maximize sound insulation. They are particularly applicable to masonry separating walls between dwellings.

a) Avoid forming recesses in the separating wall, but, if it is necessary to recess electrical sockets in the wall, they should not be placed back-to-back to avoid the risk of complete penetration.

b) Complete filling of mortar joints, particularly perpends, is important. In brick walls, if the bricks have frogs they should be laid frog up so that the frogs are filled with mortar.

c) In the case of walls formed from permeable materials, the wall surface should be sealed with cementitious paint or render unless it is to have a plaster finish. Ideally, this sealing should include the wall surface where it passes through a suspended timber floor.

d) The minimum number of connections between the leaves of masonry cavity separating walls consistent with structural stability should be used. Butterfly or similar low stiffness ties are recommended. Further information is given in the Building Regulations [30, 31, 32].

e) Care should be taken to ensure that mortar droppings or other foreign matter do not bridge cavities.

f) A cavity separating wall construction should continue right through the roof space.

g) Air paths through or round a separating wall, even in the loft space, should be kept to the minimum possible by careful sealing around any necessary penetration of the wall. Joists should preferably run parallel to a separating wall, but if they are perpendicular joist hangers should be used, or if they are built in all air paths should be filled.

h) The reveals of windows should be well sealed to prevent sound getting into the wall cavity. At the junction with the separating wall it is good practice to stop the external wall cavity with a flexible closer, such as mineral wool, to reduce sound transmission along the cavity. If the cavity is to be filled or partially filled for thermal insulation, additional stopping is not necessary.

i) Masonry separating walls should be rigidly bonded or tied to the inner leaf of a cavity wall or only leaf of a solid external masonry wall.

8.4.4 Doors

The main factors determining the sound insulation of a single door set are the mass of the door and the gaps around the edges; usually, the latter are critical. For good sound insulation, the door should form airtight joints with the frame when closed and the joints between frame and wall should be sealed. A threshold seal is essential, and even keyhole covers should be fitted in critical situations.

A nomogram is given in Annex A for estimating the insulation of elements comprising two components having different values of sound insulation, such as a partition containing a door.

Single door sets providing a sound insulation greater than 35 dB R_w are specialist products and are normally supplied as complete door sets. High performance seals might make the door hard to open and close. The most effective solution, where space is available, is to use two well-sealed doors separated by a lobby lined with absorbing material. Such sound lobbies are particularly useful where uninterrupted sound insulation is required (e.g. audiometric examination rooms) because one door can be closed before the other is opened. Well-constructed lobbies can be expected to provide sound insulation of 45 dB to 60 dB, although the higher figure can only be achieved if the whole construction is carefully designed.

Where infrequent access to a space is required, a removable panel may be installed in place of a door.

8.4.5 Windows

8.4.5.1 General

BS EN 12758 gives values for the sound insulation of windows.

NOTE Further information is given in BS 6262, [46] and [47]. Figure A.1 can be used to estimate the insulation of a wall containing a window.

The full sound insulation value of any window cannot be realized if there are air gaps. These commonly occur around frames due to insecure fixing, shrinkage of wood and poor maintenance, and between frames and opening lights.

Glass often shows a pronounced dip in insulation at its critical frequency (see Annex E). For 6 mm glass this is around 2 000 Hz. Laminated glass performs better because the increased damping reduces the effect.

When adjoining rooms have their windows open the sound reduction from one to the other is limited to approximately 30 dB if there are other buildings close to the windows to reflect the sound back. When the window is closed in one of the rooms, a reduction of over 50 dB between the rooms should be obtainable and, with both windows closed, this flanking path should not limit the insulation provided by normal separating elements.

8.4.5.2 Double-glazed units

A double-glazed unit is unlikely to perform better than a single pane of mass equivalent to the thicker pane of the sealed unit, and should be used in a frame with good seals to realize its full insulating potential.

8.4.5.3 Secondary windows

In addition to the need for good sealing, the following recommendations apply for double windows.

a) The air space should be at least 100 mm, although for good performance over the main frequency range of interest, a cavity of approximately 300 mm is desirable.

b) The sides and top of the reveal should be lined with sound-absorbing material (the bottom should be left clear to avoid staining due to condensation).

c) The best results are obtained if both windows are sealed, but this has obvious difficulties for cleaning (and means of escape where appropriate). When opening lights are used some loss of insulation occurs, but this can be minimized by good quality fittings and weather stripping.

d) The outer pane can be a double-glazed unit to improve thermal performance and reduce condensation.

8.4.5.4 Ventilation

The Building Regulations' supporting documents on ventilation [48, 49, 50] recommend that habitable rooms in dwellings have background ventilation. Where openable windows cannot be relied upon for this ventilation, trickle ventilators can be used and sound attenuating types are available. However, windows may remain openable for rapid or purge ventilation, or at the occupant's choice.

Alternatively, acoustic ventilation units (see **7.7.2**) are available for insertion in external walls. These can provide sound reduction comparable with double glazed windows. However, ducted systems with intakes on the quiet side of the building might be required in very noisy situations, or where appearance rules out through-the-wall fans.

8.4.6 Floors and ceilings

8.4.6.1 General

Airborne sound insulation is mainly considered for intermediate floors between spaces containing either noise sources or noise-sensitive occupants. For a ground or basement floor where there is neither an appreciable noise source nor a noise-sensitive occupant below the floor, the floor is only of interest if it could contribute to flanking transmission.

Separating floors suitable for use in dwellings, which are described in the technical documents that support the appropriate Building Regulations [1, 33, 34], fall into the following three broad categories for new buildings:

a) a concrete base with a soft covering;

b) a concrete base with a floating layer; and

c) a timber base with a floating layer.

Guidance on upgrading existing floors is also provided. The technical documents contain details of points to consider, and should be consulted for work in dwellings. As the gaps between precast units in beam and block floors are difficult to seal well, a bonded screed is strongly recommended.

Dwellings that adjoin other buildings with activities that generate noise levels greater than normal domestic activities might require constructions offering better performance than those described in the documents that support the appropriate Building Regulations [1, 33, 34].

8.4.6.2 Partitions on floating floors

It is generally better to build partitions on the structural base rather than on top of a floating floor. This is because a partition built on a floating floor might overload the resilient layer and reduce its isolation properties, and movement of the floating floor could cause cracking in the partitions. A partition built on a floating layer might also provide a flanking path between the floor and the walls. The isolation between the floating floor and the partition should be maintained. Specialist advice should be sought for floating floors.

8.4.6.3 Pipes and conduits in floating floors

It is often necessary for services, such as electrical conduits and gas and water pipes, to run across a concrete floor. Whenever possible these pipes should be accommodated within the thickness of the floor slab or levelling screed, but sometimes they have to be laid on top of the slab and contained within the depth of the floating layer. Pipes or conduits are less likely to damage floating floors, providing they do not extend more than approximately 25 mm above the base, are properly fixed so as not to move while the floating floor is being laid, and are haunched up with mortar on each side to give continuous support to the resilient quilt. When two pipes cross, one of them should be sunk into the base slab. The resilient quilt should be carried right over the pipes.

NOTE Although channel systems have been devised to allow access to pipes in concrete and timber floors, the acoustic performance of these is not well documented.

8.4.6.4 Squeaking floor boards

Floating floors of timber or similar materials might squeak when walked on. To minimize the risk for boarding or panels, deep battens and long nails or screws may be used. For softwood tongued and grooved boards, latex adhesive between boards and on joists may be used, while for tongued and grooved chipboard sheets, a polyvinyl acetate emulsion adhesive is more suitable.

NOTE Further information is given in [51].

Timber joists made from reconstituted wood are available and can also be used to help minimize squeaking.

8.4.7 Roofs and mansards

Roofs and mansards generally have lower sound insulation than masonry facade walls, but in many cases they are required to reduce noise from external sources such as aircraft or road traffic. The performance of various roof types is indicated in Table 8. As rainfall noise can be a problem with lightweight roofs and skylights, these should be avoided in critical situations. Laminated glass is likely to transmit slightly less noise than an equivalent solid pane, but the manufacturer's advice should be sought.

Table 8 **The sound insulation of roofs**

Roof type	Weighted sound reduction index R_w dB
Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling	43
100 mm flat concrete roof (230 kg/m^2)	52
Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation	45
Single-skin galvanized steel cladding	22
50 mm sandwich panel, galvanized steel panels with thermal foam infill	26
Double-skin galvanized steel cladding with mineral fibre infill	38

9 Noise from building services

9.1 General

Detailed building services design advice is beyond the scope of this British Standard and it might be necessary to seek advice from an acoustic consultant. Several useful texts are available, which provide guidance on noise from mechanical services [28] and [52].

The general principles are discussed in **9.2** to **9.6**.

9.2 Main components

The components of a heating, ventilating and air conditioning (HVAC) system move air, water or refrigerant, as appropriate, around the system. The following contain advice on control of noise from the components of a typical air conditioning system, from intake to outlet.

a) *Intakes*. There should be sufficient ducting distance between intake grilles and fans to enable fan noise travelling back to the opening to be reduced. Common methods of attenuation are splitter attenuators and sound-absorbing lined ducts. However, fibrous absorbent materials should be used with caution as these can damage health.

b) *Fans*. The type and size of fans are influenced by noise control needs. In general, larger and slower fans are quieter, for a given volume and pressure duty. The casing, fan and drive motors commonly require vibration isolating mountings to reduce structural vibration. It is often essential that the fan casing is isolated from ducting using flexible connectors, and the ducting may need to be supported from resilient hangers.

c) *Chillers*. Chillers create high levels of noise and vibration and so should be located in an enclosure if situated near sensitive areas. Careful attention should be paid to air gaps allowing noise to escape. Resilient mountings are usually necessary. It is essential that all pipework leading to and from the chillers is held by isolating clips or hangers (or is fixed to joists that can be isolated), and passes through the enclosure in sleeves lined with a resilient material.

d) *Ducts*. Ducts might have fan noise propagating inside them, or turbulence noise generated in them by fast-moving air or by drumming of the duct walls. Noise generated in one room can be transmitted to a neighbouring room by a common duct, resulting in poor sound insulation (cross-talk). Noise can escape from inside a duct to the outside (break-out). Consequently, ducts that pass close to sensitive areas might need to be lagged with noise insulating material. Conversely, if a duct passes through a noisy area, noise can break in and be transmitted down the duct. This is most likely to occur in a plant room where, for example, a silencer has been located close to a fan and the silenced duct runs through the plant room. The silencer should be located at the position where the duct penetrates the plant room wall.

e) *Outlets*. Air movement through diffuser grilles can be the source of significant levels of noise (known as regenerated noise). Reduction of the velocity of the air or removal of any obstructions can significantly reduce the regenerated noise from the grilles. In some cases where background noise is needed, noisier grilles can be useful, but to achieve a steady noise level the velocity of the air from the grille should be constant.

9.3 Frequency characteristics of noise

The frequency ranges of noise from the components can be generalized as follows.

a) Fan instability, air turbulence, structure-borne noise: 10 Hz to 80 Hz perceived as throb and rumble.

b) Fan and pump noise: 50 Hz to 500 Hz perceived as rumble and roar.

c) Variable air volume (VAV) unit noise: 125 Hz to 2 500 Hz, perceived as roar and whistle or whirr.

d) Chiller noise: 250 Hz to 1 000 Hz, perceived as roar and whistle or whirr.

e) Outlet (or diffuser) noise: 800 Hz to 4 000 Hz, perceived as whistle or whirr and hiss.

Many types of silencer are available, which can work over a wide frequency range (broad band) or be tuned to a particular frequency band.

NOTE For more information about silencers see BS EN ISO 14163.

9.4 Rating noise from services

Continuous ventilation noise is commonly rated in the UK using either dBA levels or noise rating (NR) curves based on an octave band analysis of the noise (see Annex B). Noise criteria curves are also used and are broadly similar to NR curves (see Annex B). CIBSE Guide B5 [52] provides further rating systems and information.

9.5 Sound-absorbing treatment

The reduction in noise within a room where the source is outside the room is limited to approximately 3 dB for each doubling of total sound absorption within the room. Increasing absorption is therefore not usually an alternative to improving sound insulation. This approach is most effective in factory buildings. Sound-absorbing materials are also used to control noise in ducts, taking into account health and safety considerations.

9.6 Quality control and workmanship

Experience has shown that effective sound insulation and noise control require careful detailing on the part of the designer and a high standard of workmanship on the part of the contractor. Correct execution of the detailing should be checked on site, and the completed building should be fully commissioned before handover.

Noise control is only one aspect of environmental design and designers should be aware that the solution to a noise problem can cause difficulties elsewhere, e.g. thermal insulation, cold bridging, solar gain, ventilation and condensation. Much information on the environment in and around buildings is available and should be considered at an early stage of the design process.

Annex A (informative) Noise calculations

A.1 General

Some of the simpler types of noise calculation are described in this annex. For methods of predicting noise from road and rail traffic, see Clause **6**.

A.2 Addition of two noise levels

To determine the combined sound pressure level (L_c) resulting from the sound pressure levels of two or more noise sources (L_1, L_2, etc.), it is necessary to calculate and add the mean-square values of their individual sound pressures and convert this back to a sound pressure level. This can be achieved using the following formula.

$$L_c = 10\lg\left(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}}\right)$$

As the individual sound pressure levels are logarithms of the mean-square sound pressures, they cannot simply be added arithmetically.

A.3 Subtraction of two noise levels

When measuring noise from a source, the true noise level of the source alone is less than that shown by the meter if the level of background sound is less than approximately 10 dB below the total noise level. This is given by the following equation.

$$L_s = 10\lg\left(10^{\frac{L_m}{10}} - 10^{\frac{L_b}{10}}\right)$$

where:

L_s is the source sound level;

L_m is the measured sound level;

L_b is the background sound level.

A.4 Non-uniform facades comprising windows and cladding

Figure A.1 shows how to calculate the overall sound insulation of a non-uniform facade comprising a window and cladding. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

A.5 A-weighting calculations

The equivalent A-weighted level is often required when data on a noise source are available as a set of octave band or one-third octave band levels. The conversion can be performed manually, using the standard A-weighting values (see Table A.1). For all but the simplest situations it is more convenient to use a computer spreadsheet to do the conversion.

A.6 Reverberation time calculation

An estimate of the reverberation time, T, of a room can be obtained using the model in BS EN 12354-6.

Figure A.1 **Sound insulation of non-uniform facades comprising windows and cladding**

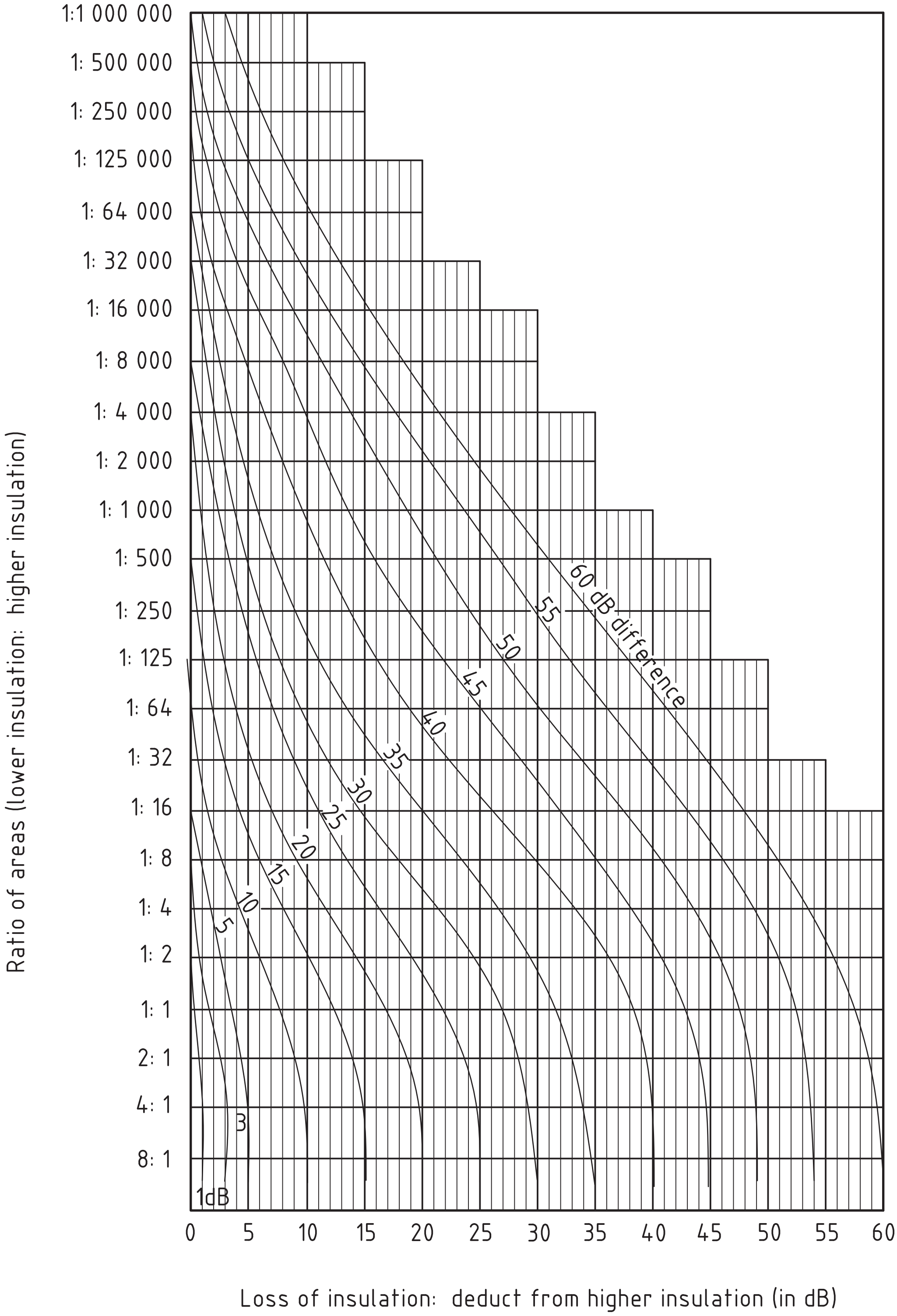


Table A.1 **Standard A-weighting values (dB)**

Third octave band centre frequency Hz	Octave band centre frequency Hz	A-weighting dB	Third octave band centre frequency Hz	Octave band centre frequency Hz	A-weighting dB
10		–70.4	500	500	–3.2
12.5		–63.4	630		–1.9
16	16	–56.7	800		–0.8
20		–50.5	1 000	1 000	0
25		–44.7	1 250		0.6
31.5	31.5	–39.4	1 600		1.0
40		–34.6	2 000	2 000	1.2
50		–30.2	2 500		1.3
63	63	–26.2	3 150		1.2
80		–22.5	4 000	4 000	1.0
100		–19.1	5 000		0.6
125	125	–16.1	6 300		–0.1
160		–13.4	8 000	8 000	–1.1
200		–10.9	10 000		–2.5
250	250	–8.6	12 500		–4.3
315		–6.6	16 000	16 000	–6.6
400		–4.8	20 000		–9.3

Annex B (informative) Noise rating

Noise rating (NR) is a graphical method for assigning a single-number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability of a noise spectrum for a particular application. The method was originally proposed for use in assessing environmental noise, but it is now used in the UK mainly for describing noise from mechanical ventilation systems in buildings. To obtain a rating, the noise spectrum is superposed on a family of NR contours. The NR of the spectrum corresponds to the value of the first NR contour that is entirely above the spectrum. The values at intervals of NR 5 (from NR 0 to NR 75) are shown in Table B.1 for the frequency range 31.5 Hz to 8 kHz.

Measured or calculated noise levels should be determined to not more than one decimal place.

NR values may be determined in each octave band by the following equation, rounded to the nearest single decimal place.

$$L = a + bN$$

where:

L is the octave band sound pressure level corresponding to NR level N;

a and b are constants for each frequency band, as given in Table B.2.

NOTE NR values cannot be converted directly to dBA values, but the following approximate relationship applies.

NR ≈ dBA – 6.

The NR level is that entirely above the spectral levels calculated.

For example, if a spectrum contains a noise level of 48.6 dB at 500 Hz, the NR level would be at least NR 46.

Although the NR system is currently a widely-used method for rating noise from mechanical ventilation systems in the UK, other methods which are more sensitive to noise at low frequencies are available [28], but they are not yet widely accepted in the UK. Low-frequency noise can be disturbing or fatiguing to occupants, but might have little effect on the dBA or NR value.

Table B.1 **Noise rating values**

Noise rating	**Octave band centre frequency** Hz								
	31.5	**63**	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**	**8 000**
NR75	106.5	94.7	87.2	81.7	77.9	75	72.6	70.8	69.2
NR70	103.1	90.8	82.9	77.1	73.0	70	67.5	65.7	64.1
NR65	99.7	86.8	78.5	72.4	68.1	65	62.5	60.5	58.9
NR60	96.3	82.9	74.2	67.8	63.2	60	57.4	55.4	53.8
NR55	92.9	78.99	69.8	63.1	58.4	55	52.3	50.3	48.6
NR50	89.4	75.0	65.5	58.5	53.5	50	47.2	45.2	43.5
NR45	86.0	71.0	61.1	53.6	48.6	45	42.2	40.0	38.3
NR40	82.6	67.1	56.8	49.2	43.8	40	37.1	34.9	33.2
NR35	79.2	63.1	52.4	44.5	38.9	35	32.0	29.8	28.0
NR30	75.8	59.2	48.1	39.9	34.0	30	26.9	24.7	22.9
NR25	72.4	55.2	43.7	35.2	29.2	25	21.9	19.5	17.7
NR20	69.0	51.3	39.4	30.6	24.3	20	16.8	14.4	12.6
NR15	65.6	47.3	35.0	25.9	19.4	15	11.7	9.3	7.4
NR10	62.2	43.4	30.7	21.3	14.5	10	6.6	4.2	2.3
NR5	58.8	39.4	26.3	16.6	9.7	5	1.6	–1	–2.8
NR0	55.4	35.5	22.0	12.0	4.8	0	–3.5	–6.1	–8

Table B.2 **Values of a and b**

Octave band centre frequency Hz	**a**	**b**
31.5	55.4	0.681
63	35.4	0.790
125	22.0	0.870
250	12.0	0.930
500	4.2	0.980
1 000	0.0	1.000
2 000	–3.5	1.015
4 000	–6.1	1.025
8 000	–8.0	1.030

Annex C (informative) Specification of sound insulation

C.1 General

Sound insulating elements work mainly by reflecting sound energy back into the source room, not by absorbing it. The methods of measurement and the terms used are described in **C.2** to **C.4**.

C.2 Insulation against airborne sound

In the tests specified in BS EN ISO 10140-2 and BS EN ISO 140-4 the insulation between a pair of rooms is measured, either:

a) in third octave bands having centre frequencies which cover at least the range 100 Hz to 3 150 Hz; or

b) in octave bands which cover at least the range 125 Hz to 2 000 Hz.

The noise is produced by a loudspeaker in one of the rooms (called the source room) and at each frequency the average noise levels are measured in the source room (L_S) and in the adjacent receiving room (L_R). The difference between these two levels (D) is a measure of the sound insulation between the rooms, regardless of the transmission path(s) the sound energy followed to travel between the rooms. The equation is as follows.

$$D = L_S - L_R$$

The actual level in the receiving room depends on:

- the sound insulation of the separating wall or floor;
- the area of the separating wall or floor;
- the volume of the receiving room;
- the flanking transmission, i.e. the importance of transmission paths other than the separating wall or floor; and
- the amount of absorbing material (e.g. furniture) in the receiving room.

For field measurements, apart from the amount of absorption, these factors are a property of the building and need to be taken into account by the measurement procedure. As the amount of absorbing material (e.g. soft furniture) in the room at the time of measurement is arbitrary, it has to be allowed for separately. This is achieved by measuring the reverberation time, T, of the room in seconds (s), which is a measure of how long it takes a sound to die away after the source has been switched off. As the sound energy is dissipated as heat in the absorbing material, T is related to the total amount of absorption in the room. The receiving room level can be corrected to the level it would be if the room has a standard reverberation time, T_o, which is typical of bedrooms, and is taken to be 0.5 s. The corrected level difference is known as the standardized level difference, D_{nT}, and is calculated using the following equation.

$$D_{nT} = L_S - L_R + 10 \log_{10} (T/T_o)$$

For laboratory measurements the insulation of the separating wall or floor being tested is assessed in a way that is independent of the actual measuring laboratory. For this reason, laboratories are designed to have minimal flanking transmission and a different correction is applied to account for the other factors.

This correction is $10 \log_{10} (S/A)$, where:

- S is the common area of the separating wall or floor in square metres (m^2);
- A is the equivalent absorption area in the receiving room in square metres (m^2).

The laboratory corrected level difference at each frequency is known as the sound reduction index, R, and is calculated using the following equation.

$$R = L_S - L_R + 10 \log_{10} (S/A)$$

If the test wall or floor is mounted in a realistic way in the laboratory and flanking transmission is low in the field, the sound reduction index may be used to predict its performance in the field. The relationship between D_{nT} and R is:

$$D_{nT} = R - 10 \log_{10} (3S/V)$$

where:

- S is the area of the separating wall or floor in the field in square metres (m^2);
- V is the volume of the receiving room in the field in cubic metres (m^3).

This equation shows that, if the source and receiving rooms have different volumes, D_{nT} depends on which is used as the source room. Using the larger room as the source room gives the lower value.

C.3 Insulation against impact sound

The procedure for measuring the impact insulation of floors is rather different (see BS EN ISO 10140-3 and BS EN ISO 140-7). Instead of a loudspeaker, a machine containing five small hammers is placed on the floor. While the hammers strike the floor at a rate of ten blows a second, the resulting noise level, L_i, is measured in the receiving room below at each of the same frequency bands used for airborne insulation. In the field, the receiving room levels are again "corrected" to a standard reverberation time, T_o, of 0.5 s to give the standardized impact sound pressure level, L'_{nT}, which is calculated as follows.

$$L'_{nT} = L_i - 10 \log_{10} (T/T_o)$$

In the laboratory, the noise level depends mainly on the characteristics of the floor being tested and the amount of absorption, A (m²), in the laboratory. It is therefore appropriate to correct the noise level to a standard area of absorption. The area used is 10 m². The resulting normalized impact sound pressure level, L_n, is calculated as follows.

$$L_n = L_i + 10 \log_{10} (A/10)$$

C.4 Rating sound insulation

Measurements of insulation against both airborne and impact sounds yield values in a number of frequency bands. To make this information more manageable, rating methods such as those in BS EN ISO 717-1 and BS EN ISO 717-2 are used to reduce the frequency band values to single-figure ratings. These single-figure ratings are generally good predictors of subjective assessments of insulation of similar constructions. However, this is not always the case for different constructions, for example the low-frequency performance of a lightweight partition might be significantly different from that of a masonry partition with the same single-number rating, so it is prudent to examine the full measurement data in critical situations.

The more common indices used to describe sound insulation are summarized in Table C.1 and Table C.2.

NOTE 1 Further guidance on rating sound insulation is given in BS EN ISO 717-1 and BS EN ISO 717-2. The terminology shown in Table C.1 is used, but with additional spectrum adaptation terms (C).

EXAMPLE

R_w (C; C_{tr}) = 41(0; –5) dB.

Here, C (value 0) is the correction needed to convert R_w to a dB insulation value against a pink noise spectrum; C_{tr} (–5) is the correction needed to convert R_w to a dB insulation value against a standardized road traffic noise spectrum. In this case the dB insulation is 41 – 5 = 36 dB.

NOTE 2 Pink noise has the same sound pressure level in adjacent frequency bands, and is used to represent general activity noise.

It is essential that the difference between the sound insulation value obtained for a single building element in the laboratory and the value for a completed construction in the field environment is understood. A common mistake is to expect to obtain values of a weighted sound reduction index, R_w, from a completed building. To clarify this, different indices are used to indicate sound insulation performance in the different environments. Table C.1 and Table C.2 show the different indices that apply to the laboratory or field environment respectively.

Due to the flanking transmission paths and a difference in the calculation method, a laboratory test value for sound insulation might not be obtained in the field, even if all elements of the construction have been specified and built correctly.

Table C.1 **Common indices used to describe laboratory airborne and impact sound insulation**

Airborne (*A*) or impact (*I*)	**Measured values**		**Single number quantity**	
	Name	Symbol	Name	Symbol
A	Sound reduction index	R	Weighted sound reduction index	R_w
A	Spectrum adaptation term	C	Spectrum adaptation term	C
A	Spectrum adaptation term	C_{tr}	Spectrum adaptation term	C_{tr}
I	Normalized impact sound pressure level	L'_n	Weighted normalized impact sound pressure level	$L'_{n,w}$

Table C.2 **Common indices used to describe field airborne and impact sound insulation**

Airborne (*A*) or impact (*I*)	**Measured values**		**Single number quantity**	
	Name	Symbol	Name	Symbol
A	Standardized level difference	D_{nT}	Weighted standardized level difference	$D_{nT,w}$
A	Spectrum adaptation term	C	Spectrum adaptation term	C
A	Spectrum adaptation term	C_{tr}	Spectrum adaptation term	C_{tr}
I	Standardized impact sound pressure level	L'_{nT}	Weighted standardized impact sound pressure level	$L'_{nT,w}$
A	Apparent sound reduction index	R	Weighted sound reduction index (dB)	R'_w

Annex D (informative) Special problems requiring expert advice: Guidance for specific applications

D.1 General

Certain design problems require reliable advice of a kind that is not easy to find in published material. The advice of an expert is necessary for these kinds of problems, some examples of which are given in **D.2** to **D.9**.

D.2 Acoustic test rooms

The design of rooms in which acoustic measurements are carried out, such as reverberation chambers, free-field rooms and audiometric test rooms, might need to conform to national or international standards and usually requires the advice of an expert.

D.3 Performing spaces

The design of theatres, opera houses, concert halls and similar performing spaces usually requires expertise in room acoustics and noise control. The intrusion of relatively low levels of noise can seriously interfere with the enjoyment of the performance and distract the performers. The requirements for low noise levels often mean that more room has to be allocated for low velocity ventilation ductwork and the impact on the design of the ventilation system is often substantial.

D.4 Broadcasting and recording studios

Broadcasting and recording studios have requirements similar to those of performing spaces (see **D.3**). For some infrequent intrusive noises, the requirements are sometimes relaxed on the grounds that a retake is possible, but this can result in higher operating costs.

D.5 Aircraft noise

As there are many variables affecting the level of aircraft noise heard on the ground, expert advice is almost always required. Contours of daytime $L_{\mathrm{Aeq},T}$ levels are available from most major airports and helipads. Where measurements of facade insulation are necessary a test method is described in BS EN ISO 140-5.

D.6 Groundborne noise

Projects involving groundborne noise from underground trains, plant or industrial sources usually require expert advice.

D.7 Low-frequency noise

Projects involving low-frequency noise usually require expert advice as accurate measurement is difficult and there is a shortage of reliable data below 100 Hz.

D.8 Active noise control

Active noise control is the reduction of noise by cancellation with a similar noise (anti-noise) generated by electro-acoustic means. Commercial systems are available which successfully reduce low frequency noise from mechanical ventilation systems.

D.9 Noise surveys

Noise surveys are carried out for a variety of reasons, for example:

a) before construction, to establish the existing noise climate at the site of a proposed development where reliable prediction is impracticable, as an aid to the design of the building envelope, either to protect against external noise or contain internally produced noise;

b) during construction, to monitor noise from building activity, either to assess the likely nuisance to the local community or the risk of hearing damage to the workforce;

c) at the end of a building contract to check the insulation of the building envelope or the noise levels produced by the services;

d) as part of a planning requirement;

e) to provide objective evidence to support or defend a legal action.

Surveys ought to be carried out by competent persons and the interpretation of survey results might require expert advice.

Annex E (informative) Airborne and impact sound insulation

E.1 General

Airborne sound refers to noise produced by sources that directly set the air around them into vibration. Impact sound refers to noise caused by sources which produce impulsive mechanical excitation of part of a building (e.g. footsteps, electric light switches, slamming doors). Many sources of impact sound also produce significant levels of airborne sound. The term structure-borne sound has no very precise meaning as the structure can be excited by both airborne and impact sources; it is often used to refer to sound that travels for long distances via the structure, especially in connection with vibrating machinery linked directly to the structure.

E.2 Direct and indirect transmission

Figure E.1 shows diagrammatically a pair of rooms in a house where the construction consists of solid walls, etc., bonded together. Sound travelling from Room 1 to Room 2 can travel via the direct path a-a and by the many indirect, or flanking, paths shown. The term flanking transmission is usually used to mean transmission paths involving the structure, while the term indirect transmission includes flanking paths and airborne paths through gaps and ducts, etc. The indirect paths can limit the sound insulation attainable no matter how much the direct sound is reduced by the separating wall or floor. The indirect transmission can be reduced by measures such as the following.

- Increasing the mass of the flanking walls.
- Increasing the mass of the partition.
- Introducing discontinuities in the indirect paths.
- Erecting independent wall linings adjacent to the flanking walls to prevent energy entering the flanking construction.
- Sealing any air gaps and paths through ducts.

Figure E.2 shows a number of indirect paths that have been found in offices.

It is important to remember that standard test laboratories are designed to minimize transmission by all paths other than the direct path. This makes it difficult to relate the results of laboratory measurements to those likely to be obtained in the field.

E.3 Airborne sound insulation

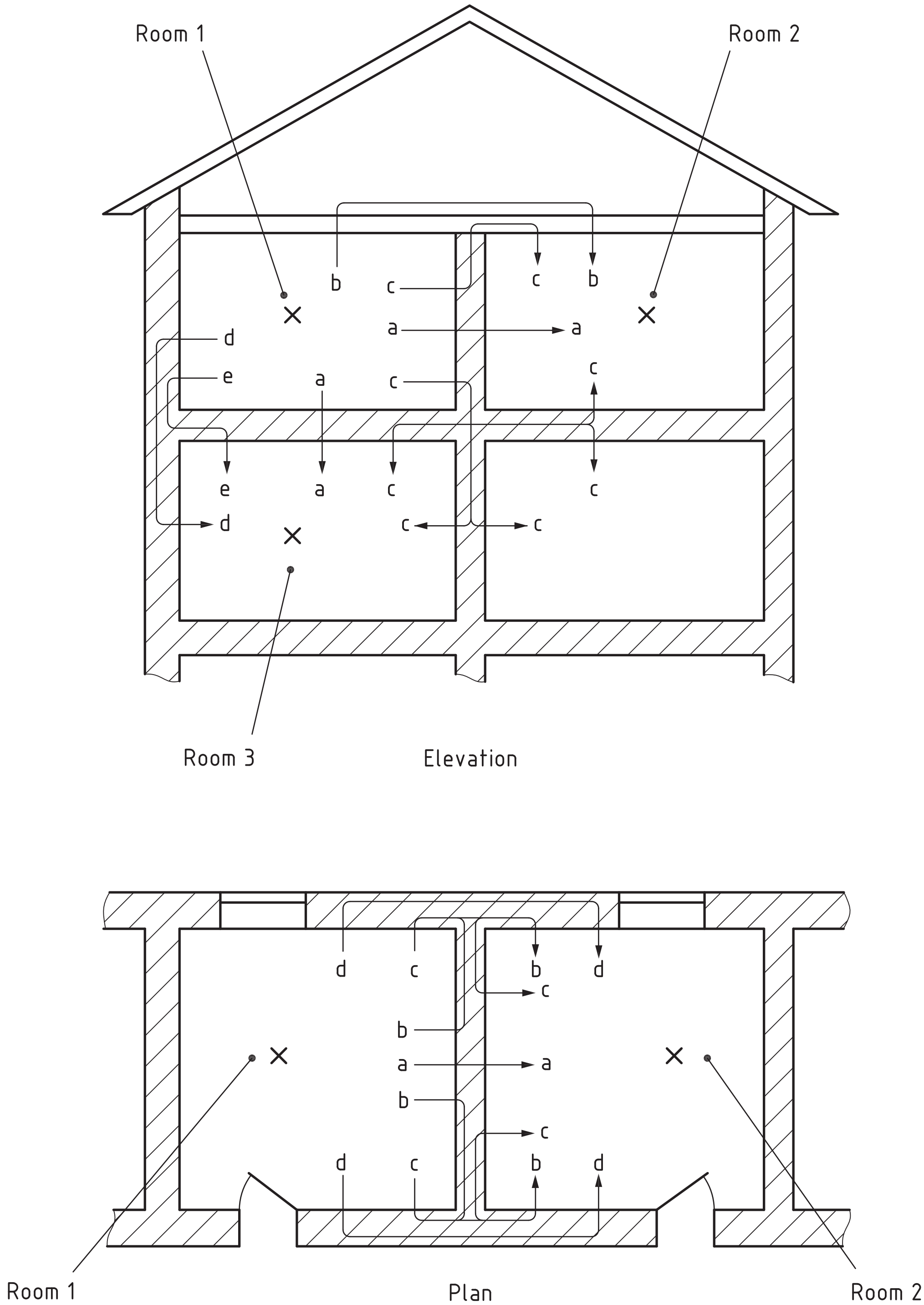
E.3.1 General

The sound insulation of structural elements, such as walls and floors, always varies with frequency, the insulation rising in general as the frequency rises.

E.3.2 Mass law

An approximate empirical relationship has been established between sound insulation and mass for single-leaf constructions, as shown in Figure E.3. This so-called “mass law” gives a useful first approximation to the behaviour of a single sheet or plate. In practice, the sound insulation predicted by the mass law might not be attained because of factors such as the coincidence effect, which is outlined in **E.3.3**. Results for specific materials vary around the value given by the mass law relationship, and so measured data are to be used when available. Table E.1 gives a list of materials and indicates the sound insulation of a single, imperforate sheet when fixed to a suitable wood or metal framework. These values are useful, for example, when assessing existing structures.

Figure E.1 **Transmission paths (via the structure) of noise originating in Room 1 (diagrammatic)**



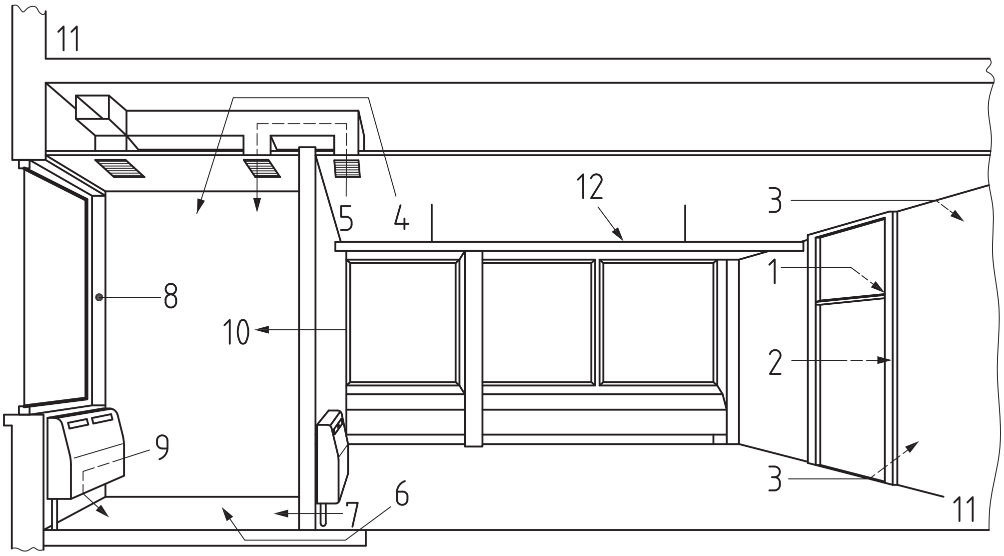
Room 1: Source room

Room 2: Horizontal receiver

Room 3: Vertical receiver

NOTE The arrows indicate the direction of transmission of sound from letter X *in the source room to the same letter* X *in the receiving room.*

Figure E.2 **Indirect sound leakage paths**

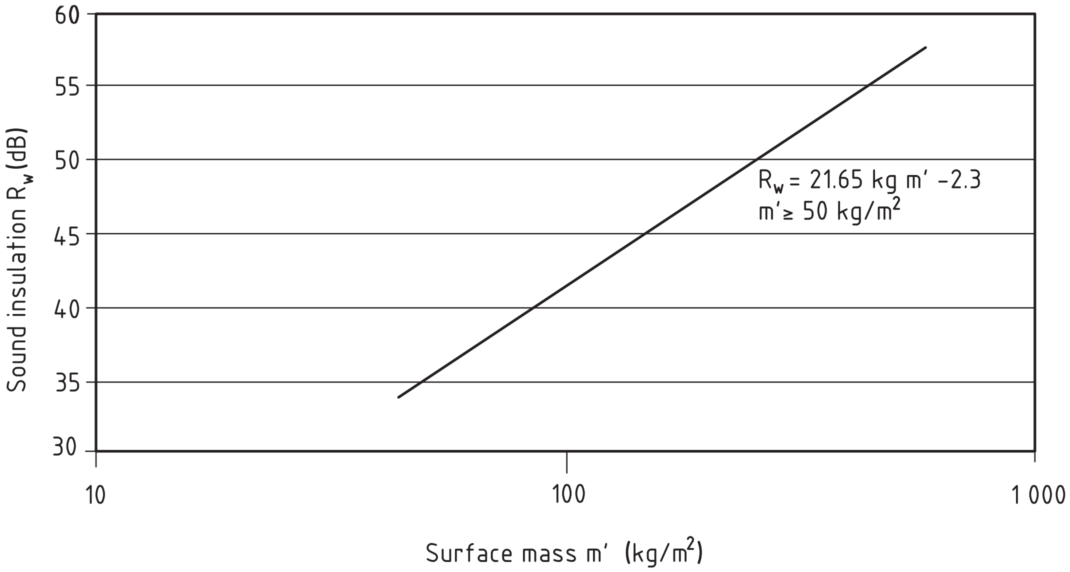


Key

1	Lightweight panels above doors	7	Electrical outlets and service pipes
2	Doors	8	Lightweight mullions or mullion/partition closers
3	Air leaks through gaps, cracks or holes	9	Continuous sill line heating
4	Sound transmission via suspended ceilings/partitions	10	Partition performance
5	Common ventilation system without silencers	11	Appliances
6	Common floor duct	12	Continuous lighting fittings

NOTE Copyright is claimed in this illustration. Reproduction of this illustration and making products from it might infringe that copyright. Details of the copyright owner can be found in the Foreword, Information about this document.

Figure E.3 **Mass law curve**



E.3.3 The coincidence effect

The coincidence effect occurs when the wavelength of the wave impressed on the panel by the incident sound wave is close to the wavelength of free bending waves in the panel. The effect of coincidence is to lower the sound insulation of a construction by as much as 10 dB below the level expected from its mass per unit area over a limited frequency range. The coincidence effect can be pronounced with thin lightweight partitions, resulting in loss of insulation at middle and high frequencies. Reducing the stiffness without a corresponding reduction of mass can raise the critical frequency above 3 150 Hz, and so improve the insulation over the important 100 Hz to 3 150 Hz range. An increase of stiffness has the reverse effect.

It is possible to design lightweight stud partitions so that they perform to their maximum effect in the speech frequency region between 250 Hz and 2 000 Hz, i.e. between the mass-spring-mass and coincidence regions respectively. The worst coincidence dips occur in materials such as plate glass and rigid metal sheets. Heavily damped materials such as lead sheets are least affected.

E.3.4 Mass-spring-mass frequency

A double-leaf wall can perform better than a single-leaf wall of similar mass because the sound has to pass through two barriers. If the two leaves are not connected to each other, the insulation values of the two leaves can be added together. However, in practice, the leaves are often connected by ties or studs, and the full insulation cannot be achieved. Even where the two leaves are isolated from each other, the full benefit can only be obtained above a certain frequency that depends on the cavity width. This is because the air in the cavity behaves like a spring connecting the leaves together, and causes a resonance at the mass-spring-mass frequency. Below this frequency, the two leaves behave more like an equivalent single leaf.

Making the cavity wide can reduce the mass-spring-mass frequency, as in the case of sound insulating secondary glazing. The mass-spring-mass frequency (F_0) can be estimated from the following equation.

$$F_0 = 59.6\sqrt{\frac{1}{d}\left(\frac{1}{m_1} + \frac{1}{m_2}\right)}$$

where:

m_1 and m_2	are the surface masses of the two leaves in kilograms per square metre (kg/m²);
d	is the cavity width in metres (m).

E.3.5 Impact sound control

A structure that receives an impact or has a vibrating source in contact with it behaves more like an extension of the source rather than an intervening element between source and listener. For this reason, a relatively small amount of impact energy can produce a loud sound and, if the structure is continuous, the sound can travel a long distance. Control is usually obtained by inserting a resilient surface at the point of contact with the source (e.g. laying a carpet) or by introducing a structural discontinuity.

Floating floors, which are an example of the latter approach, are a common method of controlling impact sound from footsteps. However, an effective floating floor might result in increased sound from impacts on the source side of the floor. The conventional forms of floating floor might be unsatisfactory if protection against the low-frequency content of impact noise is required (e.g. a dance floor over a restaurant).

E.4 Airborne insulation values of walls and airborne and impact insulation values of floors

Table E.1 and Table E.2 give examples of common types of wall and floor construction with sound insulation in the ranges shown. The insulation indices are for laboratory and field measurements assessed in accordance with BS EN ISO 717-1 and BS EN ISO 717-2. The insulation values given are necessarily approximate since examples of nominally identical constructions might show variations of several decibels. Variation in the amount of indirect transmission can affect significantly the insulation between two rooms separated by a given barrier. For example, the sound insulation of some types of floor could be reduced by indirect transmission along the walls supporting them, particularly if these walls are of lightweight masonry and carried past the floor.

In many cases, simple solid partitions give insulation values according to their mass (see **E.3.2**). Moreover, with partitions of this type there is usually little variation between field and laboratory test results unless the laboratory insulation exceeds 45 dB. Exceptions can occur in buildings that have not been specially designed to minimize common cavities and strongly coupled elements in lightweight panelling. The examples given are not exhaustive. Flanking structures are not listed since these can vary widely and are often dependent upon other factors, such as thermal insulation, which are outside the scope of this British Standard.

Table E.1 and Table E.2 give general, non-exhaustive guidance on the potential sound insulation performance of generic constructions. Manufacturers' products and systems are continually being developed. Additional information on the most up-to-date specifications available ought to be obtained directly from the manufacturers. When considering separating partitions above 50 R_w or $D_{nT,w} + C_{tr}$, expert advice might be required.

Table E.1A **Laboratory airborne sound insulation of walls and partitions**

Sound insulation R_w dB	Type of wall or partition
26 to 33	a) 1 mm steel sheet panels fixed to steel frame members to form demountable partition units 50 mm overall thickness. Mineral wool cavity insulation.
	b) Plywood or wood fibre board 12 mm thick nailed both sides of (50 × 50) mm timber framing members spaced at 400 mm centres.
	c) Paper faced strawboard or wood wool 50 mm thick panels plastered both sides.
	d) Chipboard hollow panels 50 mm thick tongued and grooved edges, hardboard faced. Joints covered with wood trim.
33 to 37	a) Lightweight masonry blockwork. Plaster or drylining on at least one side. Overall mass per unit area not less than 50 kg/m².
	b) Timber stud partitions any size timbers greater than (50 × 350) mm, 400 mm centres, cross noggins, 9.5 mm plasterboard lining on both sides, any suitable finish.
	c) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 18 kg/m².
	d) 50 mm lightweight masonry blockwork, plastered both sides to 12 mm thickness or drylined with 9.5 mm plasterboard.
37 to 43	a) Lightweight masonry blockwork, plaster or dry lining on at least one side. Overall mass per unit area not less than 75 kg/m².
	b) Either 75 mm or (100 × 50) mm timber studs (no noggins) spaced 600 mm apart, 50 mm mineral fibre quilt in stud cavity. Frame-lined on both sides with one layer 12.5 mm plasterboard. Approximate mass per unit area 19 kg/m².
	c) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 15 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 26 kg/m².
43 to 50	a) Masonry wall, joints well filled. Either plaster or dry lining on both sides. Overall mass per unit area not less than 150 kg/m².
	b) 100 mm metal stud partition, "C" section studs not greater than 600 mm spacing, not less than nominal 50 mm web depth. Clad on both sides with two layers of plasterboard of not less than 22 mm combined thickness. Mineral fibre quilt hung between studs. Approximate mass per unit area 35 kg/m².
	c) (75 × 50) mm timber framing using stagged studs at 300 mm spacing with 25 mm stagger forward and back. Frame clad with two layers of 12.5 mm of plasterboard on both sides. Mineral fibre quilt hung between studs. Approximate mass per unit area 36 kg/m².
	d) (50 × 25) mm timber stud partition to form a 25 mm cavity, clad on both sides with minimum 38 mm wood wool slabs having their outer faces screeded or plastered.
	e) Solid autoclaved aerated concrete blocks, 215 mm thick plaster or dry-lined finish on both sides, blockwork joints well filled. Overall mass per unit area not less than 160 kg/m².
50 to 54	a) Two separate frames of timber studs not less than (89 × 38) mm, or boxed metal studwork with 50 mm minimum web depth. Studs at 600 mm maximum centres. A 25 mm mineral wool quilt suspended between frames. Frames spaced to give a minimum 200 mm overall cavity. Clad on outside of each frame with a minimum of 30 mm plasterboard layers (e.g. 19 mm plus 12.5 thickness). Approximate mass per unit area 54 kg/m².
	b) Either in situ or precast concrete wall panel not less than 175 mm thick and not less than 415 kg/m². All joints well filled.

Table E.1A **Laboratory airborne sound insulation of walls and partitions**

Sound insulation R_w dB	Type of wall or partition
	c) Brick laid frogs up, wall nominal 200 mm thickness, weight (including plaster) not less than 380 kg/m². Plaster or dry-lined finish both sides. Brickwork joints well filled.
	d) "No fines" concrete 225 mm thickness, weight (including plaster) not less than 415 kg/m². Plaster or dry-lined finish both sides.
	e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m³) with 75 mm cavity and wall ties of the butterfly wire type. Dry-lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m².
	f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Dry-lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m².
	g) Autoclaved aerated concrete block cavity wall consisting of two leaves, 100 mm blocks not less than 75 mm apart, with wall ties of the butterfly type. Plaster or dry-line finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 150 kg/m².
	h) Metal stud partition, 70 mm acoustic studs 600 mm centres, clad both sides with 15 mm plasterboard, joints filled and perimeters sealed. Mineral fibre within cavity. Approximate mass per unit area 26 kg/m².
54 to 60	a) Two separate frames of timber studs not less than (100 × 50) mm, spaced at 600 mm maximum centres. A 50 mm mineral wool quilt in each frame between studs. Frames spaced to give a minimum 300 mm overall cavity. Each frame clad on outside with three layers of 12.5 mm plasterboard nailed to framing. Approximate mass per unit area: 51 kg/m².
	b) Metal stud partition, 146 mm acoustic studs 600 mm centres, clad both sides with a double layer 15 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area: 51 kg/m².
	c) Solid masonry with an overall mass per unit area of not less than 700 kg/m², fully sealed both sides.
	d) Dense aggregate concrete block solid wall 215 mm thick plaster finish to both surfaces. Overall mass per unit area not less than 415 kg/m².
	e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m³) with 75 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m².
	f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m².
	g) Metal stud partition, 146 mm acoustic studs 600 mm centres, clad both sides with a double layer 15 mm plasterboard, joints filled and perimeters sealed. Mineral fibre within cavity. Approximate mass per unit area 52 kg/m².
60+	a) Two separate frames of metal 48 mm "C" studs 600 mm centres, clad both sides with a double layer 15 mm plasterboard, joints filled and perimeters sealed. Minimum overall width of 200 mm. Mineral fibre within cavity. Approximate mass per unit area 55 kg/m².

NOTE 1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

NOTE 2 Constructions might not achieve these laboratory performances in the field, even if correctly specified and correctly built, due to flanking transmission paths.

Table E.1B **Field airborne sound insulation of walls and partitions**

Sound insulation $D_{nT,w} + C_{tr}$ dB	Type of wall or partition capable of achieving required performance
40 - 44	a) Metal stud partition of overall nominal width of 208 mm. 146 mm metal "C" studs at 600 mm centres, 50 mm mineral wool insulation in the cavity, double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m² each side).
	b) Metal stud partition of overall nominal width of 138 mm. 70 mm metal "C" studs at 600 mm centres with resilient bars at 600 mm centres fixed to one side of the stud framework, 50 mm mineral wool insulation positioned in the cavity, double layer of 15 mm plasterboard each side (minimum plasterboard density 22 kg/m² each side).
45 - 49	a) Metal stud partition of overall nominal width of 208 mm. 146 mm metal acoustic studs at 600 mm centres, 50 mm insulation in the cavity, double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m² each side).
	b) Metal stud partition of overall nominal width of 200 mm. Two frames of 48 mm metal "C" studs at 600 mm centres, cross-braced at 1 200 mm centres. Cavity width of 140 mm. 50 mm mineral wool insulation positioned between the frames. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m² each side).
50 - 52	a) Aggregate block cavity wall, minimum 100 mm blocks (minimum density 1 350 kg/m³), minimum 75 mm cavity between leaves, finished with 13 mm plaster.
	b) Aggregate block cavity wall, minimum 100 mm blocks (minimum density 1 350 kg/m³), minimum 75 mm cavity between leaves, finished with nominal 8 mm (minimum 6 mm) gypsum parge coat, 12.5 mm plasterboard (minimum plasterboard density 8 kg/m²).
	c) Metal stud partition of overall nominal width of 250 mm. Two frames of minimum 60 mm metal "I" studs at 600 mm centres (no bracing between leaves). Minimum cavity width of 190 mm. 100 mm mineral wool insulation positioned between the frames. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m² each side).
	d) Timber stud partition of overall nominal width of 300 mm. Two frames of timber studs at 600 mm centres (no bracing between leaves). Minimum cavity width of 240 mm. 90 mm mineral wool insulation positioned between the studs in each timber frame. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m² each side).
53+	a) Aggregate block cavity wall, minimum 100 mm blocks (minimum density 1 350 kg/m³), minimum 100 mm cavity between leaves, 100 mm mineral wool insulation in the cavity, finished with plasterboard (minimum plasterboard density 10 kg/m²).
	b) Metal stud partition of overall nominal width of 300 mm. Two frames of minimum 60 mm metal "I" studs at 600 mm centres (no bracing between leaves). Minimum cavity width of 240 mm. 100 mm mineral wool insulation positioned between the frames. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m² each side).

NOTE 1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

NOTE 2 These constructions might perform better than the field values given above if tested in a laboratory where flanking paths are idealized.

Table E.1C **Typical performance measured in the field of walls built to Robust Details generic systems**

dB $D_{nT,w}$ Mean	dB $D_{nT,w}+C_{tr}$ Mean	Type of wall [A)]
59	53	E-WM-1 - cavity masonry – dense aggregate blockwork (wet plaster)
59	53	E-WM-2 - cavity masonry – lightweight aggregate blockwork (wet plaster)
60	54	E-WM-3 - cavity masonry – dense aggregate blockwork (render and gypsum-based board)
59	53	E-WM-4 - cavity masonry – lightweight aggregate blockwork (render and gypsum-based board)
58	52	E-WM-6 - cavity masonry – aircrete blockwork (render and gypsum-based board)
55	50	E-WM-9 - solid masonry – solid dense aggregate blockwork (render and gypsum-based board)
62	55	E-WM-11 - cavity masonry – lightweight aggregate blockwork (render and gypsum-based board) with 100 mm minimum cavity [For Scotland: V-WM-11]
62	55	E-WM-16 - cavity masonry – dense aggregate blockwork (render and gypsum-based board) with 100 mm minimum cavity
60	53	E-WM-18 - cavity masonry – dense aggregate blockwork (wet plaster) with 100 mm minimum cavity
62	56	E-WM-21 - cavity masonry – lightweight aggregate blockwork (wet plaster) with 100 mm minimum cavity [For Scotland: V-WM-11]
63	55	E-WT-1 – twin-leaf timber frame – without sheathing board [For Scotland: V-WT-1]
63	54	E-WT-2 – twin-leaf timber frame – with sheathing board [For Scotland: V-WT-2]
58	51	E-WS-1 - steel frame – twin metal frame

[A)] See the Robust Details (RD) Handbook [53] or, for Scotland, [54] for full specification details, including flanking requirements.

Table E.2A **Laboratory airborne sound insulation of floor constructions**

Sound insulation R_w dB	**Type of floor construction**
Below 43	Timber joist floor consisting of 22 mm tongued and grooved floor boarding or equivalent fixed directly to floor joists. Ceiling of 12.5 mm plasterboard and skim with no floor covering.
Above 43	a) A concrete floor having mass per unit area not less than 365 kg/m², including any screed or ceiling finish directly bonded to the floor slab, together with a floating floor or resilient floor covering equivalent to rubber or sponge rubber underlay or thick cork tile (e.g. carpet and underlay or sponge rubber backed vinyl flooring).
	b) A solid floor consisting of: • a solid slab; or • concrete beams and infilling blocks; or • hollow concrete planks, together with a floating floor. A ceiling finish is required for a beam and block floor. In each case the slab is to have a mass per unit area of at least 300 kg/m², including any screed or ceiling finish directly bonded to it. Where a floating floor is laid over a floor of beams and hollow infill blocks or hollow beams along the top of the structural floor, the latter is to be sealed and levelled before the resilient layer is put down. It is also essential to have due regard for conduits and pipework to be be laid and covered so as to prevent any short circuit of the floor’s isolating properties. If precast units are used as a structural floor it is essential that the joints are filled to ensure that the sound insulation performance is maintained. The resilient material is laid to cover completely the structural floor and turned up against the surrounding wall along all edges. The resilient layer is usually of mineral fibre, or a special grade of expanded polystyrene. When the screed is laid, it is important that none of the mix finds its way through the resilient layer to the structural floor, as this short-circuits the isolation between the two decks and significantly reduces the sound insulation.
	c) A floor consisting of boarding nailed to battens laid to float upon an isolating layer of mineral fibre capable of retaining its resilience under imposed loading. With battens running along the joists, a dense fibre layer can be used in strips. The ceiling below to be of metal lath and plaster not less than 29 mm thick, with pugging on the ceiling such that the combined mass per unit area of the floor, ceiling and pugging is not less than 120 kg/m².
	d) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard, laid on battens running parallel to the joists and supported on 25 mm thick mineral wool of approximately 90 kg/m³ to 140 kg/m³ density; 100 mm of fibre absorbent (as used for insulation in roof spaces) laid between the joists on top of the plasterboard ceiling. The ceiling can be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.
	e) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard floating on a 25 mm thick mineral wool layer of approximately 60 kg/m³ to 80 kg/m³ density; this on a 12.5 mm plywood platform; 100 mm of fibre absorbent laid between the joists on top of the plasterboard ceiling. The ceiling can be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.

NOTE 1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

NOTE 2 Constructions might not achieve these laboratory performances in the field, even if correctly specified and correctly built, due to flanking transmission paths.

Table E.2B **Typical performance measured in the field of floors built to Robust Details generic systems**

dB $D_{nT,w}$ Mean	dB $D_{nT,w}$+C_{tr} Mean	dB $L'_{nT,w}$ Mean	Type of floor [A)]
54	50	51	E-FC-1 - precast concrete plank with directly applied screed and floating floor treatment
62	56	44	E-FC-2 – in situ concrete slab and floating floor treatment
60	52	52	E-FT-1 - timber I-joists and floating floor treatment [For Scotland, V-FT-1]
60	52	52	E-FT-2 - timber solid joists and floating floor treatment [For Scotland, V-FT-2]
64	56	37	E-FS-1 - steel deck and in situ concrete and floating floor treatment [For Scotland, V-FS-1]

A) See the Robust Details (RD) Handbook [53] or, for Scotland, [54] for full specification details, including flanking requirements.

Annex F (informative) Legislative framework and guidance

NOTE Much of the advice already given in ***5.1*** *to* ***5.5*** *can also be applied to a new noise producing development. As the local planning authority might require noise control measures, and failure to implement these properly could result in widespread annoyance and legal action, it is necessary to consider the legislative framework.*

F.1 Legislative framework

For many projects involving buildings, there is usually a need to carry out some form of noise impact assessment in order to satisfy local and national noise management and planning policies. The scope of the assessment needs to include all phases of the proposed development including construction and operation.

Certain types of project that meet specific criteria require either a full environmental impact assessment (EIA) [55] to be carried out, an important part of which is often noise, or a more specific noise assessment process to be followed. In all cases, it is prudent to consult, at an early stage, with:

a) the relevant local planning authority;

b) the relevant local authority environmental health department;

c) the relevant building control authority.

F.2 Construction noise

Sections 60 and 61 of the Control of Pollution Act 1974, as amended [56], provide the legislative basis for controlling construction noise, including local authority powers. Useful advice on controlling construction noise is given in BS 5228-1.

F.3 Noise from other sources

A local authority can take legal action to prevent or stop a noise from fixed premises, including land, which it considers prejudicial to health or a nuisance. Any new noise source of that nature has the potential to be a statutory nuisance. Furthermore, an existing noise source can become susceptible to nuisance legislation if residential premises are introduced into its vicinity. Useful advice on the assessment of sources of an industrial nature can be found in BS 4142.

In England, Wales and Scotland, a local authority's power is primarily to be found in section 80 of the Environmental Protection Act 1990 [57] and, in Northern Ireland, Article 70 The Clean Neighbourhoods and Environmental Act (Northern Ireland) 2011 [58]. These Acts also make provision for private individuals to take complaints directly to a magistrate's court (or Sheriff's court in Scotland).

The main principles established under these Acts are as follows.

a) There is no prescribed level above which a noise automatically becomes a statutory nuisance. Each case is considered on its merits taking account of a range of factors, including the likely reaction of a typical person.

b) Where the noisemaker is operating from industrial, trade or business premises, it is a defence to show that the best practicable means to control noise have been used.

F.4 Civil action

Civil action can be taken against the perpetrator of noise that is felt to be a nuisance and, again, each case is assessed on its merits. The criterion for a civil action is how the noise affects the individual, compared with the ordinary inconvenience suffered by the public at large, or how it affects land in which the individual has an interest. The defence of best practicable means is not available.

Annex G (informative) Typical design problem

G.1 Typical design problem: Simple calculation

A small housing development is to be situated 55 m from the edge of an existing road. The average traffic speed is 50 km/h, and the intervening ground is paved.

To establish the noise exposure of the site, the $L_{A10,18h}$ could be calculated or measured for a typical unit near the road. This has been calculated from CRTN [16] to be 65 dB free-field. This is approximately 63 dB $L_{Aeq,16h}$. The local planning authority has requested noise control measures; in this case to reduce the noise level inside the bedrooms to 35 dB $L_{Aeq,16h}$ during the day and 30 dB $L_{Aeq,8h}$ at night.

To reduce the noise exposure inside the houses, attention needs to be given to the sound insulation of both the roof and facade. A traditional pitched roof with concrete tiles and a 9 mm plasterboard ceiling, covered in thermal insulating material, has an insulation of approximately 43 dB R_w (see Clause **8**).

The windows, and any trickle ventilators, are normally the weakest part of a brick and block facade. Insulating glass units have an insulation of approximately 33 dB R_w and, assuming suitable sound attenuating trickle ventilators [2)] are used, the resulting internal noise level, roughly 30 dB, ought to be determined by the windows. This level is acceptable with the windows closed and attenuated background ventilation, even with the correction for first floor level. If partially open windows were relied upon for background ventilation, the insulation would be reduced to approximately 15 dB [3)], resulting in the target levels being exceeded. However, windows may still be openable for rapid or purge ventilation, or occupant's choice.

---

2) Note that, where more than one ventilator is used to meet the ventilation requirement, the overall ventilator attenuation needs to be suitable (see **G.2.1**, Note 5). Where the glazing exceeds the required attenuation, the ventilation is usually the weakest part of the facade.

3) Note that the level difference through a window partially open for ventilation can

This calculation ought to be repeated for night-time traffic conditions, and the design needs to satisfy both sets of requirements. Strictly, the insulation values used here relate to a pink noise spectrum, and actual values achieved are lower for traffic noise. Furthermore, the method does not take account of the absorption (e.g. furnishings) in the room. However, the R_w values suffice for a rough calculation, although it is likely to underestimate the level in the room by up to 5 dBA. Where the estimate is within 5 dBA of the target noise level, a more rigorous calculation needs to be carried out using octave bands, as explained in **G.2**.

G.2 Typical design problem: More rigorous calculation

G.2.1 Calculation method

This calculation method is based on that given in BS EN 12354-3.

NOTE 1 This method is applicable for simple facades without balconies. The calculation is different for external noise intrusion from a point source, e.g. an item of construction plant, and that for a line source. The external noise is assumed to irradiate the external facade at random incidence, whereas for a point source there is irradiation from a single direction of incidence, with a cosθ factor being applied to account for various incident angles. BS EN 12354-3, which in any case is more difficult to follow than the example given here, does not distinguish between point and line source cases.

NOTE 2 Measurement methods for the insulation of facade elements are given in BS EN ISO 10140-2.

The following equation, which gives the equivalent sound pressure level in a room, $L_{eq,2}$, needs to be evaluated for each frequency band of interest.

$$L_{eq,2} = L_{eq,ff} + 10\log_{10}\left(\frac{A_0}{S}10^{\frac{-D_{n,e}}{10}} + \frac{S_{wi}}{S}10^{\frac{-R_{wi}}{10}} + \frac{S_{ew}}{S}10^{\frac{-R_{ew}}{10}} + \frac{S_{rr}}{S}10^{\frac{-R_{rr}}{10}}\right) + 10\log_{10}\left(\frac{S}{A}\right) + 3 \quad \text{(G.1)}$$

where:

$L_{eq,ff}$ is the equivalent continuous sound pressure level outside the room elements under consideration;

NOTE 3 It is the free-field sound level (i.e. in the absence of the facade), measured or estimated at the intended position of the element under consideration. It is related to the level $L_{eq,1}$ measured within a few millimetres of the actual facade by the relation $L_{eq,ff} \approx L_{eq,1} - 6$, and to the level $L_{eq,2m}$ measured 2 m away from the facade by the relation $L_{eq,ff} \approx L_{eq,2m} - 3$.

NOTE 4 The calculation method assumes the source is traffic noise and a facade shape correction factor is not required. BS EN 12354-3 provides a more detailed calculation method where these assumptions are not valid.

A_0 is a reference absorption area of 10 m² and is independent of frequency;

S_f is the total facade area in square metres (m²) of the room in question;

S_{wi} is the area in square metres (m²) of the windows of the room;

vary significantly depending on the window type and the frequency content of the external noise. If the specific details of the window and external noise are known the value for insulation may be adjusted accordingly.

S_{ew}	is the area in square metres (m²) of the external wall of the room;
S_{rr}	is the area in square metres (m²) of the ceiling of the room;
S	is the total area in square metres (m²) of elements through which sound enters the room, i.e. $S_f + S_{rr}$;
$D_{n,e}$	is the insulation of the trickle ventilator measured according to BS EN ISO 10140; *NOTE 5 Where more than one ventilation unit is required to achieve the background ventilation, the $D_{n,e}$ of the combined ventilators should be used in the calculation.*
R_{wi}	is the sound reduction index (octave band value) of the window (see Annex C);
R_{ew}	is the sound reduction index (octave band value) of the external wall (see Annex C);
R_{rr}	is the sound reduction index (octave band values) of the roof/ceiling (see Annex C);
A	is the equivalent absorption area of the receiving room being considered (see Annex C);
3	is a correction factor.

Values of L_{eq}, $D_{n,e}$, R and A are frequency dependent, and the calculation of $L_{eq,2}$ has to be repeated using values for each octave band of interest. If the dBA level in the room ($L_{Aeq,2}$) is to be estimated, the resulting values of $L_{eq,2}$ ought to be A-weighted (to give $L_{Aeq,125}$ in the 125 Hz octave band, etc.) and summed logarithmically (see Annex A). The equation for summing the levels in each frequency is as follows.

$$L_{Aeq,2} = 10\log_{10}\left(10\frac{L_{Aeq,125}}{10} + 10\frac{L_{Aeq,250}}{10} + ... + \right) \quad (G.2)$$

G.2.2 The calculation of the noise level inside a room

The calculation for this example is conducted most easily on a spreadsheet, using the data in Table G.1. Each term in the equation is evaluated for each frequency band, as shown in Table G.2.

In this example the exposure of the roof and all facade elements is the same. Where this is not the case the calculation has to be undertaken on an element-by-element basis and the resulting internal levels summed using equation (G.2).

The calculated noise level is above the target of 35 dBA, and Table G.2 shows that the main contribution comes from the window (row C), although the roof (row E) dominates at low frequencies. A better product ought to be selected and the procedure repeated until it has no significant effect on the insulation. The revised value may be compared with the rough estimate of 34 dBA. This procedure needs to be repeated for night-time conditions and the design has to satisfy both sets of requirements. The rapid ventilation problem still needs to be tackled.

In this calculation the trickle ventilators were not an important transmission path, but this might not always be the case.

Although this calculation is more rigorous than the simple example, the method still makes assumptions, and it is likely that the estimated levels differ from measured values. It does, however, indicate the relative performance of each element in each octave band and allows iterative changes. Facade calculations are also covered in [15].

Table G.1 **Data used in the calculation of the noise level inside a room**

Terms that are frequency dependent								
Term	**Description**	**Single-figure rating**	**Octave band centre frequency** Hz					**A-weighted level**
			125	**250**	**500**	**1 000**	**2 000**	
$L_{eq,ff}$	—	—	70	66	63	61	61	67
$D_{n,e}$	Sound attenuated trickle ventilator	—	37	36	35	36	34	—
R_{wi}	6-12-6 insulated glass unit	33	26	29	33	28	24	—
R_{ew}	Brick and block external wall	50	40	44	45	51	56	—
R_{rr}	See Table G.2	43	28	34	40	45	49	—
A	—	—	11	14	16	16	15	—

Terms that are not frequency dependent		
Term	**Derivation**	**Value** m[2]
S_f	Facade area (including window)	10
S_r	Roof area (exposed side)	40
S_{wi}	Window area	1.5
S_{ew}	$S_f - S_{wi}$	8.5
S_{rr}	Area of ceiling	15
S	$S_f + S_{rr}$	25
A_0	Reference absorption area given in BS EN ISO 10140-2	10

NOTE The expected precision of this calculation is ±2 dB.

Table G.2 **The calculation of the noise level inside a room**

Term from equation (G.1)	**Reference letter of result**	**Octave band centre frequency Hz**				
		125	**250**	**500**	**1 000**	**2 000**
$L_{eq,ff}$	A	70	66	63	61	61
$D_{n,e}$		37	36	35	36	34
$\frac{A_0}{S}10^{\frac{-D_{n,e}}{10}}$	B	0.000 08	0.000 10	0.000 13	0.000 10	0.000 16
R_{wi}		26	29	33	28	24
$\frac{S_{wi}}{S_f}10^{\frac{-R_{wi}}{10}}$	C	0.000 15	0.000 08	0.000 03	0.000 10	0.000 24
R_{ew}		40	44	45	51	56
$\frac{S_{ew}}{S_f}10^{\frac{-R_{ew}}{10}}$	D	0.000 03	0.000 01	0.000 01	0.000 00	0.000 00
R_{rr}		28	34	40	45	49
$\frac{S_{rr}}{S_f}10^{\frac{-R_{rr}}{10}}$	E	0.000 95	0.000 24	0.000 06	0.000 02	0.000 01
$10\log_{10}(B+C+D+E)$	F	–29.2	–33.7	–36.4	–36.6	–33.9
A (furnished)		11	14	16	16	15
$10 \log \frac{S}{A}$	G	3.6	2.5	1.9	1.9	2.2
$L_{eq,2}$	A + F + G + 3	47.4	37.8	31.5	29.3	32.3
A-weighting dB		–16	–9	–3	0	1
$L_{eq,2}$ + A-weighting	$L_{Aeq,125}$ etc.	31.4	28.8	28.5	29.3	33.3

$L_{Aeq,2}$ is obtained by combining these values using equation (G.2).
A-weighted level in the room $L_{Aeq,2}$ is 37.7 dB

Annex H (informative) Examples of design criteria adopted by hotel groups

H.1 General

Airborne sound insulation between spaces is not to be less than the values given in Table H.1, when measured in accordance with BS EN ISO 140-4 and rated in accordance with BS EN ISO 717-1.

Table H.1 **Airborne sound insulation**

Room areas	Performance
Bedroom – Bedroom Bedroom – Bathroom (different rooms) Bathroom – Bathroom	Walls: 43 dB $D_{nT,w} + C_{tr}$ Floors: 45 dB $D_{nT,w} + C_{tr}$
Bedroom – Restaurant/bar	60 dB $D_{nT,w}$
Bedroom – Kitchen	60 dB $D_{nT,w}$
Bedroom – Other tenancies	65 dB $D_{nT,w}$
Bedroom – Corridor	Walls: 43 dB $D_{nT,w} + C_{tr}$
Bathroom – Corridor	45 dB $D_{nT,w}$
Bedroom – Laundry	43 dB $D_{nT,w} + C_{tr}$
Bedroom – Plant room	60 dB $D_{nT,w}$

NOTE It might be important to take account of the purpose of the room.

Internal wall constructions within bedrooms (but not to en suite bathrooms) are to have a sound insulation performance of not less than 40 dB R_w. Doors to bedrooms are to have a sound insulation performance of not less than 29 dB R_w, when measured in accordance with BS EN ISO 10140-2 and rated in accordance with BS EN ISO 717-1. Interconnecting doors should maintain the required room-to-room sound insulation performance of the total wall as identified in accordance with **H.2**.

Where moveable walls are to be installed between meeting rooms and between function rooms, the entire wall, including cupboards for parking the wall panels and the wall above and beneath the ceiling or floor, is, in its entirety, to achieve a minimum installed performance of 48 dB $D_{nT,w}$.

H.2 Impact sound insulation

Impact sound insulation between spaces is not to exceed the values given in Table H.2, when measured in accordance with BS EN ISO 140-7 and rated in accordance with BS EN ISO 717-2.

Table H.2 **Impact sound insulation for hotels**

Room areas	Performance
Bedroom – Bedroom	62 dB $L'_{nT,w}$
Bathroom – Bedroom	62 dB $L'_{nT,w}$
Corridor – Bedroom	62 dB $L'_{nT,w}$

NOTE The applicable Building Regulations [30, 31, 32] might require more stringent standards than those given in this table.

All separating floor systems need to be free from "squeaks" and "creaks" from footsteps (see **8.4.6.4**). All doorsets should include seals on the sides, head and threshold in order to meet the necessary acoustic requirements. Smooth-closing doors are to be installed in order to minimize noise disturbance from occupant movement.

H.3 Sound absorption in common parts

Sound absorption is to be provided for corridors, staircases and hallways in accordance with Clause **8**. The applicable Building Regulations [30, 31, 32] contain provisions for sound absorption that is necessary in corridors, staircases and hallways.

H.4 Internal noise levels from external sources

The noise level in any hotel bedroom, with windows closed, from all external sources, including road, rail and air traffic and noise from activities outside the hotel and any adjacent premises, are to be within the range of average noise levels in Table H.3.

Table H.3 **Indoor ambient noise level ranges for hotel bedrooms**

Period	Noise level
Daytime (07:00 – 23:00 hrs)	30 – 40 dB $L_{Aeq,1hour}$
Night-time (23:00 – 07:00 hrs)	25 – 35 dB $L_{Aeq,1hour}$
Night-time (23.00 – 07.00 hrs)	45 – 55 dB L_{Amax}

NOTE Some hotels may set lower noise levels, depending on location.

Music and patron noise intrusion from inside any adjacent, neighbouring or connected bar/restaurant or nightclub into the guest bedrooms is to be controlled such that it is unlikely to cause disturbance.

In hotels, other commercial factors could influence the criteria adopted for the break-in to bedrooms of building services noise from adjacent rooms or spaces.

External facade constructions and components, such as brise soleil, grilles, ventilators, curtain walling systems or other architectural features, are not to give rise to intrusive whistling, creaking, rattling or other noises as a result of wind or other climatic effects.

H.5 Background noise levels: Internal sources

The background noise level in any hotel bedroom arising from comfort cooling room units serving the bedroom is not to exceed NR25 L_{eq} when the units are operating at their design duty. Comfort cooling systems installed in bedrooms are to have the facility to be operated at quieter duties and to be switched off by room occupants.

The background noise level in any hotel bedroom as a result of constant minimum fresh air ventilation systems serving the bedroom or other parts of the development is not to exceed NR20 L_{eq} when the systems are operating at their design duty.

The background noise level in any hotel bedroom arising from any other building services systems serving the bedroom or any other parts of the development is not to exceed NR20 L_{eq} within the bedroom.

The building services noise in other areas of the hotel is not to exceed the levels given in Table H.4.

Table H.4 **Building services noise in hotels**

Area	Noise level
En suite bathrooms	NR35 to NR 45 $L_{eq,\ 1hr}$
Corridors/lobbies	NR40 $L_{eq,\ 1hr}$
Restaurants	NR35 to NR 45 $L_{eq,\ 1hr}$
Public toilets	NR40 $L_{eq,\ 1hr}$
Staff rooms	NR40 $L_{eq,\ 1hr}$

Noise emission from hydraulic systems, including domestic hot and cold water services, refrigerant pipework, and soil and waste pipes serving other bedrooms, is not to cause disturbance in normal use.

Noise from the operation of lifts is not to cause disturbance in hotel bedrooms (see **7.7.3.4**).

H.6 Noise control measures for bedrooms, corridors and stairwells

The air conditioning system is to be designed to conform to Table H.4, and to avoid compromising sound insulation between rooms. Bedrooms are not to be located next to lift shafts, plant rooms or other areas where there are high noise levels. Effective protection against indoor noise is necessary, and partitions and floors between rooms are required to meet the appropriate Building Regulations [30, 31, 32].

To avoid unnecessary transmission of airborne noise between adjoining rooms by way of open windows, windows are not to open in such a way as to direct sound immediately from one room into the next. Where possible, bedrooms are not to overlook courtyards, or to be over kitchens or service vehicle areas that are frequently noisy in the early morning.

Door openings on opposite sides of corridors may be staggered and fitted with acoustic seals on all four edges to reduce noise transmission (but without making it necessary to slam the doors closed). Doors may have quiet-action latches. Corridors can be fitted with carpeted floors. Sound-absorbing ceilings are beneficial, though not always essential if a carpet is fitted in the corridor. Staircases and lift halls may be separated from the corridors by means of doors that can open and close quietly (such as swing doors) and, where possible, isolated from bedrooms by linen stores and similar rooms. If bedroom doors have to be located close to lift doors, acoustic lift signals are not to be audible in the bedrooms. Except within the same suite, bathrooms are not be planned next to bedrooms. In all cases, the types of sanitary fittings chosen ought ideally to be quiet in operation and the plumbing system designed to minimize noise by avoiding sharp bends and restrictions of flow.

H.7 Function rooms

Large hotels often have ballrooms, banqueting rooms and meeting rooms, which are hired out separately for public and private functions. Proceedings might go on well into the night and it is essential, therefore, that these rooms can be effectively isolated from bedrooms, with all noise paths suitably insulated. For example, a ballroom in an internal court does not sufficiently insulate from bedrooms in higher storeys if it has windows opening into the well of the court, or a lightweight roof construction. To minimize disturbance the roof is to be of concrete or other solid construction, and any top lights or windows are to be double-glazed and sealed, with a separate air conditioning system if necessary.

The insulation between the public rooms themselves also needs to be considered. In rooms in which dancing could take place on one side of a division wall and speech-making on the other, a wall of less than 60 dB R_w insulation might not provide adequate protection. Folding partitions are not normally sufficient to separate rooms where disparate activities take place.

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 5228-1:2009, *Code of practice for noise and vibration control on construction and open sites – Part 1: Noise*

BS 5839-8, *Fire detection and fire alarm systems for buildings – Part 8: Code of practice for the design, installation, commissioning and maintenance of voice alarm systems*

BS 6262, *Glazing for buildings*

BS 7445, *Description and measurement of environmental noise*

BS EN 1793-3, *Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 3: Normalized traffic noise spectrum*

BS EN 12354, *Building acoustics – Estimation of acoustic performance in buildings from the performance of elements*

BS EN 12354-3, *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 3: Airborne sound insulation against outdoor sound*

BS EN 12354-6, *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 6: Sound absorption in enclosed spaces*

BS EN 12758, *Glass in building – Glazing and airborne sound insulation – Product descriptions and determination of properties*

BS EN 61400-11, *Wind turbine generator systems – Part 11: Acoustic noise measurement techniques*

BS EN ISO 140-5, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 5: Field measurements of airborne sound insulation of facade elements and facades*

BS EN ISO 717-1, *Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation*

BS EN ISO 717-2, *Acoustics – Rating of sound insulation in buildings and of building elements – Part 2: Impact sound insulation*

BS EN ISO 3382-1, *Acoustics – Measurement of room acoustic parameters – Part 1: Performance spaces*

BS EN ISO 3382-2, *Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms*

BS EN ISO 3382-3, *Acoustics – Measurement of room acoustic parameters – Part 3: Open plan offices*

BS EN ISO 11654, *Acoustics – Sound absorbers for use in buildings – Rating of sound absorption*

BS EN ISO 14163, *Acoustics – Guidelines for noise control by silencers*

BS ISO 9568, *Cinematography – Background acoustic noise levels in the theatres, review rooms and dubbing rooms*

ISO 9613-2, *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation*

Other publications

[1] GREAT BRITAIN. *The Building Regulations 2010. The Building (Approved Inspectors etc) Regulations 2010. Approved Document E: Resistance to the passage of sound*. 2003 edition (incorporating 2004 and 2010 editions). London: NBS. (http://www.planningportal.gov.uk/buildingregulations/approveddocuments/parte/approved/)

[2] DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (DCLG). National Planning Policy Framework 2012. London: DCLG. 2012.

[3] ASSOCIATION OF NOISE CONSULTANTS. *Association of noise consultants guidelines – Noise measurements in buildings (ANC-C9801) – Part 1: Building services noise; Part 2: Noise from external sources (e.g. traffic noise) within buildings*. Guilden Morden: Association of Noise Traffic Consultants. 2012.

[4] DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (Defra). Noise Policy Statement for England (NPSE). London: Defra. 2010.

[5] WELSH GOVERNMENT. Planning Policy Wales. Edition 5. 2012. (Available at: http://wales.gov.uk/topics/planning/policy/ppw/?lang=en)

[6] WELSH GOVERNMENT. Technical Advice Note (TAN) 11: *Noise*. 1997. (Available at: http://wales.gov.uk/topics/planning/policy/tans/tan11/;jsessionid= 6A1A0555B1A9C8AD869AA93D0BB719F3?lang=en)

[7] SCOTTISH GOVERNMENT. Planning Advice Note PAN 1/2011: *Planning and Noise*. Edinburgh: Scottish Government. 2011. (Available at: http://www.scotland.gov.uk/Resource/Doc/343210/0114180.pdf)

[8] SCOTTISH GOVERNMENT. Technical Advice Note: *Assessment of Noise*. Edinburgh: Scottish Government. 2011. (Available at: http://www.scotland.gov.uk/Publications/2011/03/02104659/12)

[9] DEPARTMENT OF ENVIRONMENT NORTHERN IRELAND (DOENI). Planning Policy Statements. (Available at: http://www.planningni.gov.uk/index/policy/policy_publications/planning_statements.htm)

[10] DEPARTMENT OF ENVIRONMENT NORTHERN IRELAND (DOENI). Development Control Advice Notes. (Available at: http://www.planningni.gov.uk/index/policy/supplementary_guidance/dcans.htm)

[11] GREAT BRITAIN. The Environmental Noise Regulations (England) 2006. London: The Stationery Office.

[12] GREAT BRITAIN. The Environmental Noise Regulations (Wales) 2006. London: The Stationery Office.

[13] SCOTLAND. The Environmental Noise Regulations (Scotland) 2006. London: The Stationery Office.

[14] NORTHERN IRELAND. The Environmental Noise Regulations (Northern Ireland) 2006. London: The Stationery Office.

[15] BUILDING RESEARCH ESTABLISHMENT and CIRIA. *Sound control for homes*. Building Research Establishment, 1993 BR 238/CIRIA report 127. Watford: Building Research Establishment.

[16] DEPARTMENT OF TRANSPORT. *Calculation of road traffic noise* (CRTN). London: The Stationery Office. 1988.

[17] HIGHWAYS AGENCY. *Design Manual for Roads and Bridges*, Volume 11, Section 3, Part 7, HD 213/11: Noise and Vibration – Revision 1. 2011. (http://dft.gov.uk/ha/standards/dmrb/vol11/section3/hd21311.pdf)

[18] TRL and CASELLAT STANGER. *Method for Converting the UK Road Traffic Noise Index $L_{A10,18h}$ to the EU Noise Indices for Road Noise Mapping*. London: Defra. 2006. (Available at: http://archive.defra.gov.uk/environment/quality/noise/research/crtn/documents/noise-crtn-update2006.pdf)

[19] PARLIAMENT AND COUNCIL OF THE EUROPEAN COMMUNITY. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. OJ L 189/12.

[20] CIVIL AVIATION AUTHORITY. *Noise Considerations at General Aviation (GA) Aerodromes: An examination of some of the environmental issues associated with general aviation-focussed aerodromes, concentrating upon noise impact and local Noise Abatement Procedures (NAP)*. Civil Aviation Authority. November 2012. (Available at: http://www.caa.co.uk/docs/7/NoiseConsiderationsAtGAAerodromesFINAL.pdf)

[21] DEPARTMENT OF TRANSPORT. *Calculation of railway noise* 1995. London: The Stationery Office. 1995.

[22] DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (Defra). *Additional railway noise source terms for "Calculation of Railway Noise 1995"*. London: Defra. 2007.

[23] ETSU WORKING GROUP ON WIND TURBINE NOISE. ETSU-R-97. *The Assessment and Rating of Noise from Wind Farms*. Didcot: ETSU. 1996.

[24] INSTITUTE OF ACOUSTICS. *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise*. St Albans: Institute of Acoustics. 2013. (http://www.ioa.org.uk/pdf/ioa-gpg-on-wtna-issue-01-05-2013.pdf)

[25] NOISE COUNCIL. *Code of practice on organised off-road motorcycle sport* (http://www.cieh.org/uploadedFiles/Core/Policy/Publications_and_information_services/Policy_publications/Publications/Noise%20Council%20Code%20on%20%20Noise%20from%20Off-Road%20Motor%20Cycle%20Sport.pdf)

[26] CHARTERED INSTITUTE OF ENVIRONMENTAL HEALTH (CIEH): *Clay target shooting: Guidance on the control of noise* (http://www.cieh.org/library/Knowledge/Environmental_protection/ClayShootingCoP.pdf); *Codes of practice on ice cream van chimes, etc., noise from model aircraft and audible intruder alarms under S71 of Control of Pollution Act 1974* (see http://archive.defra.gov.uk/environment/quality/noise/research/minimising-noise/cop- minimisingnoise.pdf)

[27] NOISE COUNCIL: *Code of Practice on Environmental Noise Control at Concerts*. London: The Noise Council.1995.

[28] SOUND RESEARCH LABORATORIES LTD. *Noise control in building services*. Oxford: Pergamon Press. 1988.

[29] LEVENTHALL, G. Noise control for providing a quality environment. *In: Proceedings of the 5th indoor air quality conference 1997*. Cambridge: Mid Career College Press.

[30] ENGLAND AND WALES. Building Regulations 2010 (England and Wales), as amended. London: The Stationery Office.

[31] SCOTLAND. Building (Scotland) Regulations 2004, as amended. Edinburgh: The Stationery Office.

[32] NORTHERN IRELAND. Building Regulations (Northern Ireland) 2012. London: The Stationery Office.

[33] GREAT BRITAIN. *Building Standards Technical Handbooks 2013 - Section 5: Noise*. Edinburgh: The Scottish Government Building Standards Division. (http://www.scotland.gov.uk/Topics/Built-Environment/Building/Building-standards/publications/pubtech)

[34] NORTHERN IRELAND. Building Regulations (Northern Ireland) 1994. Technical Booklet G:1990 – *Sound*, and Technical Booklet G1: 1994 – *Sound (Conversions)*. Belfast: Department of Finance and Personnel Northern Ireland.

[35] UNITED KINGDOM. *The Building Regulations 2000 Approved Document B – Fire Safety*. London: NBS. 2006.

[36] Scottish Technical Handbooks: Section 2 – *Fire*. 2011.

[37] DEPARTMENT OF FINANCE AND PERSONNEL (DFP*). Building Regulations (Northern Ireland) 2012 Guidance. Technical Booklet E: Fire safety*. Bangor: DFP. 2012.

[38] BRITISH COUNCIL FOR OFFICES. *Guide to Specification*. London: British Council for Offices. 2009.

[39] BRITISH COUNCIL FOR OFFICES. *Guide to Fit Out*. London: British Council for Offices. 2011.

[40] ASSOCIATION OF INTERIOR SPECIALISTS. *A guide to office acoustics*. Solihull: AIS. 2011. (Available at: http://ais-interiors.org.uk/interiors_focus/AIS-a-guide-to-office-accoustics/index.html#/1/zoomed)

[41] GREAT BRITAIN. The Control of Noise at Work Regulations 2005. London: The Stationery Office.

[42] HEALTH AND SAFETY EXECUTIVE, *Sound solutions – Techniques to reduce noise at work*. London: The Stationery Office. 1995.

[43] DEPARTMENT FOR EDUCATION. *BB 93: Acoustic design of schools*. London: The Stationery Office. 2003.

[44] DEPARTMENT OF HEALTH. Specialist Services - Health Technical Memorandum 08-01: *Acoustics*. Norwich: The Stationery Office. 2008.

[45] HOPKINS, C. *Sound insulation*. Oxford: Butterworth-Heinemann. 2007.

[46] TINSDEAL, N. J. *The sound insulation provided by windows*. BRE Information Paper IP6/94. Watford: Building Research Establishment. 1994.

[47] DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (Defra). NANR116: Open/Closed Window Research: *Sound insulation through ventilated domestic windows*. London: Defra. 2007.

[48] GREAT BRITAIN. *The Building Regulations 2010. Approved Document F: Ventilation*. 2010 edition (incorporating further 2010 editions). London: NBS. (http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partf/approved#Download).

[49] GREAT BRITAIN. *Building Standards Technical Handbooks 2013 - Section 3: Noise*. Edinburgh: The Scottish Government Building Standards Division. (http://www.scotland.gov.uk/Topics/Built-Environment/Building/Building-standards/publications/pubtech).

[50] NORTHERN IRELAND. Building Regulations (Northern Ireland) 1994. Technical Booklet K: 1998 – *Ventilation*. Belfast: Department of Finance and Personnel Northern Ireland.

[51] TRADA. Wood Information Sheet, Section 1, Sheet 36. *Timber joist and deck floors avoiding movement*. High Wycombe: TRADA, 1995.

[52] CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS (CIBSE). *Guide B5: Noise and vibration control for HVAC*. London: CIBSE. 2002.

[53] ROBUST DETAILS LTD. Section 5 Robust Details (RD) Handbook (Edition 1). Milton Keynes: Robust Details Ltd. 2012.

[54] Scotland Robust Details Handbook. 2012.

[55] GREAT BRITAIN. Town and Country Planning (Assessment of Environmental Effects) Regulations 2011. London: The Stationery Office.

[56] GREAT BRITAIN. Control of Pollution Act 1974 (Part III), as amended. London: The Stationery Office.

[57] GREAT BRITAIN. Environmental Protection Act 1990. London: The Stationery Office.

[58] NORTHERN IRELAND. The Clean Neighbourhoods and Environmental Act (Northern Ireland) 2011. Belfast: The Stationery Office.

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

...making excellence a habit.™

Reference 4

SEL definition

Maximum sound pressure level – L_{Amax}

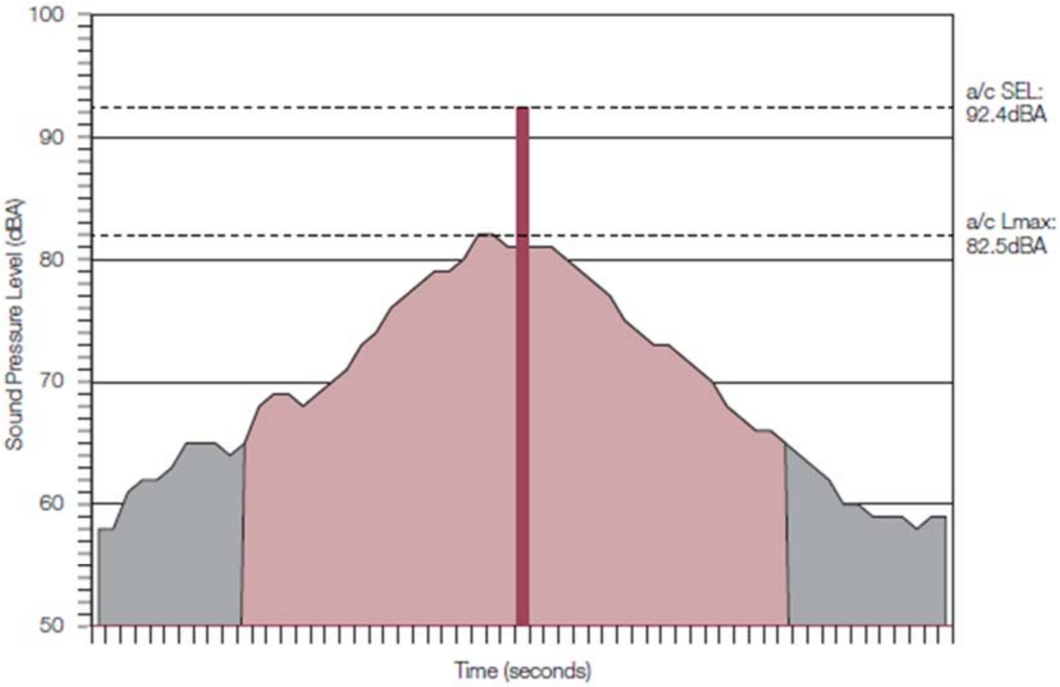
3.13 The simplest measure of a noise event such as the over-flight of an aircraft is the maximum sound level that occurred during the event, measured in dB(A). As the name implies, it is the highest sound level that occurred during the over-flight. The greater the value, the greater the risk of disturbance or intrusion.

Sound Exposure Level – SEL

3.14 The Sound Exposure Level (SEL) of a noise event is the sound level, in dB(A), of a one second burst of steady noise that contains the same total sound energy as the whole event. In other words, it is the value that would be measured if the energy of the entire event were compressed into a constant sound level lasting for one second. This measure combines information about the maximum level and the duration of the event. Figure 3.1 gives an illustration of the time history of an aircraft flyover showing the L_{Amax} and the SEL value.

3.15 For aircraft flyovers, the value of an SEL of an event is always higher than the corresponding L_{Amax}. As a rule of thumb, the numerical difference between SEL and L_{Amax} for aircraft on departure is 10dB(A); and on arrival is 8dB(A).

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



Source: CAA data

40 Most of the sound energy recorded from an aircraft is concentrated in the highest sound levels. This is why the size of the SEL bar in the diagram does not correspond to the size of the sound pressure level of the entire event history.

1. Test arrangements
Acoustic tests are arranged on a sample of residential properties to measure the building both before and after the sound insulation works are carried out.

2. Aircraft noise measurements
Measurements are made in accordance with an International Standard (BS EN ISO 16283-3). This includes simultaneous measurements of aircraft events both outside the house and inside the house. Measurements are made of individual aircraft events. These last around 20-30 seconds. We typically measure around 10 events per room. However, we look for at least 5 measurements of the more typical Easyjet/Whizz flights.

3. Reverberation/echo measurements
Aircraft sound levels inside habitable rooms will vary depending on how much reverberation/echo there is in a room. Aircraft noise levels will sound much lower in a living room with thick carpets, lots of soft furnishings, curtains etc. Aircraft noise will sound higher in a room with hard floor finish, blinds rather than curtains and little furniture. We therefore measure the amount of reverberation in the room and correct the results to the acoustic conditions of a standard habitable room. This enables a like for like comparison.

4. Background measurements
We also must measure and correct for background noise. We need quiet conditions inside homes to measure aircraft noise accurately and residents are helpful at being quiet for our tests. Nevertheless, there will be continuous background sound which interferes with the measurements. This can be from external sources (A1081 and distant M1 noise) or this can be from internal sources (fridge hum). We measure this background noise and correct our results to minimize this effect.

5. Calculations
We calculate the level difference between inside and outside (after correcting for echo/background). This provides a level difference in decibels. Typically, we would expect a performance of around 35 dB for a property treated under the scheme. We present the results of the test using a $D_{at,E,2m,nTw}$ metric. This provides an indication of the difference between inside and out. Therefore, if someone is exposed to 63 dB $L_{Aeq,16h}$ of noise outside then you would expect an internal noise level of 63-35=28 dB inside. This is somewhat of an over-simplification but hopefully provides some context as to the results.

6. Review
The results of the testing provide us with evidence as to whether the installation has “worked”. If the result is poor this may indicate that the windows are not well sealed and/or there is an issue with noise coming into the room from a different path (roof for example). We also carry out visual inspections of the installed windows and vents to see if these have been installed well.

Reference 5

ANC-AVO Residential Design Guide January 2020 v1.1

January 2020

Version 1.1

ACOUSTICS VENTILATION AND OVERHEATING

Residential Design Guide

ANC | ACOUSTICS & NOISE CONSULTANTS

Institute of Acoustics

Foreword

For those acousticians involved in the design of buildings to prevent noise ingress to reasonable internal levels, issues related to overheating of properties and the adverse impacts that may occur have become more prevalent in recent years. This is an area which has been difficult to reconcile with the competing requirements to ensure that properties do not overheat and a requirement to maintain the acoustic integrity of the proposed buildings.

Time and time again we are encountering buildings where even in the winter the occupiers are identifying a need to open the windows on some properties in order to regulate the internal temperatures to a comfortable level. This opening of windows then invariably exposes the occupiers to levels of noise which the acoustic design of the buildings has been trying to avoid.

The Acoustics, Ventilation and Overheating Residential Design Guide provides an approach as to how the competing aspects of thermal and acoustic comfort can be managed. This important publication has taken a long time to complete due to its technical complexities and all of those involved in the process deserve our thanks for the immense time and effort that they have put in to make this a valuable resource for the future.

The Association of Noise Consultants and its member companies is made up of a large number of individual members of the Institute of Acoustics and the Association recognises the immense value that the two organisations working together bring to endeavouring to solve those acoustic and other environmental issues which we encounter on a daily basis.

Graham Parry, ANC President

The need to reconcile what can be competing demands of sound insulation and ventilation has been one of the challenges faced by practitioners in this field for many years. The production of this document now, which brings together guidance on acoustics and ventilation, is particularly timely given the concerns about climate change and the likely need to adapt our approach to design to account for it.

The Acoustics, Ventilation and Overheating Residential Design Guide provides an integrated approach to sustainable design for both thermal and acoustic comfort in our work and living spaces. The advice is needed in this period of increased urbanisation and the growth of heat islands, increased land costs and the demand for housing resulting, at times, in building closer to highways, industrial processes and flight paths than would be otherwise desirable. It should become the key guide for planners, designers, building services engineers, noise control engineers, consultants and regulators dealing with this issue.

It has been prepared by experts from all these sectors and I would like to thank them for volunteering their valuable time and experience in producing this guide, which I am sure will become the first reference point for practitioners.

The Institute of Acoustics gratefully acknowledges the lead taken by the Association of Noise Consultants and is pleased to have been involved in the production of this Guide.

Barry Gibbs, IOA President

Further Work

Many buildings require closed windows to provide good internal acoustic conditions whereas opening a window is the normal way to keep a building cool. These opposing requirements are becoming a major issue in the design of buildings, in particular for housing, especially if we are to avoid the widespread use of mechanical cooling. This document starts to tackle the issue by helping those involved in building design and/or the Planning process to understand the likely degree of noise disturbance when windows are opened. To enable designers and planners to make fully informed decisions, however, requires two further pieces of information. The first is to know how long windows will need to be open, which may be determined from a dynamic thermal model, or more qualitatively from the GHA Overheating Risk Tool. The second requires a better understanding of the potential adverse impact of combined exposure to noise and overheating. Crucially, how long will people tolerate higher noise levels in order to stay cool? One suggestion is to consider the overall average day (16h) and night (8h) time average noise levels. There is some logic to this as we all know that we can tolerate high noise levels for a short duration and moderately high levels for a little longer. But is it that simple? The Association of Noise Consultants wants to work together with natural ventilation experts and thermal modellers to build on the excellent work done to date in creating this Guide so that we can better understand this complex issue and possibly find more effective ways of ventilating and cooling spaces. The ultimate goal is to create cost effective and sustainable buildings where people can live and work in comfort.

TABLE OF CONTENTS

1 Introduction

Acknowledgements

1.1 The guide has been prepared with contributions from members of the Association of Noise Consultants' Acoustics, Ventilation and Overheating (AVO) Group.

1.2 The principal authors of the guide include:

- Anthony Chilton, Max Fordham (Chair of Working Group)
- Andrew Long, Sandy Brown Associates
- David Trew, Bickerdike Allen Partners
- Jack Harvie-Clark, Apex Acoustics
- James Healey, WSP
- Mathew Hyden, Cundall
- Nick Conlan, Apex Acoustics
- Stephen Turner, Stephen Turner Acoustics

1.3 Additional support was provided by the following AVOG committee members:

- Adrian Passmore, Arup
- Barry Jobling, Hoare Lea
- Ian MacArthur, Clarke Saunders Acoustics
- John McCullough, Mid Kent Shared Service
- Juliette Paris-Newton, Robin Mackenzie Partnership
- Mark Scaife, MLM Group
- Michael Swainson, BRE
- Robert Osborne, ANC

Background

1.4 This Acoustics, Ventilation and Overheating Guide ('AVO Guide') is intended to be used by acoustics practitioners as well as all those involved in the planning, development, design and commissioning of new dwellings. It recommends an approach to acoustic assessments for new residential development that take due regard of the interdependence of provisions for acoustics, ventilation, and overheating. Application of the AVO Guide is intended to demonstrate good acoustic design as described in the ProPG: Planning & Noise, May 2017 [1] ('ProPG'), when considering internal noise level guidelines.

1.5 Indoor environmental quality (IEQ) is dependent on air quality (and hence ventilation), thermal comfort and acoustic comfort. These factors are clearly interdependent but, due to lack of guidance, have hitherto typically only been addressed independently. Provisions for both ventilation and mitigation of overheating may include façade openings that permit external noise ingress, and/or mechanical equipment that generates noise. In both cases, there is potential for noise impact. The noise impact itself may be the problem for occupants, or it may lead to consequential action by occupants such as turning off ventilation systems. In modern dwellings with high standards for airtightness such action can have unintended adverse consequences for air quality.

1.6 Previously, the provision of façade sound insulation to protect against outdoor sound has been considered separately from the ventilation strategy and any strategy for mitigating overheating. A review [2] of recent planning applications for major developments in London reveals the problem. Of the applications reviewed, 122 had both noise and overheating assessments; 85% of these developments required closed windows for reasonable noise conditions, while the overheating assessment relied on open windows for reasonable thermal conditions. The result is residential accommodation in which the occupants may choose either acoustic comfort or indoor air quality and thermal comfort, but not achieve both simultaneously.

1.7 The AVO Guide aims to assist designers to adopt an integrated approach to the acoustic design within the context of the ventilation and thermal comfort requirements.

1.8 A requirement to assess and provide mitigation against outdoor sound for a residential development may be invoked through the planning system; thus the local planning authority may be responsible for assessing and enforcing the proposed mitigation. The need for, and provision of adequate ventilation is outlined in building regulations, and therefore managed through the building control system. Although an overheating assessment to inform the design of dwellings is not currently mandatory under The Building Regulations, an assessment may be undertaken to meet planning and/or the developer's requirements. Hence, as well as being undertaken by different designers, the adequacy of the provisions for each aspect of IEQ may be assessed by different bodies and potentially based on different assumptions regarding use of the building.

1.9 The evolution of energy performance requirements under The Building Regulations has led to increased airtightness and enhanced thermal insulation. However, these changes can have unintended consequences. Internal air quality can be poor unless ventilation systems are effective, whereas the efficacy of ventilation systems in leakier buildings was of less consequence. When there is an increased capacity to retain heat, dissipation of excessive heat gains can become more problematic, with the consequential increase in overheating risk. Other factors currently contributing to overheating risk include global heating (climate change) and the urban heat island effect.

1.10 A fragmented design approach results in accommodation that may be uncomfortable to occupants, and hence may be unsustainable. Residual risks for stakeholders include:

- Health & wellbeing risks for occupants
- Design risks for consultants; and
- Legal risks for developers.

1.11 The increasingly urgent need for an integrated approach to consider noise, ventilation, and overheating has been the motivation to produce the AVO Guide. The purpose of this document is to help avoid these risks by delivering accommodation that is comfortable, resilient and sustainable.

Overview of Document

1.12 The AVO Guide includes:

- an explanation of ventilation requirements under The Building Regulations as described in 'Approved Document F – Means of Ventilation, 2010 Edition' [3] ('ADF') along with typical ventilation strategies and associated noise considerations;
- an explanation of the overheating assessment methodology described in CIBSE *'Design methodology for the assessment of overheating risk in homes'* [4] ('TM59');
- potential acoustic scale and guidance relating to different ventilation and overheating conditions, for both environmental noise ingress and building services noise; and
- a worked example of the application of the AVO Guide including indicative design constraints for different ventilation and overheating mitigation strategies.

In the case of environmental noise ingress, a two-level assessment procedure is described for the overheating condition. The first level is a site risk assessment based on external noise levels and the assumption that opening windows are the primary means of mitigating overheating. The second level assessment considers the potential for adverse effect on occupants based on internal ambient noise level.

Scope

1.13 The AVO Guide is intended for the consideration of new residential development that will be exposed predominantly to airborne sound from transport sources, and to sound from mechanical services that are serving the dwelling in question. Other sources of noise, such as noise from industrial, commercial or entertainment premises, and of ground-borne noise and vibration, are outside the scope of the AVO Guide. New apartments, flats and houses are the most common type of new residential development. The approach may also be used for other types of residential development such as residential institutions, care homes etc, although it needs to be remembered that some of the occupants of these types of premises can be more sensitive to indoor environmental conditions.

1.14 The AVO Guide seeks to:

- encourage an assessment of noise that recognises the interdependence between the acoustics, ventilation and overheating designs;
- provide a means of assessment to satisfy the need to consider acoustics, ventilation and overheating at the planning stage;
- assist in educating clients, environmental health/planning officers and other stakeholders of the interdependence of design for acoustics, ventilation and overheating.

1.15 Although the policy coverage is limited to England, the approach may be applicable in other parts of the UK.

1.16 This document assumes the user has general knowledge of acoustics and standard terminology. To assist the reader, a glossary of terminology used throughout this document is provided (see Part 4).

1.17 The external air quality environment may also impact on the ventilation strategy adopted, and influence selected locations for any external air inlets. This aspect is outside the scope of the AVO Guide.

1.18 There are other benefits for occupants from opening windows, such as the connection with the outside, sense of fresh air, experience of draughts when overheating, and sense of control over one's environment. Consideration of these factors is also beyond the scope of the AVO Guide.

Good Acoustic Design

1.19 The ProPG emphasises the importance and principles of good acoustic design; the AVO Guide is intended to contribute to the practice of good acoustic design. It is noted that the over-arching aspiration of good acoustic design is that residents may open windows without any adverse acoustic impact (ProPG paragraph 2.33); where a site layout achieves these conditions, the portion of the AVO Guide relating to environmental noise is not applicable.

1.20 In particular, the paragraphs 2.34 – 2.36 of the ProPG indicate that an integrated design approach must be taken to acoustic, ventilation and thermal comfort conditions:

- Paragraph 2.34: "*design the accommodation so that it provides good standards of acoustics, ventilation and thermal comfort*"
- Paragraph 2.36: "*[where a] scheme is reliant on open windows to mitigate overheating, it is also necessary to consider the potential noise impact during the overheating condition. In this case a more detailed assessment of the potential impact on occupants should be provided in the ADS*".

1.21 In addition, paragraph 2.38 says: "*Where mechanical services are used as part of the ventilation or thermal comfort strategy for the scheme, the impact of noise generated by these systems on occupants should also be assessed*".

1.22 The AVO Guide provides a practical method to address these requirements.

1.23 Good acoustic design may be considered as a component of sustainable design. Other aspects of sustainable design include a response to climate change, in terms of aiming to minimise use of energy and other resources.

1.24 The UK's Committee on Climate Change [5] notes that:

"UK homes are not fit for the future … The quality, design and use of homes across the UK must be improved now to address the challenges of climate change. Doing so will also improve health, wellbeing and comfort…", and *"new homes must be built to be low-carbon, energy and water efficient and climate resilient"*.

1.25 The AVO Guide is essential to fill the gap left between other guidance in achieving comfortable, climate-resilient, sustainable dwellings.

Application of this Guide

1.26 The practical application of the AVO Guide is described in Appendix B. The starting position when considering mitigation of noise impact on new residential development is to apply good acoustic design, site-wide, as described in the ProPG.

1.27 Prior to further developing the design, the acoustician should highlight this to the wider design team/developer. The role of the acoustician is then to assist the team in developing options to suitably control external noise ingress in conjunction with adequate ventilation and mitigation of overheating.

1.28 There is a need to address how:

- The ventilation strategy impacts on the acoustic conditions.
- The strategy for mitigating overheating impacts on the acoustic conditions, and whether a more detailed overheating assessment is required to inform this.

1.29 The guidance in Appendix B aims to:

- help acousticians prepare suitable advice for developers and their design teams so that informed decisions can then be made on how best to progress designs.
- assist local planning authorities to seek evidence of appropriate design details and of post-completion verification, to comply with suitably-worded planning conditions.
- enable a consistent and practical approach to considering noise impact under different ventilation and overheating conditions.
- outline where there is evidence for risks of adverse noise effects and the need for balanced consideration with other aspects of indoor environmental quality when developing the design of new homes.

2 Relevant Legislation and Guidance

2.1 This chapter presents some of the key legislation, policy and guidance relevant to ventilation, overheating and acoustics.

Ventilation

2.2 Guidance on ventilation requirements for dwellings under The Building Regulations is described in Approved Document F ('ADF').

2.3 ADF describes three types of ventilation provision and associated ventilation rates for dwellings. The types of ventilation are summarised in Table 2-1.

2.4 The document then goes on to state that:

"*Ventilation may also provide a means to control thermal comfort but this is not controlled under the Building Regulations*".

However, it is important to differentiate between the need to provide 'purge ventilation' as required occasionally under ADF (i.e. to remove smoke from burnt food etc.); against the provision of ventilation to help control overheating, which is not covered by The Building Regulations.

2.5 ADF provides details of four template '*Systems*' which comply with the ventilation requirements for new dwellings and can be adopted to demonstrate compliance.

2.6 These '*Systems*' are summarised in Table 2-2 and further details are provided in Appendix A. See note to Table 3-1 and notes in paragraphs A.8 and A.9.

Table 2-1 ADF types of ventilation required

Type of ventilation	Definition in ADF	Location/reason for ventilation	Required
Whole Dwelling Ventilation [Note 1]	Whole building ventilation (general ventilation) is nominally continuous ventilation of rooms or spaces at a relatively low rate to dilute and remove pollutants and water vapour not removed by operation of extract ventilation, purge ventilation or infiltration, as well as supplying outdoor air into the building. For an individual dwelling this is referred to as "whole dwelling ventilation".	To provide fresh air to the building and to dilute and disperse residual water vapour not dealt with by extract ventilation as well as removing other pollutants which are released throughout the building.	Continuously
Extract Ventilation	Extract ventilation is the removal of air directly from a space or spaces to the outside. Extract ventilation may be provided by natural means (e.g. by passive stack ventilation) or by mechanical means (e.g. by an extract fan or central system).	From rooms where most water vapour and/or pollutants are released, e.g. due to activities such as cooking or bathing. This is to minimise their spread to the rest of the building.	Continuously or intermittently
Purge Ventilation	Purge ventilation is manually controlled ventilation of rooms or spaces at a relatively high rate to rapidly dilute pollutants and / or water vapour. Purge ventilation may be provided by natural means (e.g. an openable window) or by mechanical means (e.g. a fan).	Throughout the building to aid removal of high concentrations of pollutants and water vapour released from occasional activities such as painting and decorating or accidental releases such as smoke from burnt food or spillage of water.	Occasionally

Note 1 'Whole Dwelling Ventilation' is often confused with 'background ventilation', a term used in the 1995 version of ADF. In the current ADF, the term 'background ventilator' refers to trickle vents.

Table 2-2 ADF template systems

Ventilation system	Provision with ADF system / purpose		
	Whole dwelling ventilation	Extract ventilation	Purge ventilation
System 1: Background ventilators and intermittent extract fans	Background ventilators (trickle vents)	Intermittent extract fans	Typically provided by opening windows
System 2: Passive stack ("natural")	Background ventilators (trickle vents) and passive stack ventilation	Continuous via passive stack	Typically provided by opening windows
System 3: Continuous mechanical extract (MEV)	Continuous mechanical extract – minimum low rate Trickle vents provide inlet air	Continuous mechanical extract – minimum high rate Trickle vents provide inlet air	Typically provided by opening windows
System 4: Continuously mechanical supply and extract with heat recovery (MVHR)	Continuous mechanical supply and extract – minimum low rate	Continuous mechanical supply and extract – minimum high rate	Typically provided by opening windows

Overheating

2.7 There are no specific requirements relating to overheating in The Building Regulations. Both ADF and Approved Document L1A of The Building Regulations briefly mention overheating but do not provide details on what constitutes overheating.

2.8 For the purposes of this document, overheating is taken to mean:

"the phenomenon of excessive or prolonged high temperatures in homes, resulting from internal or external heat gains, which may have adverse effects on the comfort, health or productivity of the occupants." [6]

2.9 TM59 (CIBSE: Design methodology for the assessment of overheating risk in homes) sets out a methodology for predicting temperatures inside dwellings and provides overheating compliance criteria which are discussed in more detail in Appendix A.

2.10 It also provides a standardised approach to predicting overheating using dynamic thermal modelling. TM59 acknowledges that the methodology is necessarily prescriptive to enable it to be consistently applied.

2.11 To undertake the assessment, information on the heat loads, thermal properties of the building construction, weather data and methods of providing ventilation are required.

2.12 Alternative assessment methods such as the Passive House Planning Package [7] (PHPP) may also be suitable for assessing overheating if considered appropriate for the specific project.

2.13 Developments will normally (but not always) require additional ventilation (above ADF whole dwelling ventilation provisions) in order to mitigate overheating. Where an overheating assessment is undertaken, it should provide details as to the duration and rate of any additional ventilation required to meet overheating compliance criteria. Where this additional ventilation is provided passively, the overheating assessment should also provide information about the required size of façade openings.

2.14 See Appendix A2 for a list of output data from an overheating assessment that may be necessary to undertake the acoustic assessment.

2.15 The *Overheating Risk – Early Stage Tool* [8] produced by the Good Homes Alliance may be used to evaluate overheating risk at the stage that the acoustic assessment is carried out.

2.16 An overheating assessment might not always be undertaken for a project and without this information it is difficult to identify noise impacts that may occur during the overheating condition.

Cooling strategies

2.17 A range of design measures can be incorporated into a residential building to control / reduce overheating. A number of these are identified in the London Plan 'Cooling Hierarchy'.

2.18 The London Plan Policy [9] encourages the design of places and spaces to avoid overheating and excessive heat generation, and to reduce overheating due to the impacts of climate change. Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the cooling hierarchy identified. The cooling hierarchy seeks to reduce any potential overheating and also the need to cool a building through active measures. Air conditioning or comfort cooling systems are a very resource intensive form of active cooling, increasing energy use.

2.19 In accordance with sustainable design and construction principles, development proposals should, amongst other things, maximise opportunities to orientate buildings and streets to minimise summer and maximise winter solar gains; use trees and other shading; increase green areas in the envelope of a building, including its roof and environs; and maximise natural ventilation. These sustainable design principles mirror good acoustic design as described in the ProPG. More information is available in paragraph A.19.

2.20 To minimise the risk of overheating in most residential buildings it is normally necessary to use some form of cooling system. The three main methods of providing additional cooling are:

- Passive ventilative cooling – Introducing external air to a space to provide a cooling effect without the use of fans. The most common method is to use open windows but other façade openings can also be used. Note that trickle vents do not enable sufficient airflow to have a significant cooling effect.
- Mechanical ventilative cooling – Using fans to introduce external air to a space to provide a cooling effect. Due to the airflow required, this type of system often involves significant plant and duct size requirements.
- Comfort cooling – Using a mechanical system to cool the air within a space to achieve a user-defined setpoint. This type of system will require some form of mechanical device to cool the air, such as a fan coil unit (FCU).

2.21 A more recently developed alternative to the systems above is a tempered fresh air system. These systems add a small amount of cooling to the whole dwelling ventilation supply system (e.g. to the MVHR). This provides a reduced temperature fresh air supply which can provide some cooling to a space. Unlike comfort cooling, these systems are not designed to achieve a specific temperature in a space.

Acoustics

Current planning policy, regulations and guidance

2.22 Noise management is a devolved issue. This means that, although there are many similarities, different policies and regulations apply in England, Wales, Scotland and Northern Ireland. In England, the overarching policy on noise management is set out in the Noise Policy Statement for England [10] ('NPSE'). The NPSE contains the vision of promoting good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development.

2.23 The NPSE also contains three aims:

"Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- *avoid significant adverse impacts on health and quality of life;*
- *mitigate and minimise adverse impacts on health and quality of life; and*
- *where possible, contribute to the improvement of health and quality of life."*

2.24 In the explanatory note to the NPSE, reference is made to concepts from toxicology that had previously been applied to noise impacts (e.g. by the World Health Organisation). They are:

- No Observed Effect Level (NOEL) which is the level below which no effect can be detected;
- Lowest Observed Adverse Effect Level (LOAEL) which is the level above which adverse effects on health and quality of life can be detected.

2.25 The explanatory note goes on to introduce the concept of a Significant Observed Adverse Effect Level (SOAEL) which is the level above which significant adverse effects on health and quality of life occur.

2.26 Although for both LOAEL and SOAEL, the word 'level' is used, this does not mean that the impact can only be described as an individual noise level or exposure. It could also include factors such as the number of times the noise impact occurs, the duration of the impact, and the time of day the impact occurs. Thus, depending on the circumstance, the noise impact could be managed by reducing how often it occurs rather than just reducing the level of impact when it does occur.

2.27 The NPSE states that it is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times.

2.28 The explanatory note confirms that the first aim of the NPSE states that significant adverse effects on health and quality of life should be avoided while taking account of the guiding principles of sustainable development. The second aim refers to the situation where the impact lies somewhere between LOAEL and SOAEL. To meet this aim requires that all reasonable steps should be taken to mitigate and minimise adverse effects on health and quality of life while also taking into account the guiding principles of sustainable development. The explanatory note goes on to state that this does not mean that such adverse effects cannot occur.

2.29 With regard to land-use planning in England, the relevant policy is primarily set out in the National Planning Policy Framework [11] ('NPPF').

2.30 For noise, the NPPF states that planning policies and decisions should:

"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 so doing they should:

- *Mitigate and reduce to a minimum potential adverse impacts resulting from noise from new development – and avoid noise giving rise to significant adverse impacts on health and quality of life (See Explanatory Note to the Noise Policy Statement for England)"*

2.31 The NPPF also states:

"Planning policies and decisions should ensure that new development can be integrated effectively with existing businesses and community facilities (such as places of worship, pubs, music venues and sports clubs). Existing businesses and facilities should not have unreasonable restrictions placed on them as a result of development permitted after they were established. Where the operation of an existing business or community facility could have a significant adverse effect on new development (including changes of use) in its vicinity, the applicant (or 'agent of change') should be required to provide suitable mitigation before the development has been completed."

2.32 Elsewhere the NPPF states that:

"Planning policies and decisions should contribute to and enhance the natural and local environment by: .....

preventing new and existing development from contributing to, being put at unacceptable risk from, or being adversely affected by, unacceptable levels of soil, air, water or noise pollution or land instability. Development should, wherever possible, help to improve local environmental conditions such as air and water quality, taking into account relevant information such as river basin management plans."

2.33 The implementation of the policies in the NPPF is supported by a suite of web-based guidance, including the Planning Practice Guidance on Noise [12] ('PPG(N)'). It includes a table which summarises the noise exposure hierarchy based on the likely average response. The Noise Exposure Hierarchy is reproduced in Table 2-3.

Table 2-3 Summary of noise exposure hierarchy based on the likely average response (from PPG(N))

Perception	Examples of Outcomes	Increasing Effect Level	Action
Not present	No Effect	No Observed Effect	No specific measures required
Present and not intrusive	Noise can be heard, but does not cause any change in behaviour or attitude. Can slightly affect the acoustic character of the area but not such that there is a perceived change in the quality of life.	No Observed Adverse Effect	No specific measures required
		Lowest Observed Adverse Effect Level	
Present and intrusive	Noise can be heard and causes small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a perceived change in the quality of life.	Observed Adverse Effect	Mitigate and reduce to a minimum
		Significant Observed Adverse Effect Level	
Present and disruptive	The noise causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.	Significant Observed Adverse Effect	Avoid [Note 1]
Present and very disruptive	Extensive and regular changes in behaviour and/or an inability to mitigate effect of noise leading to psychological stress or physiological effects, e.g. regular sleep deprivation/awakening; loss of appetite, significant, medically definable harm, e.g. auditory and non-auditory.	Unacceptable Adverse Effect	Prevent

2.34 The PPG(N) makes it clear that noise can override other planning concerns, where justified, although it is important to look at noise in the context of the wider characteristics of a development proposal, its likely users and its surroundings, as these can have an important effect on whether noise is likely to pose a concern. [See Footnote]

2.35 In clarifying how the term 'the context of Government policy on sustainable development' should be interpreted, some assistance can be obtained from the Government decision letter associated with the Thames Tideway Tunnel project. In that letter, it is stated that:

"The National Planning Policy Framework, the National Planning Practice Guidance on noise and the Noise Policy Statement for England are all clear that noise management should be determined in the context of sustainable development including the environmental, economic and social benefits of the proposal."

2.36 The PPG(N) states that local authority planning policies can include noise standards which apply to various forms of proposed development and locations in their area. The PPG(N), however, states that care should be taken to avoid these standards from being applied as rigid thresholds as specific circumstances may justify some variation being allowed.

2.37 Furthermore, as mentioned above, the explanatory note to the NPSE states that the policy does not mean that adverse effects arising from noise cannot occur.

2.38 Not all development is required formally to seek planning consent from the relevant Local Planning Authority (LPA). Some proposals fall under the terms of Permitted Development Rights (PDR). The definition of those developments which can be promulgated under PDR is set out in Statutory Instrument 2015/596. This order was amended by SI 2016/332 requiring that, in the case of a change of use of offices to dwelling houses:

"the developer must apply to the LPA for a determination as to whether the prior approval of the authority will be required as to….impacts of noise from commercial premises on the intended occupiers of the development."

2.39 In SI 2016/332, commercial premises are defined as:

"any premises normally used for the purpose of any commercial or industrial undertaking which existed on the date of the application, and includes any premises licensed under the Licensing Act 2003 or any other place of public entertainment."

2.40 This definition means that there is no formal requirement for a developer to determine whether prior approval is needed regarding any noise from transportation sources affecting such a change of use. However, it may be in the interests of the developer to consider the transportation noise impacts and the associated ventilation/overheating issues with such a change of use.

2.41 For Nationally Significant Infrastructure Projects promulgated under the Planning Act 2008, the relevant policy is set out in the topic specific National Policy Statements (NPS). For noise, the policies in the various NPSs reflect the NPSE.

Guidance on the effects of noise

2.42 As indicated in the NPSE, objective values associated with SOAEL will depend on the specific circumstances. More information can be derived for values associated with LOAEL from existing guidance. Relevant examples are set out below.

BS 8233:2014 [13]

2.43 This standard provides a wide range of guidance regarding sound insulation and noise reduction in buildings. In the Foreword, it states that:

"As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it."

2.44 BS 8233:2014 states that,

"for steady external noise sources, it is desirable that the internal ambient noise level does not exceed the guidelines values in Table 4."

Footnote - When stating that noise can override other planning concerns, the original version of the PPG(N) stated that neither the NPSE nor the NPPF expects noise to be considered in isolation, separately from the economic, social and other environmental dimensions of proposed development. This is still the case.

2.45 Table 4 from BS 8233:2014 is reproduced in Table 2-4. Some local authorities have used these values to represent LOAEL as far as applying the policy in the NPPF and NPSE is concerned for that situation.

Table 2-4 Desirable indoor ambient noise levels for dwellings (reproduced from Table 4 of BS 8233:2014)

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

2.46 These levels are accompanied by various notes including:

- The levels are based on existing guidelines issued by the World Health Organisation [14] and assume normal diurnal fluctuations in external noise;
- The levels are based on annual average data and do not have to be achieved in all circumstances. For example, it is normal to exclude occasional events such as fireworks night and New Year's Eve;
- If relying on closed windows to meet the guide values, there needs to be an appropriate alternative ventilation that does not compromise the façade insulation or resulting noise level. If applicable, any room should have adequate ventilation (e.g. trickle ventilators should be open) during assessment;
- Where a development is considered necessary or desirable, the levels in Table 2-4 may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

2.47 BS 8233:2014 also sets out the maximum steady noise levels that can permit reliable speech communication. These are reproduced in Table 2-5.

Table 2-5 Maximum steady noise levels for reliable speech communication (reproduced from Table 7 of BS 8233:2014)

Distances between talker and listener (m)	Noise Level (dB(A))	
	Normal Voice	Raised Voice
1	57	62
2	51	56
4	45	50
8	39	44

2.48 The values from this table can be used to estimate the extent of the impact on speech communication from the internal noise levels.

ProPG: Planning & Noise 2017

2.49 The ProPG was prepared in 2017 by a group comprising members representing the Chartered Institute of Environmental Health (CIEH), the Institute of Acoustics (IOA) and the Association of Noise Consultants (ANC).

2.50 This document provides technical guidance on how to assess the impact of transportation noise on new residential development. It is designed to assist with the implementation of existing planning policy.

2.51 The ProPG promotes the use of 'Good Acoustic Design' as a primary noise management measure to optimise the acoustic environment that would be experienced by the residents. It recognises that there will be some situations where there would be a need to rely on closed windows and associated ventilation in order to achieve the desired acoustic outcome. In that situation it states that:

"special care must be taken to design the accommodation so that it provides good standards of acoustics, ventilation and thermal comfort without unduly compromising other aspects of the living environment. In such circumstances, internal noise levels can be assessed with windows closed but with any façade openings used to provide "whole dwelling ventilation" in accordance with Building Regulations Approved Document F (e.g. trickle ventilators)."

2.52 The document also states that:

"It should also be noted that the internal noise level guidelines are generally not applicable under "purge ventilation" conditions as defined by Building Regulations Approved Document F, as this should only occur occasionally (e.g. to remove odour from painting and decorating or from burnt food)."

2.53 The document continues

"In addition to providing purge ventilation, open windows can also be used to mitigate overheating. Therefore, should the LPA accept a scheme is to be assessed with windows closed, but this scheme is reliant on open windows to mitigate overheating, it is also necessary to consider the potential noise impact during the overheating condition. In this case a more detailed assessment of the potential impact on occupants should |be provided in the ADS [Acoustic Design Statement]*."*

2.54 The aim of this document is to assist the acoustician making this more detailed assessment.

2.55 ProPG concludes that:

"It should be noted that overheating issues will vary across the country and any specific design solutions will need to be developed alongside advice from energy consultants."

2.56 The ProPG is referenced in the PPG(N) as a document published by other organisations which may be of assistance.

WHO Environmental Noise Guidelines for the European Region [15] (WHO 2018)

2.57 This document has been produced with two key objectives:

- *"In the general population exposed to environmental noise, what is the exposure–response relationship between exposure to environmental noise (reported as various indicators) and the proportion of people with a validated measure of health outcome...*
- *In the general population exposed to environmental noise, are interventions effective in reducing exposure to and/or health outcomes from environmental noise?"*

2.58 The document also provides recommendations regarding external noise exposures that should be achieved to protect human health.

2.59 The noise sources covered by these guidelines are road traffic, rail traffic, aircraft and wind turbines. Recommendations are also provided regarding leisure noise.

2.60 The document is clear that the recommended values are not LOAELs and that meeting the recommended values would not protect every person affected. The document does, however, state that the *"GDG [Guideline Design Group of WHO] stresses that the aim of the current guidelines is to define an exposure level at which effects certainly begin"*.

2.61 The document also states that

"The current environmental noise guidelines for the European Region supersede the CNG from 1999 [WHO 1999]. Nevertheless, the GDG recommends that all CNG indoor guideline values and any values not covered by the current guidelines (such as industrial noise and shopping areas) should remain valid. Furthermore, the current guidelines complement the NNG from 2009."

WHO Night Noise Guidelines for Europe [16]

2.62 Within these guidelines it is stated that $L_{night,outside}$ 40 dB is equivalent to the LOAEL for night noise.

2.63 The guidelines also suggest that $L_{night,outside}$ above 55 dB represents a situation that is considered increasingly dangerous for public health.

Individual Noise Events

2.64 The WHO Night Noise Guidelines (2009) state that:

"The 1999 guidelines are based on studies carried out up to 1995 (and a few meta-analyses some years later). Important new studies (Passchier-Vermeer et al., 2002; Basner et al., 2004) have become available since then, together with new insights into normal and disturbed sleep. New information has made more precise assessment of exposure-effect relationship. The thresholds are now known to be lower than L_{Amax} of 45 dB for a number of effects."

2.65 More recent research [17, 18], some of which is contained within ProPG, has examined the probability of additional awakenings caused by individual noise events.

2.66 This approach combines the number of events and the maximum level of those events inside the bedroom. It may be possible to use this approach to evaluate a SOAEL in relation to individual noise events, albeit in the context of the development under consideration.

Dose Response Relationship

2.67 As required by policy, any acoustic guidelines should not be regarded as fixed thresholds. In reality, there is a continuous relationship between the noise level and the resulting effects. WHO 2018 present dose-response relationships between environmental noise and effects on humans including annoyance, sleep disturbance and other health effects derived from systematic reviews of the evidence.

All Party Parliamentary Group for Healthy Homes and Buildings – White Paper (October 2018) [19]

2.68 The publication of this document followed the gathering of evidence from various sources including the Institute of Acoustics and the HEMAC [Health Effects of Modern Airtight Construction network] Noise Group. One of the recommendations in the white paper states:

"Maximising the occupant's health and wellbeing must be placed at the centre of housing and building design and a holistic approach should be taken including elements of safety, space, energy efficiency, ventilation, heating, noise, air quality and lighting."

3 Internal Ambient Noise Level Guidelines

3.1 This chapter presents guidance regarding indoor ambient noise levels in new residential development that will be exposed predominantly to airborne sound from transport sources, and to sound from mechanical systems serving the development.

3.2 The contribution to internal noise levels from transport sources and from mechanical services are considered separately and independently, because there is evidence [20] that occupants have a different tolerance to each. The next Section considers transport noise sources and the subsequent Section considers mechanical services noise.

3.3 Where there are other requirements to manage the total internal noise exposure there will be a need to consider how the level due to transportation sources combines with that due to mechanical services and there may be a requirement to set separate lower limits for each component.

3.4 For both sources of noise, the guidance makes a clear distinction between provisions for fresh air to achieve whole dwelling ventilation rates ('ADF ventilation condition'), and provisions for ventilative cooling to mitigate overheating ('overheating condition').

3.5 In terms of noise effect, the important distinction between these two situations is that the ADF ventilation condition applies for the entire time whereas the overheating condition applies only for part of the time.

3.6 In the case of noise from mechanical services, the guidance for the overheating condition makes reference to existing guidance documents. In the case of noise from transport sources, there is no appropriate existing guidance for the overheating condition. Instead, the guidance presented here considers the suitability of higher internal ambient noise levels in terms of the effect on occupants.

3.7 In the case of noise from transport sources, a two level assessment procedure is described for the overheating condition as summarised in Figure 3-1. Level 1 is a site risk assessment based on external noise levels and the assumption that opening windows are the primary means of mitigating overheating. Based on the Level 1 indication of risk, a subsequent Level 2 assessment may be required. The Level 2 assessment considers the potential for adverse effect on occupants based on internal ambient noise level.

3.8 Where Tables 3-2 and 3-3 indicate different categories, these should not be regarded as fixed thresholds and reference can also be made to relevant dose-response relationships [15, 18].

Internal Ambient Noise Levels due to Transport Noise Sources

Introduction

3.9 It is suggested here that the desirable internal noise standards within Table 4 of BS 8233:2014 should be achieved when providing adequate ventilation as defined by ADF whole dwelling ventilation. However, it is considered reasonable to allow higher levels of internal ambient noise from transport sources when higher rates of ventilation are required in relation to the overheating condition.

3.10 The basis for this is that the overheating condition occurs for only part of the time. During this period, occupants may accept a trade-off between acoustic and thermal conditions, given that they have some control over their environment. In other words, occupants may, at their own discretion, be more willing to accept higher short-term noise levels in order to achieve better thermal comfort. The importance of control is relevant to daytime exposure, but not to night time exposure where the consideration is sleep disturbance.

3.11 It is important to note that there is no specific research available to support this view regarding human response to combined exposure to heat and noise. However, the notion that control over one's environment moderates the response to exposure is well established in the field of thermal comfort, and underpins the adaptive thermal comfort model.

3.12 The suitability of higher internal ambient noise levels in the case of the overheating condition has been considered in terms of various effects such as:

- Daytime annoyance
- Daytime interference with activities (conversation/telephone)
- Night-time sleep disturbance (using average noise level parameters such as L_{Aeq})
- Night-time sleep disturbance (using parameters for individual noise events L_{Amax} /SEL).

3.13 The values in Table 3-2 are based on the assumption of a 13 dB difference between external free-field noise levels and internal ambient noise levels. Refer to paragraph 3.24 for further discussion.

3.14 Table 3-2 suggests that a Level 2 assessment is not required in situations where it is expected that reasonable internal conditions, described in ProPG as BS 8233 levels relaxed by up to 5 dB, will be achieved.

3.15 For the daytime period, the upper category in Table 3-3 is defined on the basis that $L_{Aeq,T}$ 50 dB represents the upper end of the range for reliable speech communication.

3.16 For the night-time period, the upper category in Table 3-3 is defined with reference to the WHO Night Noise guidelines, which state that for external levels above $L_{Aeq,T}$ 55 dB:

"*adverse health effects occur frequently and a sizeable proportion of the population is highly annoyed and sleep-disturbed*".

3.17 The individual noise event L_{max} value associated with the upper category in Table 3-3 refers to the level that has been shown in Basner et al [17] to result in longer duration awakenings that are more likely to be remembered the next day. The paper states that *"from a medical point of view, recalled awakenings …should be prevented as much as possible"*. It is noted that the paper uses the $L_{AS,max}$ metric, whereas $L_{AF,max}$ is used here. Given that $L_{AF,max}$ is typically between 1dB and 4dB higher than $L_{AS,max}$, this is a conservative amendment. Refer to references [1, 17, 18, 22] for further guidance regarding individual noise events.

3.18 In the case of the overheating condition, the effect of increased internal ambient noise from external noise sources will depend both on the absolute noise level and the amount of time for which the overheating condition occurs. A good design process should therefore, as a priority, seek to minimise heat gains thereby reducing the amount and duration of ventilation required to control overheating and the consequential effect from increased ingress of noise.

3.19 No quantitative guidance regarding the combined effect of level and duration for the overheating condition is included in the current version of this document. However, the situation is summarised qualitatively in Figure 3-2 and also addressed in the worked examples included in Appendix B.

3.20 Appropriate research work is urgently needed to better inform the guidance for the overheating condition.

Approved Document F (ADF) Ventilation Condition

3.21 Recommendations for desirable internal ambient noise levels for ADF ventilation conditions are set out in Table 3-1.

Overheating Condition

3.22 A two-level assessment procedure is recommended to estimate the potential impact on occupants in the case of the overheating condition. Refer to Figure 3-1.

3.23 The Level 1 site risk assessment is based on external free-field noise levels and the assumed scenario where a partially open window is used to mitigate overheating. The Level 1 assessment is sufficient for developments on 'Negligible' risk sites (as defined by Table 3-2). The Level 2 assessment is recommended for 'High' risk sites. For 'Low' and 'Medium' risk sites, a Level 2 assessment can optionally be undertaken to give more confidence regarding the suitability of internal noise conditions. This may be particularly appropriate for sites in the 'Medium' risk category.

3.24 For the purposes of the Level 1 assessment, it is assumed that a partially open window will provide an outside-to-inside level difference of 13 dB. This level difference is considered representative of typical domestic rooms with simple façade openings of around 2% of the floor area. Refer to Table B-4 and Appendix C for further information.

3.25 The outside-to-inside level difference for a partially open window is related to the window opening area, type and orientation in respect of directional noise sources. This is likely to differ from project-to-project and would require due consideration as part of a Level 2 assessment. A 13 dB correction ought not to be automatically taken as appropriate for all cases.

3.26 The Level 2 assessment suggests that assessment of the adverse effect from noise exposure should include an estimate of how frequently and for what duration the overheating condition occurs. Reference should be made to Figure 3-2 and the worked examples included in Appendix B.

3.27 The noise levels suggested in Tables 3-2 and 3-3 assume a steady road traffic noise source but may be adapted for other types of transport by taking account of the differing responses to different transport sources.

Table 3-1 Indoor Ambient Noise Levels resulting from transport noise sources - ADF ventilation condition

Ventilation condition	Operational condition of System	Desirable internal ambient noise level from transport noise sources
Part F - Whole dwelling ventilation	Systems 1 & 2: Background ('trickle') ventilators open to provide whole dwelling ventilation in the winter period. Additional ventilation required at other times of the year – windows are assumed to be ajar for assessment [Note 2].	Guideline values from Table 4 of BS 8233:2014.
	System 3: Continuous mechanical extract with background ('trickle') ventilators open [Note 2].	
	System 4: Continuous mechanical supply and extract with heat recovery (MVHR) – no trickle vents required.	
Part F – Purge Ventilation [Note 1]	Option 1: Opening external window(s) meeting requirements described in Appendix B of Part F.	No specific acoustic criterion needs to be met in a room using purge ventilation for the purpose of rapidly diluting indoor pollutants.
	Option 2: Manually controlled fan extracting 4 air changes per hour.	

Note 1 ADF has a clearly defined objective definition of purge ventilation to rapidly dilute pollutants and/or water vapour for indoor air quality purposes. This is defined as 4 air changes per hour in Appendix A of the Approved Document. This is used for occasional activities such as painting and decorating or accidental releases such as smoke from burnt food or spillage of water. Provisions for purge ventilation can also be used to improve thermal comfort. This is not controlled under the Building Regulations. Purge ventilation may form one part of a design strategy to control the risk of overheating. The level of ventilation required to control overheating will depend on the details of the individual room and dwelling and can be different than the 4 air changes per hour required to dilute pollutants/water vapour. See Table B-4. When using provisions for purge ventilation (eg opening windows) to mitigate overheating, refer to Tables 3-2 and 3-3.

Note 2 For Systems 1 and 2, the background ventilators are sized for the winter period as described in Tables 5.2a, b of ADF. For Systems 3 and 4, the systems are sized for the winter period. If additional ventilation is required to control excess humidity in warmer months, appropriate consideration should be given to the resulting internal ambient noise levels under this condition.

Figure 3-1 Two-level noise assessment procedure - overheating condition

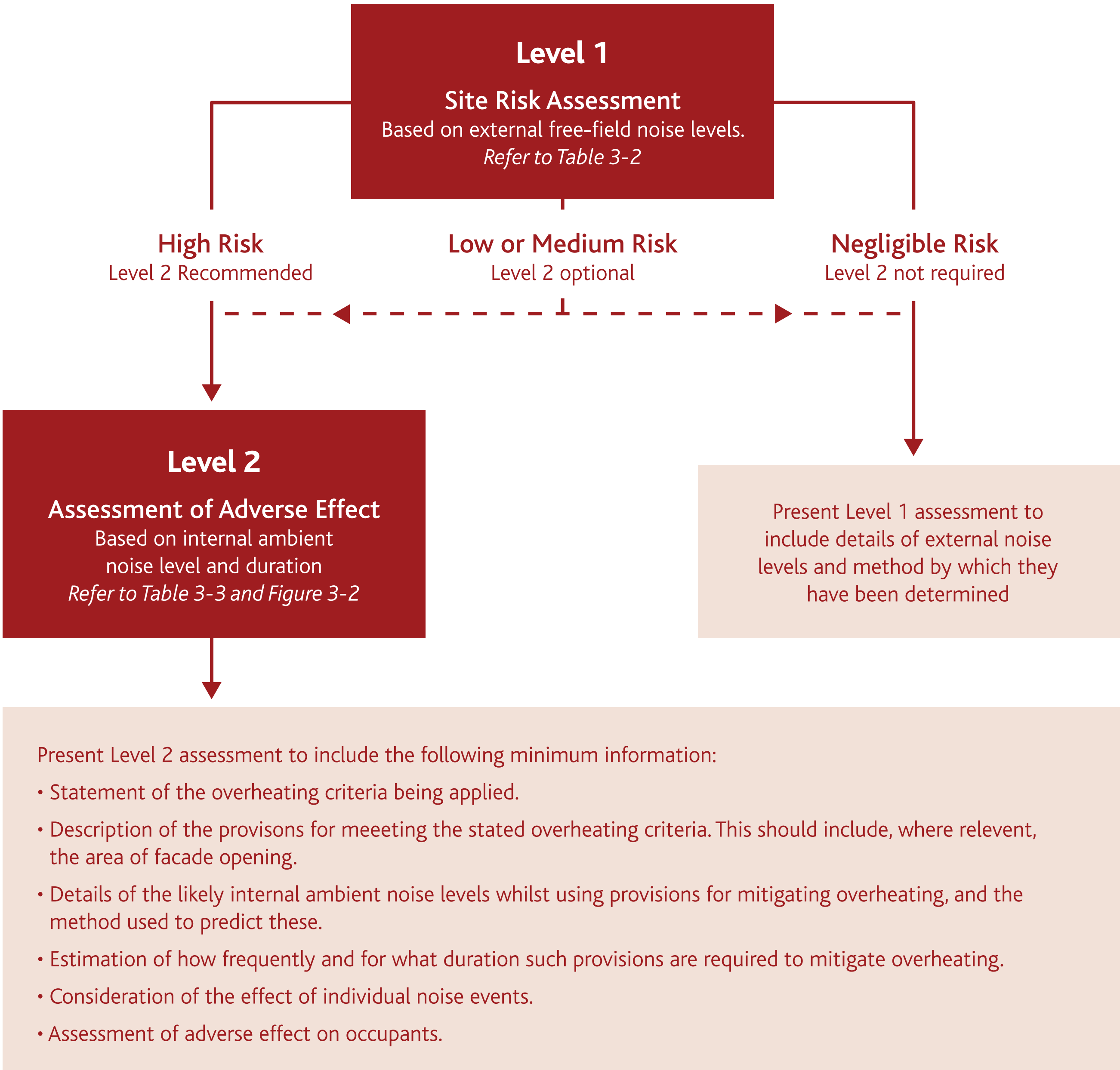


Table 3-2 Guidance for Level 1 site risk assessment of noise from transport noise sources [Note 1] relating to overheating condition

Risk category for Level 1 assessment [Note 5]: $L_{Aeq, T}$ [Note 3] during 07:00 - 23:00	Risk category	$L_{Aeq, 8hr}$ during 23:00 - 07:00	Potential Effect without Mitigation	Recommendation for Level 2 assessment
65 dB	High	55 dB	Increasing risk of adverse effect	Recommended
60 dB	Medium		Increasing risk of adverse effect	Optional
55 dB	Low	50 dB	Increasing risk of adverse effect	Optional
50 dB	Negligible	45 dB	Use of opening windows as primary means of mitigating overheating is not likely to result in adverse effect	Not required

Note 1 The noise levels suggested assume a steady road traffic noise source but may be adapted for other types of transport. All levels are external free-field noise levels.

Note 2 The values presented in this table should not be regarded as fixed thresholds and reference can also be made to relevant dose-response relationships, [15, 17].

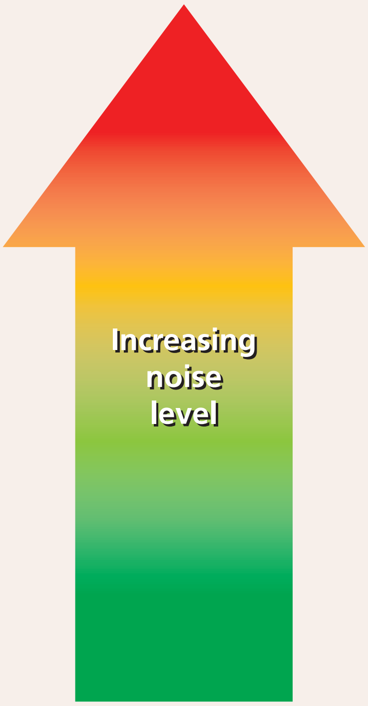
Note 3 A decision must be made regarding the appropriate averaging period to use. The averaging period should reflect the nature of the noise source, the occupancy profile and times at which overheating might be likely to occur. Further guidance can be found within the 2014 IEMA Guidelines [23].

Note 4 Refer also to references [1, 17, 18, 22] for further guidance regarding individual noise events. Where 78dB LAFmax is normally exceeded during the night-time period (23:00-07:00), a Level 2 assessment is recommended.

Note 5 The risk of an adverse effect occurring will also depend on how frequently and for what duration the overheating condition occurs. Refer to Figure 3-2.

Note 6 To evaluate the risk category for a dwelling, all three aspects of external noise exposure (i.e. daytime, night-time and individual noise events) should be evaluated. The highest risk category for any of the three aspects applies.

Table 3-3 Guidance for Level 2 assessment of noise from transport noise sources[Note 1] relating to overheating condition

Internal ambient noise level [Note 2]			Examples of Outcomes [Note 5]	
$L_{Aeq,T}$ [Note 3] during 07:00 – 23:00 [Note 6]	$L_{Aeq,8h}$ during 23:00 – 07:00	Individual noise events during 23:00 – 07:00 [Note 4]		
> 50 dB	> 42 dB	Normally exceeds 65 dB $L_{AF,max}$	Noise causes a material change in behaviour e.g. having to keep windows closed most of the time	Avoiding certain activities during periods of intrusion. 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.
			Increasing likelihood of impact on reliable speech communication during the day or sleep disturbance at night	At higher noise levels, more significant behavioural change is expected and may only be considered suitable if occurring for limited periods. As noise levels increase, small behaviour changes are expected e.g. turning up the volume on the television; speaking a little more loudly; having to close windows for certain activities, for example ones which require a high level of concentration. Potential for some reported sleep disturbance. Affects the acoustic environment inside the dwelling such that there is a perceived change in quality of life. At lower noise levels, limited behavioural change is expected unless conditions are prevalent for most of the time. [Note 8]
≤ 35 dB	≤ 30 dB	Do not normally exceed $L_{AF,max}$ 45 dB more than 10 times a night	Noise can be heard, but does not cause any change in behaviour	Noise can be heard, but does not cause any change in behaviour, attitude, or other physiological response[Note 9]. Can slightly affect the acoustic character of the area but not such that there is a perceived change in the quality of life.

Note 1 The noise levels suggested in Tables 3-2 and 3-3 assume a steady road traffic noise source but may be adapted for other types of transport.

Note 2 The values presented in this table should not be regarded as fixed thresholds and reference can also be made to relevant dose-response relationships such as those described in a DEFRA 2014 study [15, 21, 22]. With the exception of individual noise events, the references [15,21] are based on evidence drawn from *external* noise levels. There is currently very little robust evidence linking *internal* averaged noise levels with health outcomes and occupant behaviour. Internal ambient noise levels would normally be considered for living rooms and bedrooms during the daytime. At night, the levels would normally only be applicable to bedrooms.

Note 3 A decision must be made regarding the appropriate averaging period to use. The averaging period should reflect the nature of the noise source, the occupancy profile and times at which overheating might be likely to occur. Further guidance can be found within the 2014 IEMA Guidelines.

Note 4 Refer to references [1, 17, 18, 22] for further guidance regarding individual noise events. The $L_{AF,max}$ indicator associated with the upper category is intended for road traffic; it may be more appropriate to use the "one additional noise-induced awakening" method for noise from rail traffic or aircraft.

Note 5 The potential for adverse effect will also depend on how frequently and for what duration the overheating condition occurs. Refer to Figure 3-2.

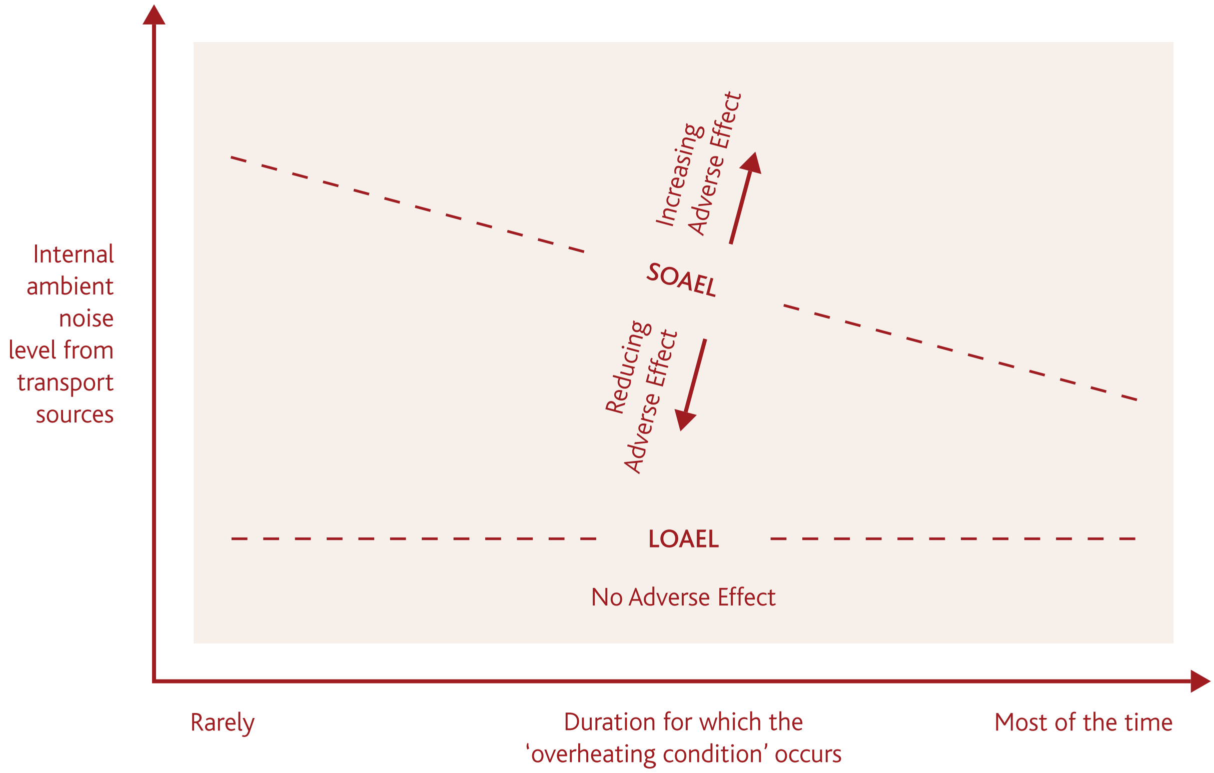
Note 6 The daytime levels presented in this table may not be appropriate for residential care homes or other situations where conditions for daytime resting are known to be of particular importance.

Note 7 When evaluating the potential for adverse effect, all three aspects of noise exposure (i.e. daytime, night-time and individual noise events) should be evaluated.

Note 8 BS 8233 states that where development is considered necessary or desirable, the internal target levels may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

Note 9 It is known that physiological responses do occur at lower levels of L_{AFmax} than 45 dB.

Figure 3-2 Qualitative guidance on combined effect of internal ambient noise level and duration for the overheating situation



Internal Ambient Noise Levels from Mechanical Services

Introduction

3.28 Human hearing response, annoyance and the health-related effects of noise are of primary concern when considering building services noise in dwellings. Research [20], [24], [25], [26], [27], [28] demonstrates that occupants will adjust mechanical ventilation systems to a level of noise that is tolerable, or disable it entirely. Either of these actions result in insufficient ventilation; the adverse effects of this include poor indoor air quality for the occupants in airtight dwellings.

3.29 While these studies are examples of how occupants respond to the noise from the equipment, the actual noise levels or the character of the noise that people may tolerate are not well documented in the literature. The guidance values in this chapter assume steady noise levels without distracting characteristics.

3.30 ADF suggests that to ensure good acoustic conditions, the noise levels within living rooms and bedrooms should not exceed $L_{Aeq,T}$ 30 dB for mechanical systems operating at the whole dwelling ventilation rate. It is included as additional commentary within the document and is not a mandatory requirement. This originates from the BS 8233:1999 [29] noise limits for noise ingress and the levels for living rooms are lower than those within CIBSE Guide A 2015 [30] and Sound Control for Homes [31] guidance.

3.31 Evidence [20] indicates that *"a more prudent limit for mechanical services noise around 24 – 26 dB(A) is likely to be required to prevent an adverse reaction from most occupants while falling asleep."*

3.32 A summary of the proposed noise levels from various guidance is provided in Appendix A.

3.33 There is very little information relating to mechanical ventilative cooling. Comfort cooling is more commonly used and its operation can be complex, with a combination of cooling options with associated airflow rates and noise levels.

Approved Document F (ADF) Ventilation Condition

3.34 Recommendations for desirable internal ambient noise levels for ADF ventilation conditions are set out in Table 3-4.

Table 3-4 Indoor ambient noise levels from mechanical services - ADF ventilation condition

Ventilation condition	Possible system or design solution	Desirable internal ambient noise levels from mechanical services
ADF – Whole Dwelling Ventilation	System 3: Continuous mechanical extract (MEV), minimum low ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum low ventilation rates	Bedrooms ≤ L_{Aeq} 26 or 30 dB [Note 1] Living Rooms ≤ L_{Aeq} 30 dB
ADF – Extract Ventilation	System 1: Intermittent extract fans System 3: Continuous mechanical extract (MEV), minimum high ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum high ventilation rates	Bedrooms ≤ L_{Aeq} 26 or 30 dB Living / Dining Rooms ≤ L_{Aeq} 35 dB Bathroom / WC / Kitchen ≤ L_{Aeq} 45 dB
ADF – Purge Ventilation	Manually controlled fan exchanging a minimum 4 air changes per hour	No desirable noise levels are currently proposed based on the lack of evidence of acceptable noise levels when providing purge ventilation for the purpose of rapidly diluting indoor pollutants.

Note 1 A lower level may be more appropriate; refer to paragraph 3.31.

Overheating Condition

3.35 The use of mechanical systems to control overheating could include systems which provide ambient air at high ventilation rates (ventilative cooling) or systems which provide cooled air, commonly referred to as comfort cooling systems. Refer to paragraphs 2.20 and 2.21 for further details.

3.36 These systems would normally be occupant controlled, but there may be options for automation.

3.37 Recommendations for desirable internal ambient noise levels for overheating conditions are set out in Table 3-5.

Table 3-5 Indoor ambient noise levels from mechanical services - Overheating condition

Possible system or design solution	Desirable upper internal ambient noise levels from mechanical services
Ventilative cooling or Comfort cooling	Bedrooms L_{Aeq} 30 (± 5) dB Living / Dining Rooms L_{Aeq} 35 (± 5) dB

3.38 The desirable noise levels shown in Table 3-5 are based on systems which are operated to meet the design conditions to control overheating.

3.39 Section 1.10.10 of CIBSE Guide A 2015 states that the values are only a guide and that:

"Higher or lower values may be appropriate based on economics, space use, user needs etc."

3.40 It goes on to state that a range of +/- 5 dB may be acceptable depending on the particular situation.

3.41 The duration, how frequently they occur, degree of occupant control and magnitude of the noise levels associated with the overheating condition should be taken into consideration when establishing suitable noise levels.

3.42 Higher noise levels, e.g. 5 or 10 dBA higher (refer to BS ISO 17772-1 [32] are likely to be acceptable in some operating scenarios, where rapid changes to the cooling or ventilation rates quickly improve the thermal comfort of the occupant.

3.43 Equally, lower noise levels may be appropriate for some types of residential development.

3.44 When considering variations to the proposed desirable levels, the classification system from Cost Action TU0901 [33] and default design values from BS EN 15251 [34] may be used as a guide.

4 Glossary

Acoustic terminology

Noise	Typically defined as unwanted, unpleasant or disturbing sound.
Frequency (Hz)	The number of oscillations in acoustic pressure per second. It represents the 'tone' of the sound. Often determined in octave bands.
Maximum sound pressure level (L_{AFmax})	The maximum or highest sound pressure level measured with a 'fast' time weighting.
Equivalent continuous sound pressure level ($L_{eq,T}$)	The average of the total sound energy over a specified time period (T). L_{eq} represents the equivalent sound level that a fluctuating source would have compared to a steady source with the same total sound energy over a specific time period. Commonly used as a descriptor of human perception of sound over time.
'A' weighting	Frequency-dependent weighting based on the response of the human auditory system which has been found to correlate well with the subjective response to sound. Denoted by the use of the letter 'A'. For example, dBA denotes an 'A' weighted sound level in decibels, or L_{Amax} denotes an 'A' weighted maximum sound pressure level.
Internal Ambient Noise Level (IANL)	The noise level within a room or enclosed space. Usually determined as an equivalent continuous sound pressure level over a specific time period ($L_{Aeq,T}$, dB).
Noise Rating (NR) curve	A single figure term used to reflect the spectral frequency content of noise. Although originally proposed to assess environmental noise, NR curves are now typically used to describe noise from mechanical ventilation systems in buildings.
$L_{night,outside}$	The incident external A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year, in which the night is eight hours between 23:00 and 07:00.

Other terms

AVO	Acoustics, Ventilation, Overheating (e.g. AVO Guide, AVO Group).
ADF	Approved Document F.
Overheating condition	The situation where measures are in place to mitigate overheating to meet agreed compliance criteria.
Dynamic thermal modelling	A technique that can be used to simulate internal temperatures in dwellings before they are built.
Heat recovery	The process of using warm air extracted from the room to heat incoming colder air before it is supplied to the room, thereby reducing the ventilation heat-losses.
Ventilative cooling	Cooling by means of introducing external ambient temperature air at a high ventilation rate. Can be either passive (no fans) or mechanical (with fans).
Purge ventilation	Ventilation to aid removal of high concentrations of pollutants and water vapour released from occasional activities such as painting and decorating or accidental releases such as smoke from burnt food or spillage of water.
Comfort cooling	Cooling by means of a refrigerant cycle. This would include 'air conditioning' systems and the use of fan coil units (FCUs).
FCU	Fan coil unit.
MEV	Mechanical extract ventilation.
MVHR	Mechanical ventilation with heat recovery.
IEQ	Internal Environmental Quality, typically considering the internal environmental conditions for light, sound, thermal comfort and air quality.
Free area, A_f	The measurable, cross-sectional, geometric area of an opening. This should not be used for comparing the air-flow performance of elements because this will also be dependent on factors such as depth (length of air-path), surface roughness and tortuosity. Refer to [56] for further information.
Effective area, A_{eff}	Defined as the product of the free area and discharge coefficient, this is the preferred parameter for comparing the air-flow performance of elements. Refer to [56] for further information.
Equivalent area, A_{eq}	The area of a sharp-edged, circular orifice that gives the same flow rate as the actual opening at a given pressure-difference. In other words, the free-area of a notional circular hole made in an infinitely thin, infinite extent baffle that gives the same air-flow performance as the real opening. Used to describe the area of trickle vents in Approved Document F. Not to be confused with Effective area. Refer to [56] for further information.

A Appendix A – additional information

A.1 This appendix provides additional information on ventilation and overheating to help provide further context to the guidance in Section 2 of this document. This is not an exhaustive list of relevant information but does signpost a number of documents referred to during the production of this guide.

Ventilation

A.2 Ventilation requirements for dwellings (and other buildings) are covered under the Building Regulations and set out within ADF, which requires that:

"There shall be adequate means of ventilation provided for people in the building."

A.3 The document then goes on to state that:

"Ventilation is simply the removal of 'stale' indoor air from a building and its replacement with 'fresh' outside air.

Ventilation is required for one or more of the following purposes:

a) Provision of outside air for breathing;

b) Dilution and removal of airborne pollutants, including odours;

c) Control of excess humidity (arising from water vapour in the indoor air);

d) Provision of air for fuel-burning appliances (which is covered under Part J of the Building Regulations)

Ventilation may also provide a means to control thermal comfort but this is not controlled under the Building Regulations. Part L addresses minimising energy use due to the effects of solar gain in summer."

A.4 ADF describes three types of ventilation provision and associated ventilation rates. These are summarised in Table 2-1 of this guide.

A.5 In addition to the above ADF also states:

"Purge ventilation provisions may also be used to improve thermal comfort, although this is not controlled under the Building Regulations."

A.6 Section 5 of ADF provides details of four template 'Systems' which comply with ventilation requirements for new dwellings and can be adopted to demonstrate compliance.

A.7 Each of these 'Systems' demonstrates adequate ventilation provision, the details of each system are summarised in Table 2-2 of this guide.

A.8 With reference to the design of ventilation systems 1 and 2, ADF states the following:

"The background ventilators have been sized for the winter period. Additional ventilation may be required during warmer months and it has been assumed that the provisions for purge ventilation (e.g. openable windows) could be used."

A.9 The document also provides similar advice with respect to the sizing of systems 3 and 4.

A.10 With regard to the provision of purge ventilation within habitable rooms, the approved document provides the following note:

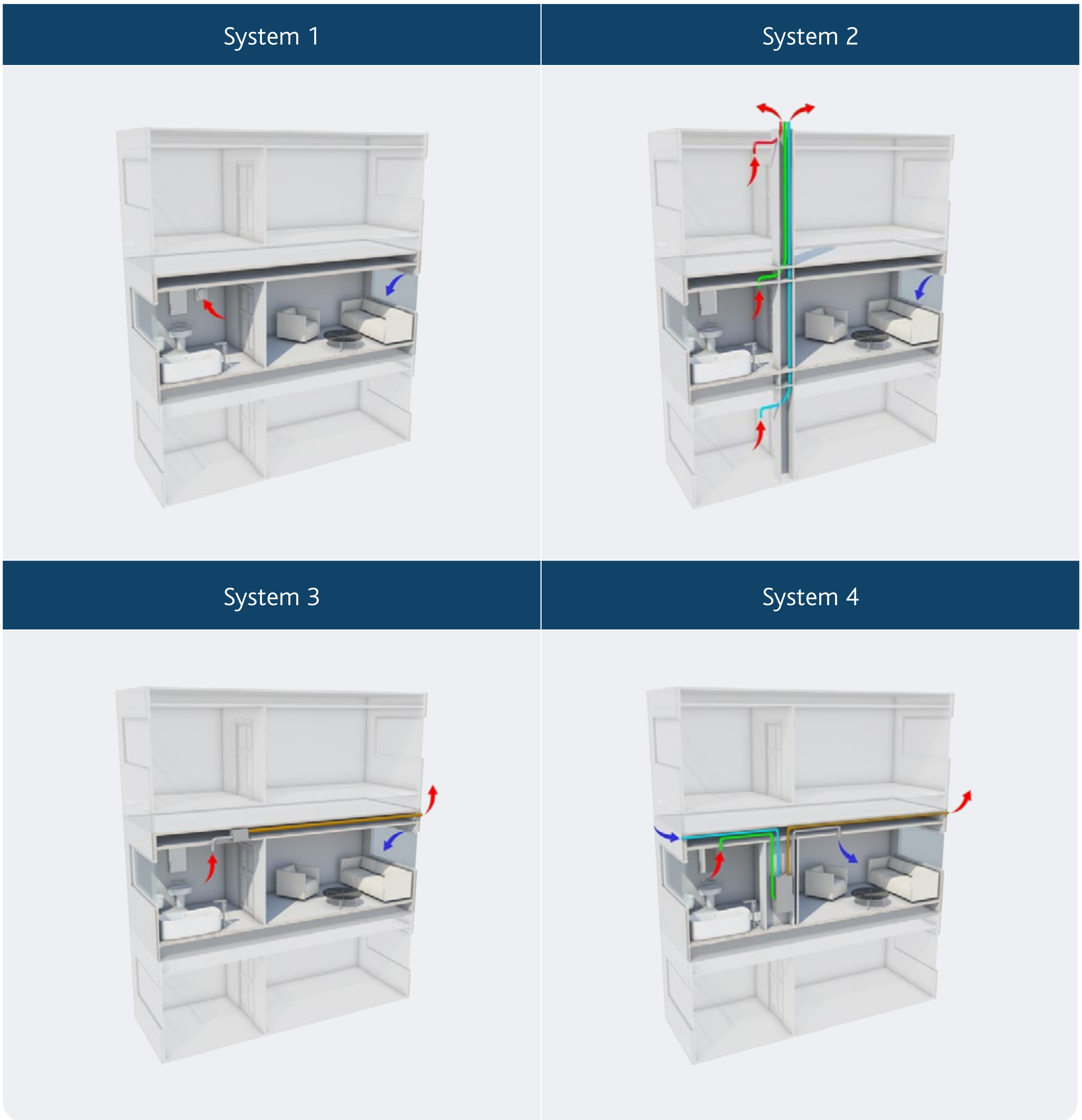
"There may be practical difficulties in achieving this (e.g. if unable to open a window due to excessive noise from outside."

A.11 No objective guidance is provided in the Approved Document as to what constitutes an 'excessive' level of noise.

A.12 Figure A-1 illustrates the principles of the ventilation systems described in Table 2-2 (i.e. systems 1, 2, 3 and 4).

A.13 Notwithstanding the above information, it is important to note that the ventilation requirements contained in ADF are a minimum standard only.

Figure A-1 Illustrations of ADF ventilation systems



Thermal Comfort and Overheating

A.14 ISO 7730 [35] describes thermal comfort as:

"that condition of body and mind which expresses satisfaction with the thermal environment."

A.15 Part of providing thermal comfort in a residential building is avoiding 'overheating'. In the Zero Carbon Hub discussion paper 'Next Steps in Defining Overheating' [6] ('ZCH') the following definition of overheating in dwellings is provided:

"In a general sense, by overheating we mean the phenomenon of excessive or prolonged high temperatures in homes, resulting from internal or external heat gains, which may have adverse effects on the comfort, health or productivity of the occupants."

Building Regulations

A.16 There are no specific requirements relating to overheating in residential dwellings as part of The UK Building Regulations. Both ADF (see above) and Part L1A of The Building Regulations [36] briefly mention overheating but do not provide detail on what constitutes overheating. In the section on 'buildings other than dwellings' ADF refers to Part L2A of The Building Regulations for guidance, however this guidance is related to limiting solar gains rather than avoiding overheating.

A.17 Approved Document L1A provides guidance on limiting the effects of heat gains in summer although no objective performance standards are identified. However, reference is provided to the SAP 2012 Appendix P assessment methodology and this document includes a simplified test for overheating risk (this is discussed in more detail below).

The London Plan – Policy 5.9 Overheating and Cooling

A.18 Policy 5.9 of the London Plan 2016 specifically mentions overheating and states the following:

"The Mayor seeks to reduce the impact of the urban heat island effect in London and encourages the design of places and spaces to avoid overheating and excessive heat generation, and to reduce overheating due to the impacts of climate change and the urban heat island effect on an area wide basis."

A.19 In relation to planning decisions the policy states that:

"Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the following cooling hierarchy:

1. minimise internal heat generation through energy efficient design

2. reduce the amount of heat entering a building in summer through orientation, shading, albedo, fenestration, insulation and green roofs and walls

3. manage the heat within the building through exposed internal thermal mass and high ceilings

4. passive ventilation

5. mechanical ventilation

6. active cooling systems (ensuring they are the lowest carbon options).

Major development proposals should demonstrate how the design, materials, construction and operation of the development would minimise overheating and also meet its cooling needs. New development in London should also be designed to avoid the need for energy intensive air conditioning systems as much as possible. Further details and guidance regarding overheating and cooling are outlined in the London Climate Change Adaptation Strategy."

A.20 In relation to Local Development Framework (LDF) preparation the policy also states:

"Within LDFs boroughs should develop more detailed policies and proposals to support the avoidance of overheating and to support the cooling hierarchy."

Overheating Criteria and Guidance

CIBSE Technical Memorandum 59 'Design methodology for the assessment of overheating risk in homes'

A.21 CIBSE TM59 provides guidance on the assessment of overheating in dwellings (including care homes and student accommodation). The document sets out a standardised methodology for predicting temperatures inside dwellings (using dynamic thermal modelling) and also provides overheating 'compliance criteria'.

A.22 CIBSE TM59 notes that:

"This methodology is proposed for all residences and should especially be considered for:

— large developments

— developments in urban areas, particularly in southern England

— blocks of flats

— dwellings with high levels of insulation and air-tightness

— single aspect flats.

Individual houses and developments with a low risk of overheating may not require the use of dynamic thermal modelling...

A.23 If taking the decision to omit dynamic thermal modelling to test overheating, TM59 states that the risk must be considered in the context of the project and the decision should be taken jointly with the client, design team and planners. A list of risk factors for identifying properties at high risk of overheating is provided in Energy Planning — Greater London Authority guidance on preparing energy assessments [37] and in BRE's Home Quality Mark [38]."

A.24 TM59 provides separate compliance criteria for dwellings that are 'predominantly naturally ventilated' and dwellings that are 'predominantly mechanically ventilated'. In relation to the different methods of ventilation TM59 states the following:

"Homes that are predominantly naturally ventilated, including homes that have mechanical ventilation with heat recovery (MVHR), with good opportunities for natural ventilation in the summer should assess overheating using the adaptive method based on CIBSE TM52 (2013)

In order to allow the occupants to 'adapt', each habitable room needs operable windows with a minimum free area that satisfies the purge ventilation criteria set in Part F of the Building Regulations for England (NBS, 2010), and equivalent regulations in other countries, i.e. the window opening area should be at least 1/20th of the floor area of the room (different conditions exist for windows with restricted openings, and the same requirement applies for external doors). Control of overheating may require accessible, secure, quiet ventilation with a significant openable area.

Homes that are predominantly mechanically ventilated because they have either no opportunity or extremely limited opportunities for opening windows (e.g. due to noise levels or air quality) should be assessed for overheating using the fixed temperature method."

A.25 The compliance criteria for each ventilation type, taken directly from TM59 are detailed below.

A.26 Compliance criteria for predominantly naturally ventilated homes:

"Compliance is based on passing both of the following two criteria:

a) For living rooms, kitchens and bathrooms: the number of hours during which ΔT is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3 per cent of occupied hours (CIBSE TM52 Criterion 1: Hours of exceedance).

b) For bedrooms only: to guarantee comfort during the sleeping hours the operative temperature in the bedroom from 10 pm to 7 am shall not exceed 26 °C for more than 1% of annual hours. (Note: 1% of the annual hours between 22:00 and 07:00 °C will be recorded as a fail.)

Criteria 2 and 3 of CIBSE TM52 may fail to be met, but both a) and b) above must be passed for all relevant rooms."

A.27 Compliance criteria for predominantly mechanically ventilated homes:

"For homes with restricted window openings, the CIBSE fixed temperature test must be followed, i.e. all occupied rooms should not exceed an operative temperature of 26 ˚C for more than 3% of the annual occupied annual hours (CIBSE Guide A (2015a))."

A.28 In addition to the compliance criteria above TM59 provides further information on adjustments for homes with vulnerable occupants and 'non-mandatory' criteria for temperatures in corridor areas.

A.29 TM59 refers to the adaptive thermal comfort criteria in CIBSE Technical Memorandum 52 (TM52) [39] and these are described in more detail in the following paragraphs.

A.30 TM52 outlines three overheating design criteria. These are all defined in terms of ΔT, the difference between the actual operative temperature in the room at any time (Top) and the limiting maximum acceptable temperature (Tmax). ΔT is calculated as:

ΔT = Top –Tmax (K)

A.31 ΔT is rounded to the nearest degree (i.e. for ΔT between 0.5 and 1.5 the value used is 1K, for 1.5 to 2.5 the value used is 2K and so on).

A.32 Criteria 1 - Hours of Exceedance (He): The number of hours (He) that ΔT is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3% of occupied hours.

A.33 How often a building/zone exceeds its comfort range during the summer months (May-September) is a useful indicator of its thermal characteristics and potential risk of overheating.

A.34 Criteria 2 – Daily Weighted Exceedance (We): To allow for the severity of overheating the Daily Weighted Exceedance (We) shall be less than or equal to 6 in any one day.

A.35 The value of 6 is an initial assessment of what constitutes an acceptable limit of overheating on any single day.

A.36 Criteria 3 - Upper Limit Temperature (Tupp):

A.37 To set an absolute maximum value for the indoor operative temperature the value of ΔT shall not exceed 4K.

A.38 This criterion covers the extremes of hot weather conditions and future climate scenarios.

Standard Assessment Procedure for Energy Rating of Dwellings' (SAP), 2012

A.39 Appendix P of 'The Government's Standard Assessment Procedure for Energy Rating of Dwellings' [40] ('SAP'), 2012 provides a method for assessing the energy performance of dwellings and as part of this provides an 'Assessment of internal temperature in summer' (the document does note that this assessment is not integral to SAP and does not affect the calculated SAP ratings).

A.40 The SAP Appendix P assessment predicts a likelihood of high internal temperature during hot weather that varies from 'not significant' to 'high'. However, it should be noted that this method is a relatively simple tick box type assessment that only considers a few basic variables as it is focussed on assessing the energy efficiency of a dwelling and not thermal comfort or health impacts etc.

Housing Health and Safety Rating System

A.41 The Housing Health and Safety Rating System [41] ('HHSRS') is a 'risk-based evaluation tool to help local authorities identify and protect against potential risks and hazards to health and safety from any deficiencies identified in dwellings'.

A.42 In Section 3 of the HHSRS document 'Guidance for landlords and property related professionals', the following is stated in relation to the effects on health as temperatures rise:

"increase in thermal stress, increase in cardio vascular strain and trauma, and increase in strokes. Mortality increases in temperatures over 25°C. Although not common, problems can occur in the UK."

A.43 In addition to the above, in the HHSRS 'Operating Guidance' document, further information in relation to overheating and noise is provided in paragraph 3.17:

"There should be means for cooling during hot summer weather, either by natural ventilation or by air conditioning. The means should be controllable, properly installed and maintained, and appropriate, having regard to the particular part of the dwelling. While openable windows can provide ventilation, occupiers may be reluctant to use them for security reasons, or because of external noise levels, especially at night."

IEA Energy in Buildings and Communities Programme – Annex 62 – Ventilative Cooling

A.44 The International Energy Agency (IEA) Energy in Buildings and Community (EBC) Programme [42] carries out research and development activities towards near zero energy and carbon emissions.

A.45 Annex 62 of the Programme looks at 'ventilative cooling' and provides the following definition of the term 'ventilative cooling':

"The application of ventilation air flow to reduce the cooling loads in buildings"

A.46 To help address cooling challenges in buildings, Annex 62 focuses on the following:

- *"Development of design methods and compliance tools related to predicting, evaluating and eliminating the cooling need and the risk of overheating in buildings, and*
- *To develop new attractive energy efficient ventilative cooling solutions."*

Dynamic Thermal Modelling

A.47 Dynamic thermal modelling is a technique that can be used to simulate internal temperatures in dwellings before they are built. This enables engineers to identify if and how often rooms in dwellings are likely to 'overheat'.

A.48 Building services engineers generally use thermal analysis software to undertake dynamic thermal modelling.

A.49 In order to model temperatures inside dwellings a large amount of information is required, including the following:

- Site location and building orientation
- Weather files for the site
- Details of elevational treatments (areas, insulation performance and solar transmittance etc.)
- Thermal mass properties
- Details of opening doors and windows (size, shape, opening type)
- Details of any mechanical ventilation and / or heat recovery systems
- Internal and external shading
- Room types and information
- Occupancy profiles (occupied hours, resident's activities etc.)
- Details of internal thermal gains (lighting, equipment, pipework etc.)

A.50 Before the release of TM59, the results of dynamic thermal modelling assessments were highly dependent upon assumptions made by the engineer undertaking the analysis, particularly in relation to occupancy profiles.

A.51 However, the CIBSE TM59 document now provides a standardised approach to predicting overheating using dynamic thermal analysis. The methodology is necessarily prescriptive to enable it to be consistently applied and it also includes clear reporting requirements to enable all stakeholders to understand the assumptions made, review the conclusions and understand the likely design implications.

A.52 To assist with the acoustic assessment, modellers should be asked to provide the information described in Table A-2 from the dynamic thermal model.

A.53 The free area may be used to assess potential external noise ingress, e.g. by reference to NANR-116 [43], or Annexe D of BS EN 12354 [45]. The effective area may be used to determine the requirements for another type of system, such as an attenuated passive vent.

A.54 It is anticipated that in a future version of this AVO Guide there will be a quantitative assessment of the overheating condition to combine with the acoustic assessment. At present the extent of time for which the overheating condition occurs can only be assessed qualitatively.

A.55 In future it is anticipated that the number of hours for which open windows are required to mitigate overheating within the daytime (07:00 - 23:00) and separately, night-time (23:00 - 07:00) periods will be detailed.

Table A-2 Information required from thermal model

Information required from dynamic thermal model in order to undertake the acoustic assessment
The physical opening area (*free area*) in the facade
The *effective area* of opening achieved

Overheating risk – early stage tool

A.56 This early stage tool [8] may be of great assistance in enabling the non-specialist to get a quantitative feel for the overheating risk. This includes assessment of where noise levels may be a reason that occupants may prefer to keep windows closed for all or part of the day or night- time periods.

B Appendix B – example application of this guide

Introduction – observing internal noise level guidelines

B.1 This appendix offers an overview of the typical design process, and provides a worked example to illustrate the steps that may be appropriate.

B.2 The level of assessment (i.e. a level 1 or level 2 assessment, and detail included for each) may be proportional to the scale of the development. This Appendix outlines an extensive assessment.

B.3 At any scale of development, it is always appropriate to integrate any façade sound insulation requirements with the ventilation strategy.

B.4 On smaller developments it may be disproportionate to carry out a formal overheating assessment. In this case, the risk factors for overheating may be noted [41] along with the provisions for mitigating overheating and the associated noise levels anticipated. The level of risk to occupants may then be considered in a qualitative manner.

B.5 A qualitative overheating assessment is likely to assume opening windows to mitigate overheating. Thus even when the overheating risk may appear to be low, the acoustic conditions during the overheating condition should be considered.

Approach to assessment & preparing advice – key steps

B.6 Prior to the acoustic assessment of ventilation and overheating the site should be assessed using guidance for good acoustic design as recommended within ProPG: Planning & Noise. In particular, where a site is considered medium or high risk following an initial site noise risk assessment, it is recommended that the examination of acoustically critical issues such as site layout, building heights, materials, landform contouring, detailed design and landscaping, the location of vehicle and pedestrian access, boundary treatments, amenity spaces etc. must be assessed at an early stage.

B.7 The suggested process in this section assumes that the site layout including building orientation has already been optimised following a process of good acoustic design, as has the space planning within the building.

B.8 There are three key steps in the process of considering the effect that noise can have in relation to design strategies for ventilation and mitigating overheating and these are highlighted in Table B-1 and illustrated in Figure B-1.

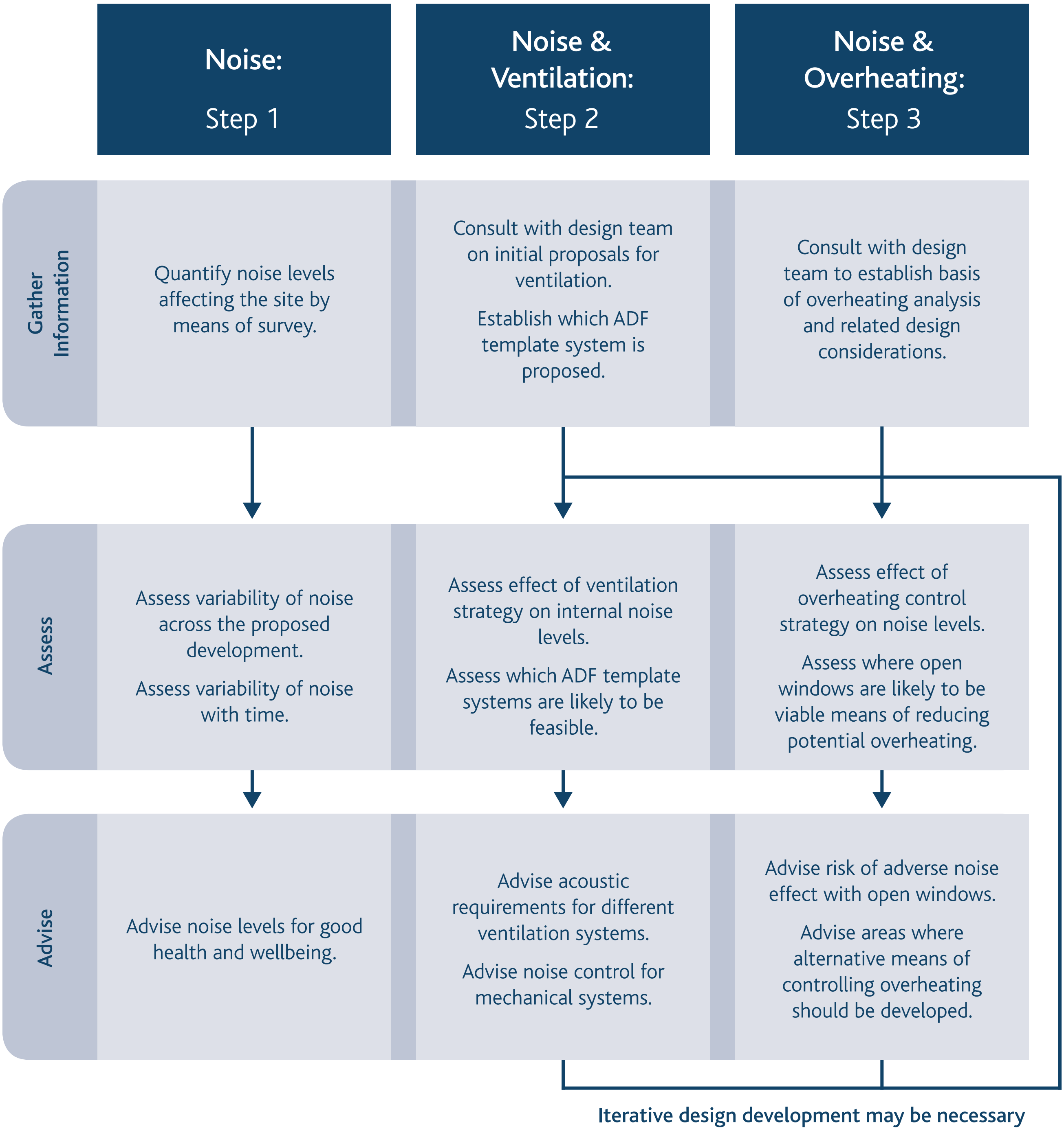
B.9 To carry out a Level 1 assessment, it is useful to consider guideline values that may inform the boundaries between negligible, low, medium, and high risk sites or aspects in this worked example.

B.10 Table 3-2 illustrates the increasing risk in a qualitative manner; paragraph 3.13 indicates that the values in Table 3-2 are based on a difference of 13 dB between external free-field and internal reverberant levels indicated in Table 3-3. Paragraphs 3.24 and 3.25 and note that the value of 13 dB is not appropriate for all situations; this approach nonetheless enables a Level 1 assessment to be undertaken before details of the proposed accommodation are known.

Table B-1 Three key steps in considering noise in relation to ventilation and overheating strategies

Step	Activity	Output advice
1	**Quantify external noise levels** Determine external noise levels impacting on proposed living rooms and bedrooms.	Report the following values and describe the method by which they have been determined. These should consider any increases that may reasonably be expected in the foreseeable future. • Daytime ($L_{Aeq,16h}$) • Night-time ($L_{Aeq,8h}$) • Ventilation design case night-time maximum (L_{AFmax}) level. • Overheating design case night-time maximum (L_{AFmax}) level.
2	**Assess noise & ventilation** Consider the effect of the proposed or potential ventilation strategies on the acoustic conditions in living rooms and bedrooms. Consider noise ingress through other parts of the building envelope as appropriate.	Refer to Table 3-1 for indoor ambient noise level guidelines from external sources, and Table 3-4 for mechanical services noise associated with ventilation provision. The facade sound insulation assessment should either include details of the proposed ventilation strategy and façade element sound insulation performance, or identify feasible ventilation strategies and the associated acoustic constraints for façade element performances. **Section on Beginning Step 2 (paragraphs B11 to B35) gives further information on this.**
3	**Assess noise & overheating** Rooms may be grouped by Negligible, Low, Medium and High risk categories according to Table 3-2 to determine the extent of further analysis or mitigation required. Consider noise from mechanical systems associated with controlling overheating.	It may be appropriate to carry out an overheating assessment regardless of the noise impact on the proposed development. Risk factors for overheating are listed in CIBSE TM59, although other methods of carrying out an overheating assessment may also be suitable. Refer to Table 3-5 for mechanical services noise associated with controlling overheating. Follow procedure in Figure 3-1 for noise from external sources. **Negligible risk category rooms according to Level 1 assessment** A "Level 1" assessment is sufficient, as noise can be heard but does not cause any change in behaviour. **Low risk category rooms according to Level 1 assessment** A "Level 1" assessment is likely to be sufficient. It is unlikely that external noise ingress will be problematic if using opening windows to mitigate overheating, although it may be appropriate to demonstrate this with calculations. **Medium risk category rooms according to Level 1 assessment** It would be prudent to carry out more detailed analysis for rooms in this category, because if open windows are required for extended periods to reduce potential overheating (i.e. during the "overheating condition") the noise impact may be significant. It may be appropriate to consider the generic overheating risk factors for the proposed development (refer to Appendix A, paragraph A.23, or use of the Good Homes Alliance Early Stage Overheating Risk Tool) along with the noise levels in order to take a balanced view of the level of formal assessment that is suitable. **High risk category rooms according to Level 1 assessment** A "Level 2" assessment is normally appropriate in accordance with Table 3-3. For rooms in this noise exposure category, an integrated approach should consider the overheating strategy along with external noise ingress. The potential adverse acoustic impact during the overheating condition should be assessed. **Section on Beginning Step 3 (paragraphs B36 to B49) gives further information on assessing noise and overheating.**

Figure B-1 Typical activity of the acoustician in developing the design



Beginning Step 2: consider noise effects of ventilation strategy

B.11 The first step in the assessment is for the acoustician to review and understand the ventilation strategy that is being proposed in relation to ADF. In the absence of a firm proposal, the acoustician might consider the viability of each of the standard ADF systems.

B.12 Acoustic considerations associated with ventilation strategies described in ADF are summarised in Table B-3. It is noted that there is no obligation to adopt one of these template systems from ADF; other systems may be considered by reference to the similar system described, subject to satisfaction of the Building Control officer.

B.13 Table B-3 indicates approximate guideline external noise levels for each system.

Potential facade elements and their associated performance

B.14 It is assumed for the sample calculations below that external noise ingress through the glazing and any vent is the most significant route, and the noise ingress through other facade elements is not significant by comparison. This is likely to be a reasonable assumption where low or moderate levels of façade sound insulation are required. Where higher levels of sound insulation are needed, consideration should also be given to other façade elements.

B.15 The calculations here assume double glazing; the sound insulation of triple glazing is not generally much better than that of double glazing. The sealing of any opening elements may be the limiting factor when trying to achieve higher levels of sound insulation, particularly the sealing of sliding doors, for example. Any performance considered for glazing should include the frame and seals for opening elements.

B.16 In the interests of simplicity in this worked example, it is assumed that the external continuous equivalent sound field is well represented by the road traffic noise spectrum described in BS EN 1793-3 [44]. On this basis façade sound insulation is well described by the (R_w+C_{tr}) parameter.

B.17 The values for attenuation of noise from events is calculated based on the weighted sound reduction indices (R_w, $D_{n,e,w}$) *without* the C_{tr} adaptation term, on the basis that noise from events typically has more energy in the higher frequency bands and attenuation is typically better represented by this parameter.

B.18 The assumptions above are made for simplicity in this example; in practice, the acoustician should determine the type of calculation that is appropriate for the particular circumstances. This may be a simple calculation using broadband sound levels, or may be a frequency-band calculations using the procedure in BS EN ISO 12354-3:2017.

Guideline external noise constraints for ADF ventilation Systems 1 & 2

B.19 The trickle vent areas indicated in ADF to provide whole dwelling ventilation rates are based on calculated air flow rates for the winter condition; provisions for purge ventilation (i.e. opening windows) may be used at other times of the year.

B.20 Two trickle vents to provide an equivalent area of 5000 mm² are assumed for the assessment of Systems 1 & 2. It is noted that the trickle vents are sized based on winter conditions; at other times of the year, partially open windows may be required to avoid poor indoor air quality. However, there is no guidance provided in ADF on the area of opening that may be required; therefore this assessment is based on external noise ingress through closed windows and open trickle vents.

B.21 External levels for use of ADF System 1 are based on calculations according to the detailed method described in BS 8233, (equivalent to the method in BS EN 12354-3) [45] A typical small bedroom is considered. The *Technical housing standards – nationally described space standard* [46] indicates that a single bedroom should be at least 7.5 m². The glazed area is considered to 25% of the floor area, as described in SAP.

B.22 These dimensions represent unfavourable ratios between element performance and overall facade level difference, but worse case conditions may be found in practice. On the basis of these assumptions, the relation between element performance and partial internal level ($L_{2,route}$) due to each noise ingress path reduces to the following relationship, following the detailed method in BS 8233 Section G.2:

- $L_{2,\,glass} = L_{1,ff} - (R_w + C_{tr}) - 2$
- $L_{2,\,vent} = L_{1,\,ff} - (D_{n,e,w} + C_{tr}) + 5$ [for each vent]

B.23 Where the total internal level is the logarithmic sum of the partial level due to ingress through the glass, $L_{2, glass}$, and ingress through the vent, $L_{2, vent}$, assuming that these routes dominate over other ingress transmission routes as noted above.

B.24 The following assumptions are made regarding potential glazing and trickle vent performance:

- Standard domestic double glazing with R_w (C_{tr}) 29 (-4) dB, from BS EN 12758 [47]
- High acoustic performance windows with R_w (C_{tr}) 43 (-6) dB, from proprietary manufacturer's data. Note that the details of the frame and sealing arrangements are important to maintain this performance for the whole window system.
- Two standard trickle vents, approx. 2500 mm^2 equivalent area, $D_{n,e,w}$ (C_{tr}) 31 (0) dB, typical manufacturer's data.
- Two high acoustic performance trickle vents, approx 2500 mm2 equivalent area, $D_{n,e,w}$ (C_{tr}) 44 (-3) dB from proprietary manufacturer's data.

B.25 Note that the total equivalent area of ventilators required to comply with AD-F may mean that more than two trickle vents are required in some rooms, but two vents are assumed in this example.

Guideline external noise constraints for ADF ventilation System 3

B.26 The guideline values for ADF System 3 are based on the same assumptions as for Systems 1 and 2, but with a single trickle vent in the façade providing a minimum equivalent area of 2500 mm^2, as indicated in ADF.

B.27 In particular, note the comment regarding the performance of the frame for the glass, sealing arrangements and other facade elements where a higher overall sound insulation performance is sought.

Guideline external noise constraints for ADF ventilation System 4

B.28 The guideline values for ADF System 4 are calculated on the same basis as for ADF System 3, omitting the trickle vent. In particular, note the comment regarding the performance of the frame for the glass, sealing arrangements and other facade elements where a higher overall sound insulation performance is sought.

Table B-2 Potential level differences associated with different ventilation Systems from ADF

Ventilation System from ADF	Cont. equiv. (L_{Aeq}) or events (L_{AFmax})	Level Difference, external free field level – internal reverberant level, dB	
		Typical windows and vent	Higher acoustic performance windows and vent
1, 2	L_{Aeq}	21	31
	L_{AFmax}	22	35
3 (with trickle vent)	L_{Aeq}	23	33
	L_{AFmax}	24	38
4 (no trickle vent)	L_{Aeq}	27	38
	L_{AFmax}	31	45

Assessment of Individual Noise Events

B.29 An assessment of the potential impact from individual noise events on sleep during the night-time should always be undertaken.

B.30 The paper Assessing L_{max} *for residential developments: the AVO Guide Approach*[22] describes the approach adopted in this guide. Representative external values of L_{AFmax} on different façade portions may be determined to establish a "design case" as described in the ANC Green Book [48] (ANC Green Book). However, the frequency content of the noise from events may be of more significance than the overall A-weighted level.

B.31 When assessing the ventilation strategy, the L_{AFmax} level associated with the ventilation design case should be used. Note that this may be a different level from the L_{AFmax} used with the overheating design case. Refer to Assessment of Individual Noise Events (paragraphs B45 –B49)

B.32 When the noise from events is transmitted through the façade, the highest internal levels of L_{AFmax} may not be caused by the same events that cause the highest L_{AFmax} externally.

B.33 On the basis of survey measurements, the acoustician must exercise discretion to determine the appropriate values and frequency content to use for the design case for noise from events. It may be necessary to use a range of values and calculate the internal values of L_{AFmax} for each scheme of façade sound insulation in order to determine external values that are suitable to use.

B.34 In particular, where the noise from events contains a high proportion of energy in the lower or higher frequency bands, the overall performance of the façade sound insulation may be poorly represented by single-figure weighted values compared to frequency-band calculations.

B.35 Either a single value or range of values for the design case for noise from events may be determined with guidance from the ANC Green Book.

Table B-3 Summary of potential noise issues associated with ventilation strategies described in ADF

ADF System	External noise ingress considerations	Mechanical system noise considerations	Approximate guideline free-field external noise limits. [Note 1]
1 or 2	Noise ingress is likely to be defined by the performance of the background ventilators (trickle vents), windows and other façade elements. Note that use of System 1, relying on the use of open trickle vents without opening windows may give rise to poor indoor air quality in airtight dwellings outside the winter period.	For System 1, intermittent kitchen and bathroom fans should have suitable noise levels to meet the guidelines in Table 3-4. System 2 has no mechanical components.	With standard double glazing and two trickle vents: • ~$L_{Aeq,16h}$ 56 dB day • ~$L_{Aeq,8h}$ 51 dB night • L_{AFmax} not normally exceeding ~ 67 dB more than 10x per night With high performing acoustic glazing and two 'acoustic' trickle vents: • ~ $L_{Aeq,16h}$ 66 dB day • ~ $L_{Aeq,8h}$ 61 dB night • L_{AFmax} not normally exceeding ~ 80 dB more than 10x per night
3	Noise ingress is likely to be defined by the performance of the background ventilators (trickle vents), windows and other façade elements. ADF advises that: "*controllable background ventilators having a minimum equivalent area of 2,500 mm² should be fitted in each room, except wet rooms…*"	This could be a centralised or decentralised MEV system. Guideline levels are shown in Table 3-4. For a centralised system, the location of the fan is important for structure-borne and airborne noise. System noise may affect living rooms and bedrooms as well as the rooms in which the extract inlets are located i.e. wet rooms. For a decentralised system, there are individual fans extracting from each bathroom, toilet, kitchen and utility room. The noise effects on adjacent living rooms and bedrooms should be considered. [Note 2]	With standard double glazing and trickle vent: • ~$L_{Aeq,16h}$ 58 dB day • ~$L_{Aeq,8h}$ 53 dB night • L_{AFmax} not normally exceeding ~ 69 dB more than 10x per night With high performing acoustic glazing and an 'acoustic' trickle vent: • ~ $L_{Aeq,16h}$ 68 dB day • ~ $L_{Aeq,8h}$ 63 dB night • L_{AFmax} not normally exceeding ~ 83 dB more than 10x per night
4	No trickle vents required. Consider noise ingress through other facade elements.	MVHR is a centralised system ducted to supply outlets in living rooms and bedrooms as well as to extracts in wet rooms. Guideline levels are shown in Table 3-4. The unit location is important for structure-borne and airborne noise. Consider ducted noise, particularly to bedrooms. Consider also cross-talk sound transmission via ducts. [Note 2]	With standard double glazing and no trickle vent: • ~ $L_{Aeq,16h}$ 62 dB day • ~ $L_{Aeq,8h}$ 57 dB night • L_{AFmax} not normally exceeding ~76 dB more than 10x per night With high performing acoustic glazing: • ~ $L_{Aeq,16h}$ 73 dB day • ~ $L_{Aeq,8h}$ 68 dB night • L_{AFmax} not normally exceeding ~ 90 dB more than 10x per night N.B. With secondary glazing higher sound insulation may be achieved.

Note 1 Refer to paragraphs B14 to B27 for the basis of calculated noise levels

Note 2 Hybrid ventilation strategies may involve mechanical supply and/or extract to specific habitable rooms, in which case those sources of noise should be considered.

Beginning Step 3: consider noise effects of overheating mitigation strategy

B.36 The first step in any assessment is for the acoustician to review and understand the strategy that is being proposed for meeting overheating design criteria. The strategy will normally consist of limiting heat gains (e.g. solar gains) and providing a means of cooling.

B.37 Table B-4 indicates acoustic considerations for four common means of cooling, noting that other means of cooling are available. Appropriate noise levels for each type of cooling strategy should also take account of how often the means of cooling needs to be employed and for what duration. See Section 3 for the detail of the assessment of overheating and noise level guidance.

B.38 It may be helpful for the acoustician to produce a mark-up indicating the Level 1 assessment risk category for each façade in accordance with guidance in Table 3-2. This will allow the other members of the design team (especially those involved in the assessment of overheating) to understand locations in which the use of opening windows to mitigate overheating may not be appropriate.

The significance of non-acoustic factors

B.39 The acoustic assessment is influenced by non-acoustic factors. The level of overheating risk will influence how often the means of cooling needs to be applied and for what duration. In the case of passive ventilative cooling, the overheating risk will also influence the size of the ventilation opening required: this changes the noise impact on occupants.

B.40 The Early Stage Overheating Risk Tool may be used to inform the overheating in conjunction with the acoustic assessment.

B.41 It may be possible to reduce the noise impact by further reducing the heat gains, and hence reducing the regularity and/or duration for which the means of cooling needs to be employed. The London Plan overheating policy provides a useful reference as to the various mitigation options and their preferred hierarchy (refer to paragraph A.19).

B.42 For example, by reducing the extent of external glazing, by improving solar shading or using exposed thermal mass, the amount of cooling that is required to meet overheating criteria may be reduced. This will likely reduce either the magnitude or duration of any noise impact associated with the cooling provision.

B.43 Clearly, it is not the role of the acoustic practitioner to advise on the strategy for mitigating overheating. However, where relevant, the acoustic practitioner is encouraged to communicate to the design team and developer any acoustic benefit of reducing heat gains or increasing thermal mass.

B.44 Ceiling mounted fans do not reduce the ambient temperature but can be used to increase air-movement in the room, and thus improve thermal comfort at hotter temperatures. If used, noise from ceiling mounted fans should be considered in the assessment.

Assessment of Individual Noise Events

B.45 Paragraphs B29 to B35 discuss potential issues with the measurement and assessment of L_{AFmax}.

B.46 Higher values may be acceptable for limited periods of the year, depending on the level and frequency of events. Refer to ProPG Appendix A for information on assessing individual noise events.

B.47 The paper *Assessing L_{max} for residential developments: the AVO Guide Approach* [22] describes the approach adopted in this guide.

B.48 Table 3-3 indicates that for the overheating design case L_{AFmax} levels up to but not normally exceeding 65 dB may be acceptable for limited periods.

B.49 For simplicity, it is considered that the external design case maximum level determined for the overheating condition should not result in the L_{AFmax} within bedrooms exceeding a value of 65 dB.

Table B-4 Summary of potential noise issues associated with cooling strategy

Means of cooling	Description	External noise ingress considerations	Mechanical system noise considerations
Passive ventilative cooling	Introducing external air to a space to provide a cooling effect without the use of fans. The most common method is to use open windows but other façade openings can also be used. It is important to note that trickle vents do not provide sufficient airflow to have a significant cooling effect.	Will require significant openings in the façade. Ingress of external noise via these openings will need to be considered. A level difference of around 13 dB from external free-field levels to reverberant internal levels can typically be assumed for a window that is sufficiently open to enable some ventilative cooling. However, the actual open area that may mitigate overheating depends on many factors [4, 8], and may differ significantly from this proportion. Therefore this should be reviewed for the specific project (refer to paragraphs 3.22 to 3.27 and IEA EBC Annexe 62 [42]). Where opening windows result in unacceptably high internal levels, other solutions can be considered – see Table B-5.	N/A (unless ceiling fans used)
Mechanical ventilative cooling	Using fans to introduce external air to a space to provide a cooling effect. Due to the airflow required, this type of system often involves significantly increased plant and duct size requirements.	These are likely to be sufficient to attenuate external noise ingress via the ducts. If intake and/or exhaust ducts penetrate the facade locally, the effect on sound insulation should be reviewed.	Air-flow rates will be significantly higher than those required for ADF whole dwelling ventilation. Fan noise will therefore be higher and duct-borne, breakout and structure-borne paths must be appropriately considered. Airflow (regenerated) noise will also need to be considered at grilles.
Comfort cooling	Using a mechanical system to cool the air within a space to achieve a user-defined setpoint. This type of system will require some form of mechanical device to cool the air, such as a fan coil unit (FCU).	No air-path to outside. Consider noise ingress through other facade elements.	Indoor units (fan-coils, cassettes etc.) include a fan and require significant air-flow rates to convey cooling to the room. Both the fan and the airflow are sources of noise and must be appropriately addressed. Outdoor units (which reject heat to the atmosphere) also generate noise and this may have an impact on nearby external amenity spaces or result in break-in to nearby dwellings.
Tempered fresh air system	These systems add a small amount of cooling to the whole dwelling ventilation supply system (e.g. to the MVHR). This provides a reduced temperature fresh air supply which can provide some cooling to a space. However, this may not be able to control overheating in isolation. Unlike comfort cooling, these systems are not designed to achieve specific temperature in a space.	No additional air-path to outside. Consider noise ingress through other facade elements.	Addition of cooling may affect noise generated by MVHR (or other ventilation supply system).

Passive ventilative cooling solutions providing enhanced sound insulation

B.50 Refer to Table B-5 for examples of passive ventilative cooling solutions that are able to provide an enhanced level of sound insulation when compared to a standard opening window. Solutions can be sized to enable the passive ventilation rate required by the design, which is identified by the mechanical engineers. At the time of writing there is little evidence of the successful use of many of these innovative systems in residential environments.

Table B-5 Examples of passive ventilation solutions providing enhanced sound insulation

Design option	Description and references	Approximate Level Difference (external free field level – internal reverberant level)	Improvement relative to a window providing a similar amount of ventilation
Standard opening windows	Window(s) open sufficiently to provide a ventilation free-area equivalent to 2% of the floor area. [42]	13 dB	0 dB
Open windows with sound attenuating balconies	Window(s) as above. Balconies may have a solid balustrade or be enclosed to a further degree (maintaining an open area for ventilation). Absorption may be provided to the balcony soffit or potentially to other surfaces. [49, 50, 51]	17 – 23 dB	4 – 10 dB
Attenuated or plenum windows	Dual windows (spaced by around 200mm) with staggered openings and absorptive linings to the cavity reveals. Various other configurations also possible in principle. [52, 53]	17 – 24 dB	4 – 11 dB
Attenuated vents/ louvres	Ventilation openings with integral means of attenuating sound. Typically this may be acoustic louvres or acoustically lined ducts/plena. [54, 55]	17 – 29 dB	4 – 16 dB
Attenuated windows or vents/ louvres with sound attenuating balconies	Combined use of balconies to provide screening and acoustically attenuated windows or vents. Refer to above for description of each element.	21 – 39 dB	8 – 26 dB

Information that may be appropriate or required to accompany a planning submission

B.51 Table B-6 lists information that may be appropriate or required by the Local Planning Authority (LPA) to provide with a planning application.

B.52 Individual circumstances of the project and the requirements of the LPA can vary. Reference should be made to local development plans.

B.53 An example of the typical full range of tests that are possible are listed in Table B-7. It is not intended that the full range of tests be carried out on every project; however, where the design information demonstrating compliance with particular criteria is not evident to the LPA, they may require completion tests to demonstrate compliance with the agreed criteria.

B.54 It may be appropriate to adopt a risk-based approach to selecting performance parameters for post-completion testing.

Table B-6 Information that it may be appropriate to provide with the planning application

Planning stage	Noise impact	Noise implications for ventilation strategy	Noise implications for overheating strategy
Outline application	Details of environmental noise impact across the site and proposed development if known. Potential effect of mitigation such as barriers, or use of buildings following good acoustic design to reduce noise impact on outdoor amenity areas and facades of habitable rooms.	Feasibility of ventilation strategies across the site with the noise levels measured and with any potential mitigation. Refer to Table B-2 or B-3, or provide alternative calculations to demonstrate feasibility of façade sound insulation with ventilation strategies.	Level 1 assessment of risk in accordance with Figure 3-1, for different aspects of the proposed development as appropriate. Feasibility of potential overheating strategies with the noise levels measured and with any potential mitigation. Reference can be made to Tables B-4 or B-5.
		Suggest a schedule of testing is developed for a proportion of dwellings at detailed design stage. Testing to include both external noise ingress and any mechanical systems in accordance with the updated ANC Guidelines - Sound Measurement in Buildings (which replaces the previous version known as Noise Measurement in Buildings).	
Detailed application	Details of environmental noise impact across the site and proposed development. Potential effect of mitigation such as barriers, or use of buildings following good acoustic design to reduce noise impact on outdoor amenity areas and facades of habitable rooms. Details of anticipated noise levels at an appropriate selection of residential properties.	Calculations demonstrating that the internal noise levels from external sources are consistent with the levels in Table 3-1, with justification where there are exceedances. Specifications for noise levels from mechanical ventilation systems.	Calculations demonstrating that the internal noise levels from external sources are consistent with the guideline levels in Table 3-3, with justification where there are exceedances. Specifications for noise levels from mechanical cooling systems.
		Consider a schedule of testing, particularly for any mechanical systems in accordance with ANC Guide to Measurement of Sound levels in buildings.[Note 1]	

Note 1 Where the development is subject to EIA Regulations, a reference to compliance testing should be included within the monitoring commitments.

Table B-7 A schedule of performance requirements that may be appropriate to include in a testing schedule

Noise Source	Time Period / function	Living rooms	Bedrooms	Bath,WC, Kitchen
Environmental noise ingress limit with provisions for whole dwelling ventilation rate	Daytime, $L_{Aeq,16h}$	≤ 35 dB	≤ 35 dB	-
	Night-time, $L_{Aeq,8h}$	-	≤ 30 dB	-
	Night-time, ventilation design case L_{AFmax}	-	≤ 45 dB	-
Environmental noise ingress limit with provisions for mitigating overheating	Daytime, $L_{Aeq,16h}$	[Note 1]	[Note 1]	-
	Night-time, $L_{Aeq,8h}$	-	[Note 1]	-
	Night -time, overheating design case L_{AFmax}	-	[Note 1]	-
Mechanical services noise, where systems present	Whole dwelling ventilation rate, $L_{Aeq,T}$	≤ 30 dB	≤ 26 or 30 dB [Note 2]	-
	Extract ventilation rate, $L_{Aeq,T}$	≤ 35 dB	≤ 26 or 30 dB [Note 2]	≤ 45 dB
	At design duty to control overheating [Note 3]	≤ 35 dB	≤ 30 dB	-

Note 1 Agreed limits for environmental noise ingress while using provisions for mitigating overheating may vary depending on the overheating risk and extent of time these measures may be required.

Note 2 Suitable limits for mechanical services noise should be adopted, see Paragraphs 3.28 to 3.34

Note 3 Refer to Table 3-5 and consider whether this criterion should be + or – 5 dB.

Sampling of rooms for environmental noise

1. Measurements should be carried out and reported by a suitably qualified person following procedures in the latest version of the ANC Guide to Measurement of Sound Levels in Buildings.
2. Specific rooms for sampling should be agreed with the local authority, or at least notified to them in writing, prior to commencing measurements.
3. Environmental noise levels may be measured in a representative sample comprising at least two dwellings on each façade where there are different provisions for façade sound insulation. The rooms sampled should include those most exposed to environmental noise ingress, i.e. those with the highest external noise impact and those most susceptible to external noise ingress due to the façade elements and element areas.
4. Measurements of mechanical services noise may be made in at least one in ten dwellings. Mechanical services noise should be free from audible tones or particular characteristics that attract attention.
5. A set of measurements in a dwelling may comprise measurements in all habitable rooms serviced by the mechanical systems, for ventilation and mitigating overheating separately. The measurements may be standardised to a reference reverberation time of 0.5 seconds across the frequency range, and corrected for background sound if required.

Worked example

Step 1: External noise levels impacting on the proposed development

B.55 The external free-field noise levels at each of four notional receptor locations are described in Table B-8. The four notional receptor locations correspond to the rooms, dwelling or groups of dwellings that are being assessed.

B.56 The noise levels have been determined by means of a combination of site noise survey and noise modelling. It is appropriate to provide full details of the method by which levels have been determined and include an estimate of uncertainty in the values. This portion of the assessment is omitted from this example for brevity.

B.57 For some receptor category noise levels, both North East and South West façades are considered, to illustrate potentially different approaches for differing overheating risk.

B.58 In some cases, more than one solution is considered; this leads to a large number of potential solutions illustrated in this worked example. The solutions are summarised at the end of this section.

Table B-8 Consider noise levels at four different receptors across the example site

External free-field noise level	Receptor A	Receptor B	Receptor C	Receptor D
Daytime $L_{Aeq,16h}$, dB	53	59	64	72
Night-time $L_{Aeq,8h}$, dB	45	52	59	67
Ventilation design case Night-time L_{AFmax}, dB	63	69	78	83
Overheating design case Night-time L_{AFmax}, dB	72	77	87	94

Notes **Ventilation design case Night- time L_{AFmax}** is the level that is not normally exceeded more than 10 times per night

Overheating design case Night- time L_{AFmax} is the level that is not normally exceeded.

Step 2: assessment

B.59 In all cases below, an assessment or specifications for noise from mechanical systems for ventilation should be carried out in accordance with Table 3-5.

Table B-9 Worked example of Step 2 assessment – considering the effect of potential ventilation strategies on the acoustic conditions

Receptor	Summary of ventilation strategies
A	ADF System 1. See notes in Table B-3. No further calculations provided beyond discussion in Table B-10 and summary of anticipated performance in Table B-14.
B	ADF System 3 (noting that System 1 may be feasible). Standard glazing and trickle vents with enhanced acoustic performance are required for ventilation – see discussion in Table B-11 and requirements in Table B-14. Detailed calculations presented (omitted from this worked example for brevity).
C	ADF System 3. Windows and trickle vents enhanced acoustic performance are required. See discussion in Table B-12 and summary of calculated requirements in Table B-14. Detailed calculations presented (omitted here for brevity)
D	ADF System 4. High performance acoustic glazing is required – see discussion in Table B-13 and summary of requirements in Table B-14. Detailed calculations presented (omitted from this worked example for brevity)

Step 3: assessment

B.60 It may be helpful to mark up different facades with the various constraints for ventilation strategies and strategies for mitigating overheating in different dwellings.

B.61 Those receptors that are considered "negligible risk" from the Level 1 assessment according to Table 3-2 do not require any further qualification of the overheating strategy to inform the acoustic strategy. This should not be construed as a comment on the overheating risk of the design – simply that there are no acoustic constraints on the use of opening windows to control overheating.

B.62 In this example, no receptors fall into the "low risk" category according to Table 3-2. Where receptors do fall into this category, a Level 1 assessment is likely to be sufficient.

B.63 For the receptors that are considered "medium" or "high risk" from the Level 1 assessment according to Table 3-2, a detailed overheating assessment has been carried out in accordance with CIBSE TM59. This demonstrates that on the north eastern elevations, open windows are required infrequently for a relatively short portion of the year. On the south-western elevations, opening windows are required frequently and extensively through the summer season.

B.64 Worked examples of Step 3 assessments for each receptor are set out in Tables B-10, B-11, B-12, and B-13.

B.65 For the purpose of this worked example, noise levels are associated with the levels of adverse effect noted in Figure 3-2, as illustrated by the AVO Diagrams shown in Figure B-2 and B-3.

B.66 For the purpose of this worked example, based on a level difference of 13 dB between inside and out, external levels can be determined for a Level 1 assessment to distinguish between different categories.

Figure B-2 'AVO Diagram' indicating noise levels associated with adverse effects during the daytime used in this worked example

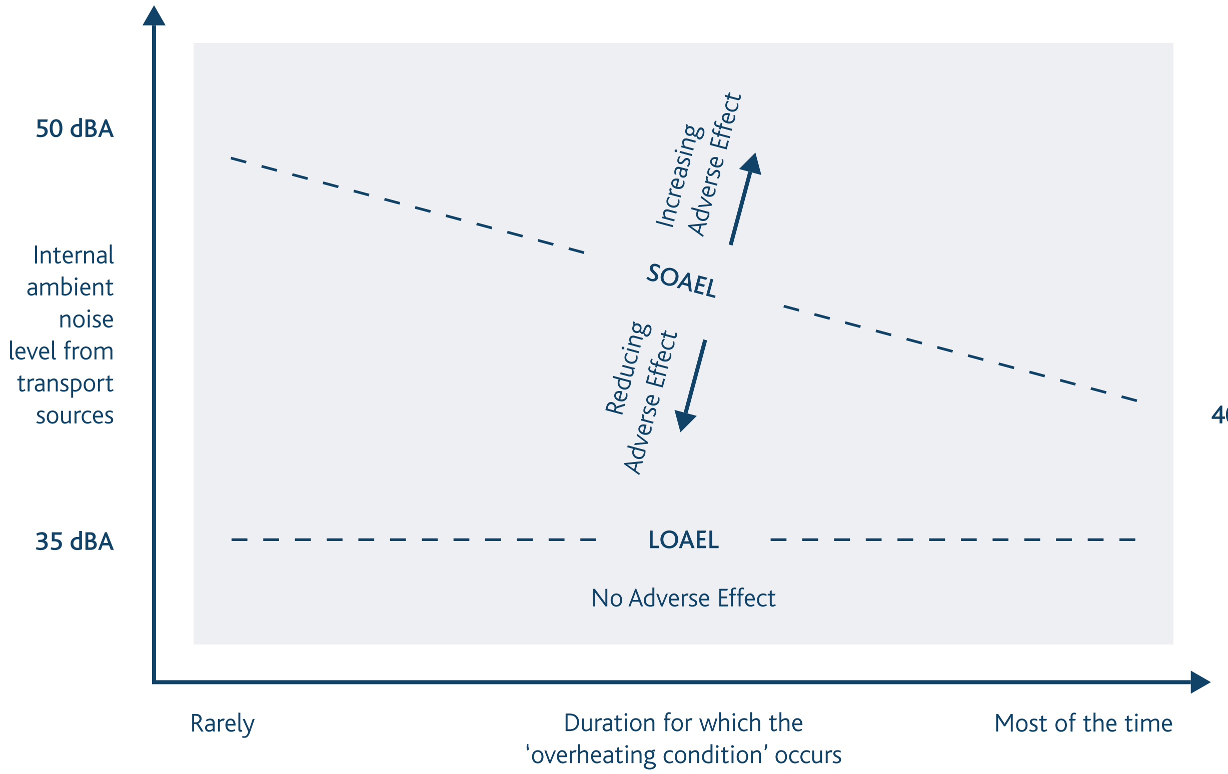


Figure B-3 'AVO Diagram' indicating noise levels associated with adverse effects during the night-time used in this worked example

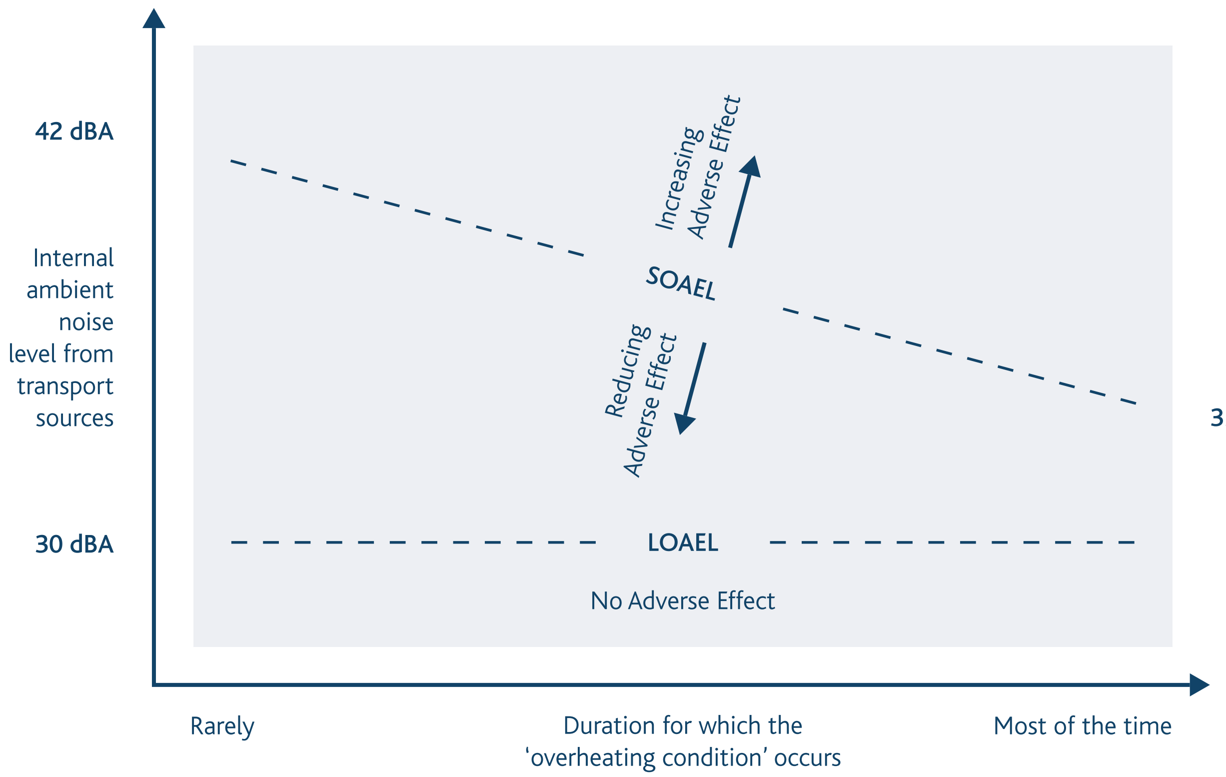


Table B-10 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor A

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 risk assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ **53** **Night-time** $L_{Aeq,8h}$ **45** **Overheating design case** L_{AFmax} **72**	Negligible	The negligible risk category according to the Level 1 assessment indicates that internal levels are expected to achieve BS 8233 reasonable conditions if overheating control is provided by means of partially open windows. When windows are partially open, there is a negligible risk of adverse effects; no further noise assessment is proposed in this example. An overheating assessment may therefore assume opening windows without acoustic constraint, and no special facade sound insulation features are required.	Not required - on basis of Level 1 assessment

Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 1 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ 59 **Night-time** $L_{Aeq,8h}$ 52 **Overheating design case** L_{AFmax} 77	Medium	**North east elevations, all room types** The overheating assessment indicates a low risk of overheating. The anticipated internal levels with a partially open window (13 dB attenuation) to control overheating would be 46 dB during the day and 39 dB at night, with overheating design case L_{AFmax} levels up to 64 dB. Considering these levels on the AVO diagrams below, these levels are below the "SOAEL" level, and below a level at which noise causes a material change in behaviour in Table 3-3. They are considered to be suitable for occupants given the relatively low overheating risk, and hence limited periods of time that windows are required to be open to mitigate overheating, especially during the night-time period.	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Illustration of daytime conditions is shown below:

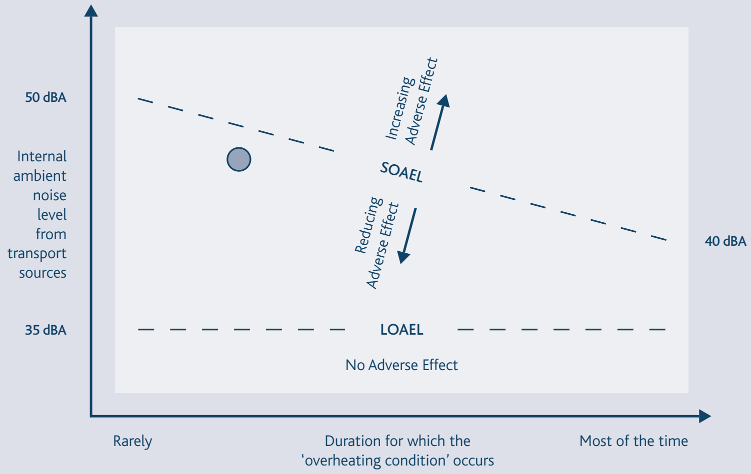


Illustration of night-time conditions is shown below:

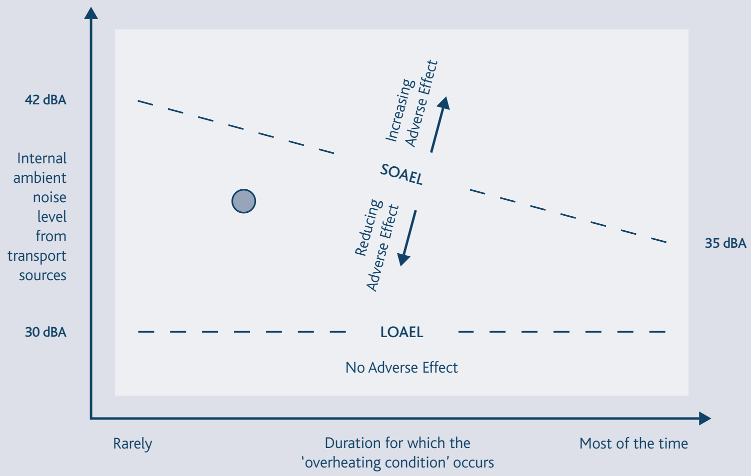


Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 2 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
		South west elevations, living rooms The overheating assessment indicates a high risk of overheating. **Scenario 1 – Mitigation of noise** Standard opening windows are not considered to be a suitable solution for SW elevations because of the higher overheating risk meaning that open windows are required more often and for longer periods, including during the night-time. These elevations therefore incorporate measures to mitigating the noise impact. Living rooms have balconies that enable staggered openings into the balcony area, containing sound absorption, so that opening windows are protected from direct noise impact. Detailed calculations demonstrate that the balcony and opening window arrangement achieve a level difference of 17 dB for the incident noise spectrum, while providing sufficient open area to enable control of overheating (the acoustician should cross-reference assumptions regarding open areas used in the overheating assessment). Thus, while mitigating overheating, the internal noise level is calculated to be 42 dBA during the daytime. This level is considered to be below a SOAEL on the AVO Diagram (see AVO Diagram below), and therefore considered suitable for the number of occasions for which open windows are required. An alternative approach to balconies may be to use passive attenuated vents.	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Illustration of daytime conditions is shown below:

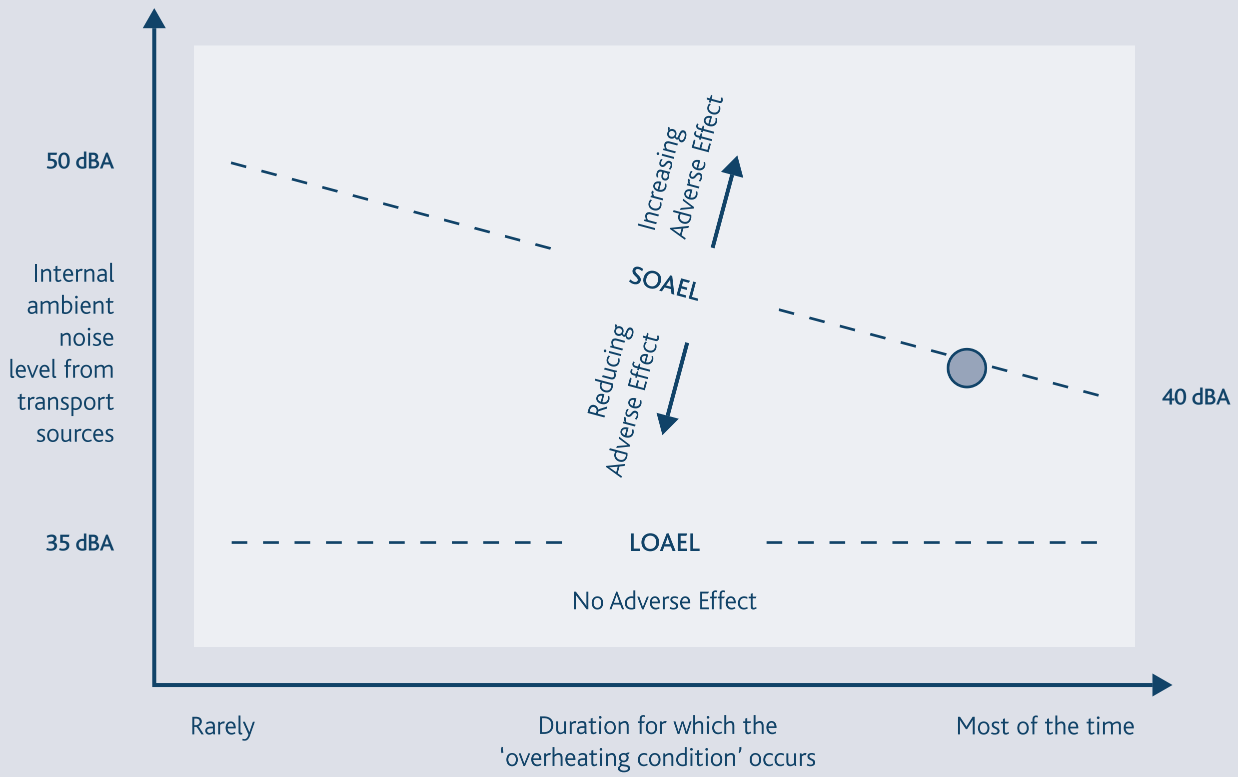


Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 3 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
		South west elevations, living rooms **Scenario 2 – Mitigation of overheating** Standard opening windows are not considered to be a suitable solution for SW elevations because the higher risk of overheating means that windows are required to be open more often. Design team are informed of the environmental noise constraint in relation to opening windows. Design changes are made to the building envelope to reduce heat entering the building. Window sizes are reduced, solar control glazing is introduced (lower G value), solar shading is added and insulation amended. There is enhanced provision of thermal mass and high ceilings with ceiling fans provided. The Good Homes Alliance Early Stage Overheating Risk Tool score is reduced from “High risk” to “Low risk”. The risk of overheating is substantially reduced and hence windows are required to be open less frequently and for a shorter duration. As for the NE elevation, the anticipated internal levels with a partially open window would be 46 dBA during the day. The AVO Diagram below illustrates that these levels are considered to be below the significant adverse effect level, and are therefore considered to be suitable for occupants given the low overheating risk, and limited periods of time that windows are required to be open to mitigate overheating.	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Illustration of daytime conditions is shown below:

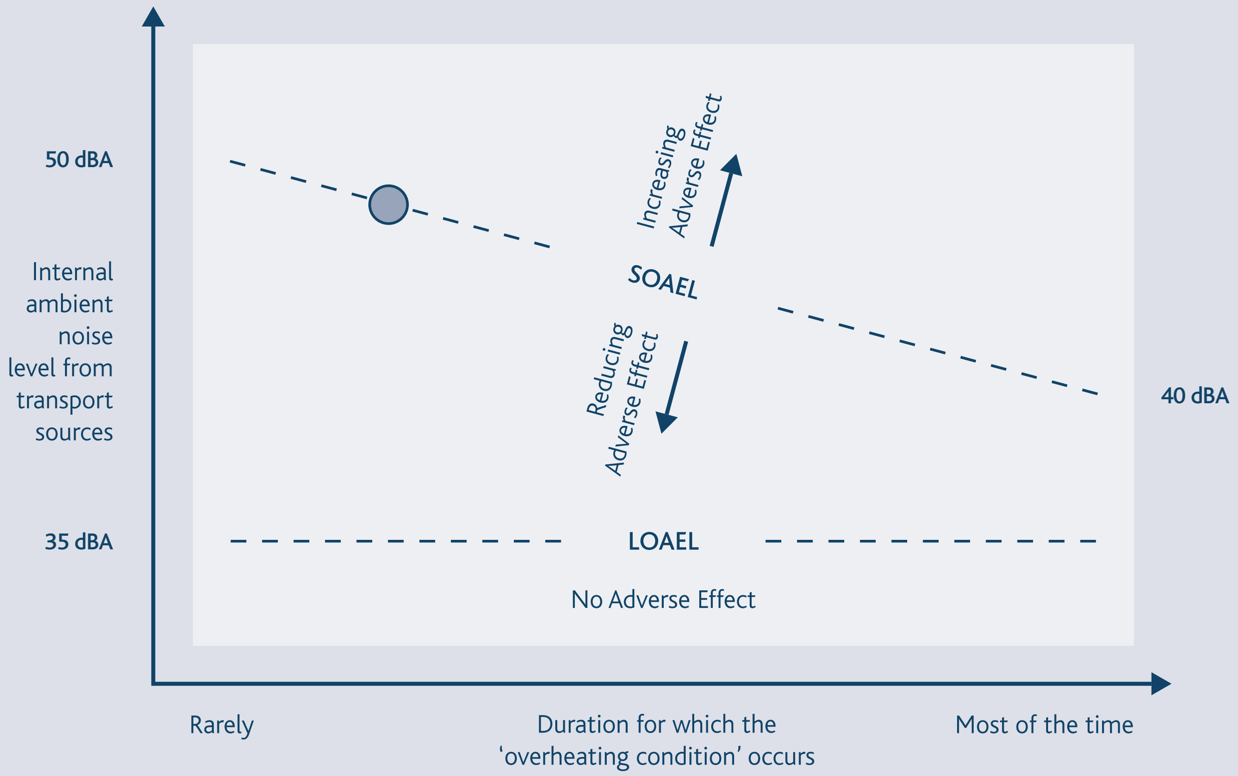


Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 4 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
		South west elevations, bedrooms The overheating assessment indicates a high risk of overheating. Standard opening windows are not considered to be a suitable solution for SW elevations because the higher risk of overheating means that windows are required to be open more often. These elevations incorporate measures to mitigating the noise impact. Bedrooms have plenum windows that are calculated to provide a level difference between outside and in of 19 dB for road traffic noise, based on the measured incident noise spectra. An attenuation of 22 dB is calculated for the typical spectrum associated with L_{AFmax} noise from events. The overheating assessment confirms that the plenum window dimensions are adequate to suitably mitigate overheating (the acoustician should cross-reference assumptions used in the overheating assessment). Thus, while mitigating overheating, an internal noise level of $L_{Aeq,8h}$ 33 dB is calculated (detailed calculations presented in accordance with the detailed method in BS 8233). This value is not more than 5 dB above the lowest category according to Table 3-3, and therefore may be considered "Reasonable" according to ProPG. This sits comfortably on the AVO Diagram shown below. Maximum noise levels from events are calculated to be up to 55 dB L_{AFmax} for the Overheating Design Case. This is significantly below the level of the upper category according to Table 3-3, and is proposed as suitable in this case.	Increasing likelihood of adverse impact, on the basis of Overheating D/C L_{AFmax} level.

Illustration of night-time conditions is shown below:

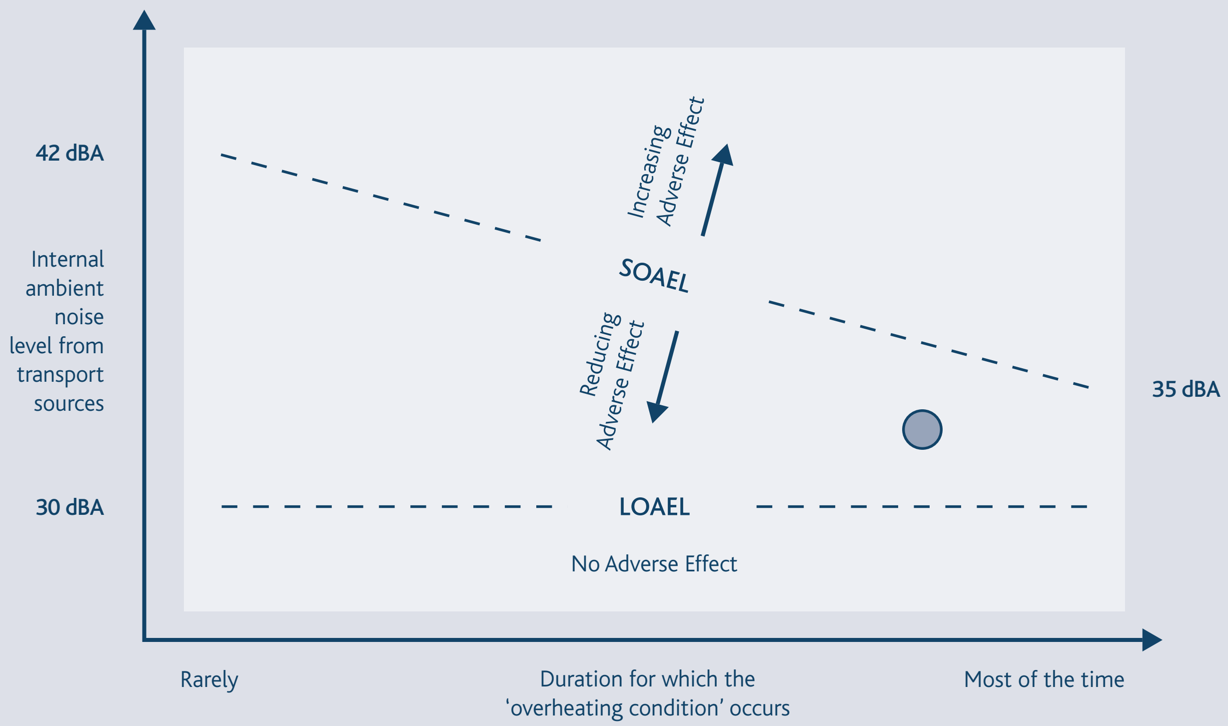
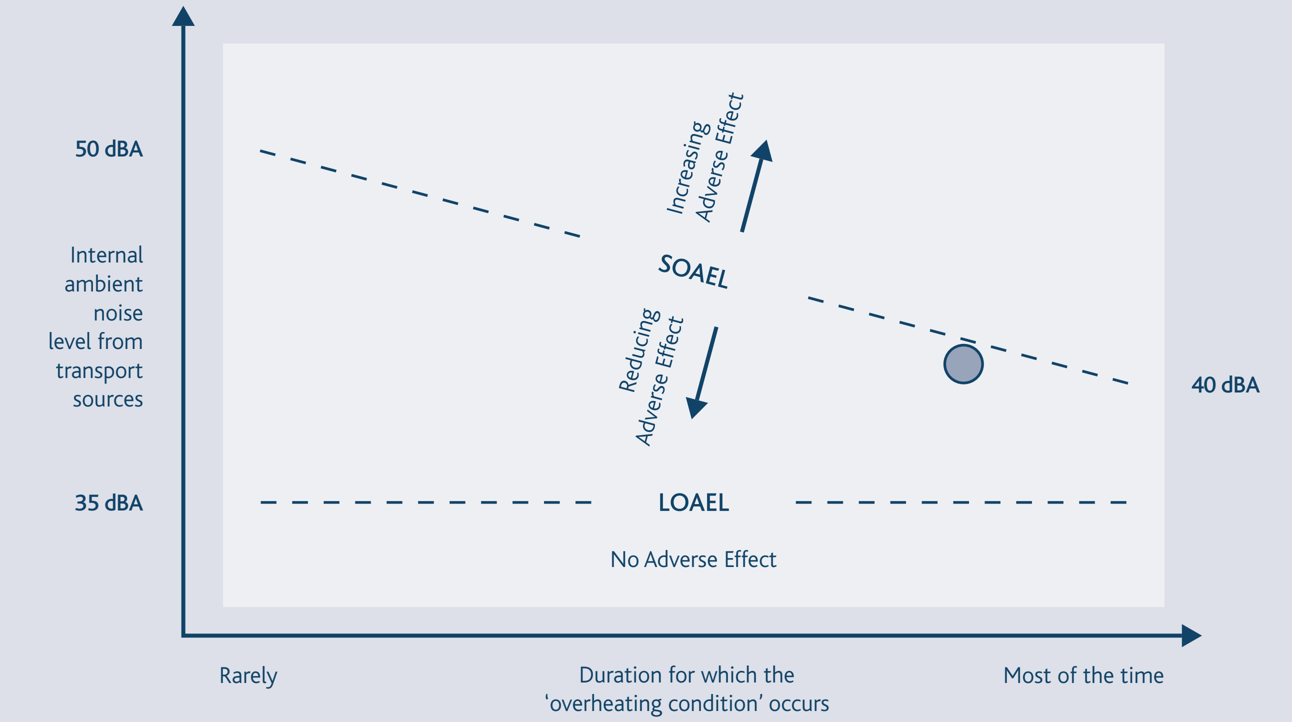


Table B-12 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor C **- Part 1 of 2**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ 64 **Night-time** $L_{Aeq,8h}$ 59 **Overheating design case** L_{AFmax} 87	High	**Southwest Elevations – Living Rooms and Bedrooms** The overheating assessment indicates a high risk of overheating. Standard opening windows are not considered to be a suitable solution for mitigating overheating. These dwellings incorporate large attenuated vents for mechanical ventilative cooling, provided with an integrated fan. Both living rooms and bedrooms have acoustically attenuated vents (2.25 m high by 1.0 m wide) that are calculated to achieve a level difference between outside and in, in combination with the other façade components, of 23 dB for road traffic noise, based on the measured incident noise spectra, and 27 dB for noise from events, L_{AFmax}. The overheating assessment confirms that the ventilation rates are adequate to suitably mitigate overheating (the acoustician should cross-reference assumptions used in the overheating assessment). An assessment of mechanical ventilative cooling noise is also required in accordance with Table 3-6. Thus, while mitigating overheating, internal noise levels are calculated to be L_{Aeq},16h 41 dB during the daytime and $L_{Aeq,8h}$ 36 dB during the night-time. Internal noise from the overheating design case for events is calculated to be L_{AFmax} 60 dB. Calculations in accordance with the detailed method in BS 8233 are presented (omitted here for brevity). The continuous equivalent levels are considered to be below the significant adverse effect level for all building façade aspects, and therefore suitable for the number of occasions for which vents are required to be open. The noise from events is also considered to be suitable with these mitigation measures, despite being above the lowest observable adverse effect level. Illustration of daytime condition with mitigation is shown immediately below, with the night-time condition illustrated further below.:	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Table B-12 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor C **- Part 2 of 2**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)



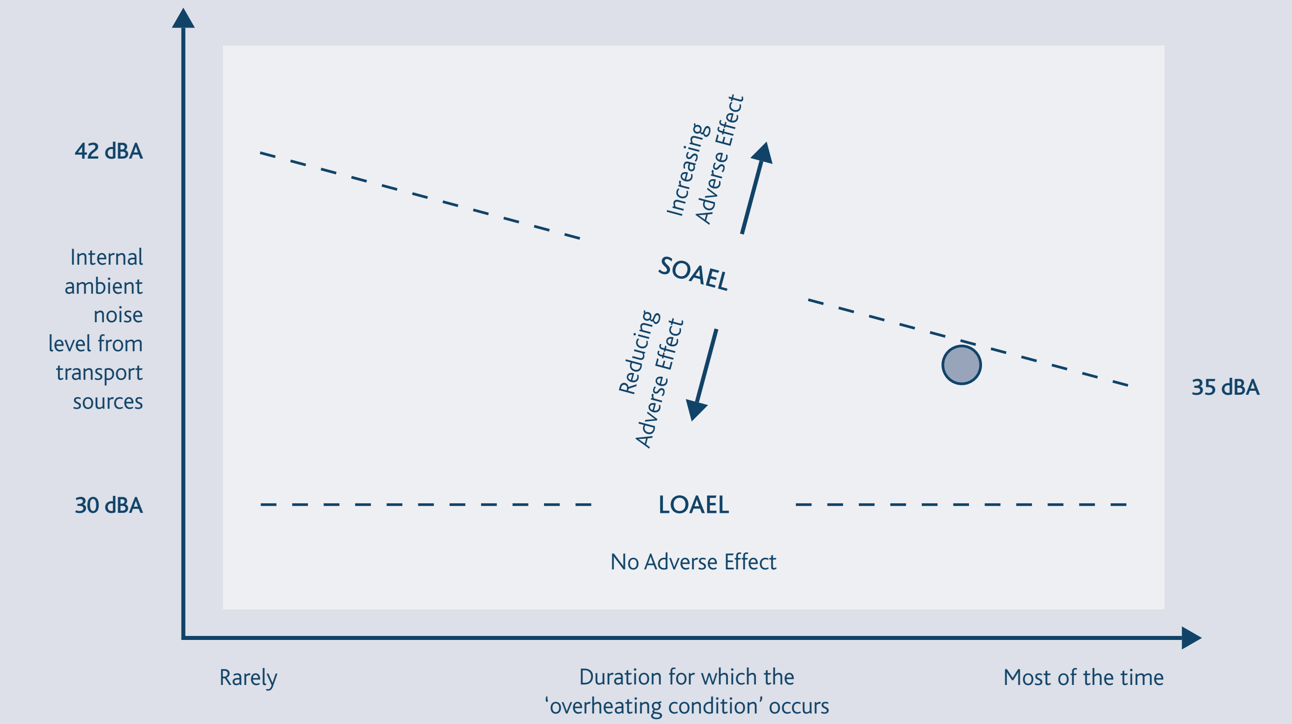


Table B-13 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor D

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 risk assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ **72** **Night-time** $L_{Aeq,8h}$ **67** **Overheating design case** L_{AFmax} **94**	High	**All Elevations – Bedrooms and Living Rooms** For these noise levels, opening windows are not considered appropriate even for the limited durations of use that are calculated. Windows are still openable for rapid dilution of smells/water vapour/VOCs. Mechanical cooling is proposed to manage thermal comfort in conjunction with the MVHR ventilation system. An assessment of mechanical noise is required, in accordance with Table 3-6.	Noise can be heard, but does not cause adverse impact internally with windows closed.

Summary of Mitigation

B.67 Table B-14 summarises the façade mitigation strategies in the worked example, the level differences achieved and calculated internal levels.

B.68 The minimum performance requirements for the relevant elements of the building envelope are noted, and potential generic products identified.

B.69 For simplicity and clarity, calculations of expected outside to inside sound insulation are made using a single-figure $R_w + C_{tr}$ or $D_{n,e,w} + C_{tr}$ / R_w or $D_{n,e,w}$, and based on a notional room of 3.0 * 2.5 * 2.4 m dimensions, with glazing to 25 % of the façade area and a 0.5 s reverberation time.

B.70 The external wall performance is calculated based on a performance of 63 (-15) dB R_w ($+C_{tr}$), such as a cavity masonry external wall build up.

Table B-14 Summary of minimum element performance requirements and associated level differences achieved - **Part 1 of 2**

		Ventilation Condition				Overheating Condition							
Location	External free-field noise levels (dB)	Design	Element performances	Expected Outside-to-inside sound insulation (dB)	Expected internal ambient noise levels (dB)	Orientation	Room Type	Design	Element performances	Expected Outside-to-inside sound insulation (dB)	Expected internal ambient noise levels (dB)	Occurrence	Level 2 Assessment
A	$L_{Aeq,16h}$ 53 $L_{Aeq,8h}$ 45 Vent D/C L_{AFmax} 63 O'heat D/C L_{AFmax} 72	ADF Sys. 1	Glazing: 31 (-6) dB R_w (C_{tr}) e.g. 4/16/4 mm double glazing Trickle vent: 34 (-1) dB $D_{n,e,w}$ (C_{tr})	$L_{Aeq,T}$ 23 $L_{AF,max}$ 25	$L_{Aeq,16h}$ 30 $L_{Aeq,8h}$ 22 *D/C:* L_{AFmax} 38	All	B&L	Standard opening windows	See Table B-5	$L_{Aeq,T}$ 13 $L_{AF,max}$ 13	$L_{Aeq,16h}$ 40 $L_{Aeq,8h}$ 32 *D/C:* L_{AFmax} 59	N/A	Not required
B	$L_{Aeq,16h}$ 59 $L_{Aeq,8h}$ 52 Vent D/C $L_{AF,max}$ 69 O'heat D/C L_{AFmax} 77	ADF Sys. 3	Glazing: 31 (-6) dB R_w (C_{tr}) e.g. 4/16/4 mm double glazing Trickle vent: 34 (-1) dB $D_{n,e,w}$ (C_{tr})	$L_{Aeq,T}$ 24 $L_{AF,max}$ 27	$L_{Aeq,16h}$ 35 $L_{Aeq,8h}$ 28 *D/C:* L_{AFmax} 42	NE	B&L	Standard opening windows	See Table B-5	$L_{Aeq,T}$ 13 $L_{AF,max}$ 13	$L_{Aeq,16h}$ 46 $L_{Aeq,8h}$ 39 *D/C:* L_{AFmax} 64	Rarely	Increasing likelihood of adverse impact, but for limited duration. Below a significant adverse effect.
						SW	L Sc1	Open windows with sound att. balconies	See Table B-5	$L_{Aeq,T}$ 17	$L_{Aeq,16h}$ 42	Often	Low end of Increasing likelihood of adverse impact. Below a significant adverse effect.
							L Sc2	Standard opening windows	See Table B-5	$L_{Aeq,T}$ 13	$L_{Aeq,16h}$ 46	Occasionally	Increasing likelihood of adverse impact, but for limited duration. Below a significant adverse effect.
						SW	B	Plenum windows	See Table B-5	$L_{Aeq,T}$ 19 $L_{AF,max}$ 22	$L_{Aeq,16h}$ 40 $L_{Aeq,8h}$ 33 *D/C:* L_{AFmax} 55	Often	Increasing likelihood of adverse impact. Below a significant adverse effect.

Table B-14 Summary of minimum element performance requirements and associated level differences achieved **- Part 2 of 2**

Location	External free-field noise levels (dB)	Ventilation Condition				Overheating Condition							
		Design	Element performances	Expected Outside-to-inside sound insulation (dB)	Expected internal ambient noise levels (dB)	Orientation	Room Type	Design	Element performances	Expected Outside-to-inside sound insulation (dB)	Expected internal ambient noise levels (dB)	Occurrence	Level 2 Assessment
C	$L_{Aeq,16h}$ 64 $L_{Aeq,8h}$ 59 Vent D/C L_{AFmax} 78 O'heat D/C L_{AFmax} 87	ADF Sys. 3	Glazing: 38 (-5) dB R_w (C_{tr}) e.g. 6/16/6.8 mm acoustic double glazing. Trickle vent: 40 (-2) dB $D_{n,e,w}$ (C_{tr}) Closed overheating vent: 52(-6) dB $D_{n,e,w}$ (C_{tr})	L_{AeqT} 30 L_{AFmax} 33	$L_{Aeq,16h}$ 34 $L_{Aeq,8h}$ 29 *D/C:* L_{AFmax} 45	SW	B&L	Acoustic vents, mechanical ventilative cooling	Glazing and trickle vent performances as for ventilation condition Open overheating vent: 33(-4) dB $D_{n,e,w}$ (C_{tr})	L_{AeqT} 23 L_{AFmax} 27	$L_{Aeq,16h}$ 41 $L_{Aeq,8h}$ 36 *D/C:* L_{AFmax} 60	SW - Often	Increasing likelihood of adverse impact. Below a significant adverse effect.
D	$L_{Aeq,16h}$ 72 $L_{Aeq,8h}$ 67 Vent D/C L_{AFmax} 83 O'heat D/C L_{AFmax} 94	ADF Sys. 4	Glazing: 43 (-7) dB R_w (C_{tr}) e.g. 8/16/9.1 mm acoustic double glazing	L_{AeqT} 37 L_{AFmax} 45	$L_{Aeq,16h}$ 35 $L_{Aeq,8h}$ 30 *D/C:* L_{AFmax} 38	All	B&L	Mechanical cooling	As for ventilation condition	As for ventilation condition	$L_{Aeq,16h}$ 35 $L_{Aeq,8h}$ 30 *D/C:* L_{AFmax} 49	As required (no acoustic constraints)	Negligible (for external noise, with windows closed)

C Appendix C – sound insulation of a partially open window

Sound Insulation for a Partially Open Window

For the purposes of this guide, the sound insulation is quantified in terms of the difference between the external free-field noise level at the location of the façade and the internal reverberant level in the room. Reference is made to two studies [43, 57] in order to provide an estimate of the typical level difference for a partially open residential window.

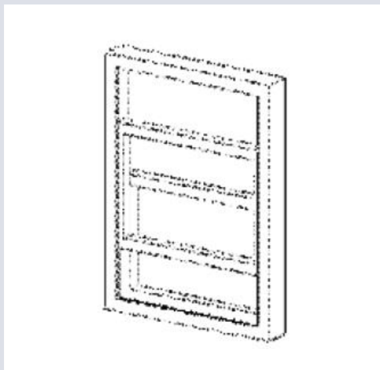
Field Study [57]

Field measurements were made in 102 traffic noise affected dwellings in Switzerland. The study distinguishes between 'open' and 'tilted' windows. No measurements of window size or open area were made, but the images show typical situations.

They measured (free-field) outside-to-inside level differences of 10.0 ± 2.9dB for open windows and 15.8 Open ± 2.7dB for tilted windows. A value of 13dB is consistent with a situation between 'open' and 'tilted'

Open

Tilted



Window Type D-1

Lab Study [43]

Laboratory measurements were made for 14 window types/arrangements with various degrees of opening. The derived Dn,e results for a 0.2m² area of opening are summarised in Table 5-5 of the document. The values for window type D-1 (Sash window with upper section open – see image) have been used to represent a conservative situation. If the area of opening is assumed to be 2% of the floor area of the room, the D2m,nT will be approximately equal to the Dn,e. Window type D-1 has Dn,e,w(C;Ctr)=16(0;0). Applying a 3dB correction between L1,2m and the free-field value suggests an outside-to-inside level difference of 13dB. It is worth noting that hinged opening windows (e.g. types C-3, D-3, E) were found to provide level differences that were 1-2dB higher. Benefits may also be achieved for off-axis, directional sources. However, it was not considered advisable to include these factors when estimating a typical performance.

References

- Part 1 of 4

Ref	Title	Author/Publisher	Year
1	ProPG Planning & Noise – New Residential Development	ANC/IOA/CIEH	2017
2	Using planning conditions to improve indoor environmental quality (IEQ) of new residential developments	Conlan, N and Harvie-Clark, J Acoustics 2018, IOA Proceedings Volume 40, Part 1, p77-86	2018
3	Approved Document F – Ventilation (2010 edition incorporating 2010 and 2013 amendments)	HM Government	2015
4	TM59 Design methodology for the assessment of overheating risk in homes	Chartered Institution of Building Services Engineers	2017
5	UK housing: Fit for the future?	Committee on Climate Change	2019
6	Next Steps in Defining Overheating	Zero Carbon Hub	2016
7	Passive House Planning Package	Passive House Institute	2015
8	Overheating in New Homes	Good Homes Alliance	2019
9	The London Plan	Greater London Authority	2016
10	Noise Policy Statement for England	Department for Environment, Food & Rural Affairs	2015
11	National Planning Policy Framework	Department for Communities and Local Government	2012
12	Planning Practice Guidance (Noise)	Department for Communities and Local Government	2012
13	British Standard 8233:2014 Guidance on sound insulation and noise reduction for buildings	British Standards Institution	2014
14	Guidelines for Community Noise	World Health Organisation	1999
15	Environmental Noise Guidelines for the European Region	World Health Organisation	2018
16	Night Noise Guidelines for Europe	World Health Organisation	2009
17	Aircraft noise effects on sleep: application of the results of a large polysomnographic field study	Basner, M, Samel, A and Isermann, U Journal of the Acoustical Society of America, Volume 119, 5 (Part 1), p2772–84	2006
18	WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep	Basner, M and Mcguire, S International Journal of Environmental Research and Public Health, Volume 15 (3), p519	2018

References

Ref	Title	Author/Publisher	Year
19	Building our Future: Laying the Foundations for Healthy Homes and Buildings White paper	All Party Parliamentary Group	2018
20	How loud is too loud? Noise from domestic mechanical ventilation systems	Harvie-Clark, J, Conlan, N, Wei, W and Siddall, M International Journal of Ventilation	2019
21	Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet	Department for Environment, Food & Rural Affairs	2014
22	Assessing L_{max} for residential developments: the AVO Guide Approach	Paxton, B, Conlan, N, Harvie-Clark, J, Chilton, A, Trew, D Acoustics 2019, IOA Proceedings Volume 41 Part 1	2019
23	Guidelines for Environmental Noise Impact Assessment	Institute of Environmental Management and Assessment	2014
24	Understanding the role of inhabitants in innovative mechanical ventilation strategies	Brown, C and Gorgolewski, M Building Research & Information, Volume 43, Part 2, p210-221	2015
25	Ventilation in new homes – A report of site visit findings	Zero Carbon Hub	2016
26	Why this crisis in residential ventilation?	Hasselaar, E Indoor Air 2008, paper ID 690	2008
27	The relationship between health complaints, the quality of indoor air and housing characteristics.	Hady M, van Ginkel, J, Hasselaar, E and Schrijvers, G Indoor Air 2008, paper ID 153	2008
28	Mechanical ventilation in recently built Dutch homes: technical shortcomings, possibilities for improvement, perceived indoor environment and health effects	Balvers, J, Bogers, R, Jongeneel, R, van Kamp, I, Boerstra, A and van Dijken, F Architectural Science Review, Volume 55, Part 1, p4-14	2012
29	BS 8233:1999 Sound insulation and noise reduction for buildings (withdrawn)	British Standards Institution	1999
30	Guide A – Environmental Design	Chartered Institution of Building Services Engineers	2015
31	Sound Control for Homes	Building Research Establishment	1993
32	BS ISO 17772-1:2017 Energy performance of buildings. Indoor environmental quality. Indoor environmental input parameters for the design and assessment of energy performance of buildings	British Standards Institution	2017

References

Ref	Title	Author/Publisher	Year
33	Transport and Urban Development COST Action TU0901	European Cooperation in Science and Technology	2013
34	BS EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics	British Standards Institution	2007
35	ISO 7730:2005 Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria	International Organization for Standardization	2005
36	Approved Document L1A: Conservation of fuel and power in new dwellings (2013 edition with 2016 amendments)	HM Government	2016
37	Energy Planning — Greater London Authority guidance on preparing energy assessments	Greater London Authority	2016
38	Home Quality Mark Technical Manual	BRE Global Limited	2016
39	TM52 The Limits of Thermal Comfort: Avoiding Overheating in European Buildings	Chartered Institution of Building Services Engineers	2013
40	Standard Assessment Procedure	Department for Business, Energy & Industrial Strategy	2012
41	Housing Health and Safety Rating System	Ministry of Housing, Communities & Local Government	2006
42	Ventilative cooling. State-of-the-art review executive summary	Heiselberg, P & Kolokotroni, M (editors) Energy in Buildings and Community Programme http://venticool.eu/annex-62-publications/deliverables/	2017
43	NANR116 Open-Closed Window Research Report	Department of Environment, Food & Rural Affairs	2007
44	BS EN 1793-3:1998 Road traffic noise reducing devices. Test method for determining the acoustic performance. Normalized traffic noise spectrum	British Standards Institution	1998
45	BS EN 12354-3:2017 Building acoustics. Estimation of acoustic performance of buildings from the performance of elements. Airborne sound insulation against outdoor sound	British Standards Institution	2017

References

- Part 4 of 4

Ref	Title	Author/Publisher	Year
46	Technical housing standards – nationally described space standard	Department for Communities and Local Government	2015
47	BS EN 12758:2011 Glazing and airborne sound insulation. Product descriptions and determination of properties	British Standards Institution	2011
48	Green Book: Environmental Noise Measurement Guide	The Association of Noise Consultants	2013
49	A Review of Residential Balconies with Road Traffic Noise	Naish, D and Tan, A Proceedings of ICSV14	2007
50	Adopting Specially Designed Balconies to Achieve Substantial Noise Reduction for Residential Buildings	Yeung, M Proceedings of Internoise 16, p 1185-90	2016
51	Research and Development of Noise Mitigation Measures for Public Housing Development in Hong Kong - A Case Study of Acoustic Balcony	Hin-Leung Ho, J Proceedings of Internoise 16, p 1199-1207	2016
52	The field performance of partially open dual glazing	Kerry, G and Ford, R D Applied Acoustics, Volume 7, p 213-227	1974
53	Open windows with better sound insulation,	Sondergaard, L S and Egedal, R Proceedings of Internoise 16, p 1173-84	2016
54	Noise control strategies for naturally ventilated	De Salis, M H F , Oldham, D J and Sharples, S Building and Environment, Volume 37, p471-84	2002
55	Methods of Controlling Noise Levels and Overheating in Residential Buildings	Conlan, N and Harvie-Clark, J ICSV 24 Proceedings, p5674	2017
56	A review of ventilation opening area terminology	Jones, B M, Cook, M J, Fitzgerald, S D and Iddon, C R Energy and Buildings, Volume 118, p249-258	2016
57	Differences between Outdoor and Indoor Sound Levels for Open, Tilted, and Closed Windows	Locher, Wunderli et. al. International Journal of Environmental Research and Public Health, Volume 15(1), p149 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5800248/	2018

ACOUSTICS, VENTILATION AND OVERHEATING

Residential Design Guide

January 2020 This document is published by the Association of Noise Consultants

ANC | ACOUSTICS & NOISE CONSULTANTS

Association of Noise Consultants
19 Omega Business Village, Thurston Road, Northallerton DL6 2NJ
Tel: 0208 253 4518
Email: INFO@THEANC.CO.UK

Reference 6

CAP 1588 Feb18

Aircraft Noise and Annoyance: Recent findings

CAP 1588

Published by the Civil Aviation Authority, 2018
Civil Aviation Authority,
Aviation House,
Gatwick Airport South,
West Sussex,
RH6 0YR.

First published 2018

Enquiries regarding the content of this publication should be addressed to: [redacted]@caa.co.uk
Environmental Research and Consultancy Department, CAA House, 45-59 Kingsway, London, WC2B 6TE

The latest version of this document is available in electronic format at www.caa.co.uk,

Contents

Chapter 1
Introduction

The aim of this report is to provide an overview of the recent research into and state of knowledge on the effects of aircraft noise and annoyance responses. It is a complex area, and this report is split into sections in order to cover each subject.

Chapter 2 addresses the definition of annoyance and how it came to attention as a public issue, the pathways in which annoyance can interact with other health endpoints and external factors, and an explanation of the current thresholds for describing degrees of annoyance.

Chapter 3 describes the methodologies used to measure aircraft noise-induced annoyance, and the most commonly used dose-response relationships to date.

Chapter 4 discusses the recent developments in research findings over the past ten years or so, and suggestions for how methodologies could be improved for future research.

Chapter 5 explains the complexities of how non-acoustic factors can influence the annoyance results and new methods that may be employed to take account of them when designing future annoyance studies.

Chapter 6 offers a summary of the report and conclusions.

Chapter 2
Background

The ever-increasing demand for regular and convenient road, rail and aircraft transportation consequently brings with it an increase in environmental noise and subsequent effects.

The most widespread and well documented subjective response to noise is annoyance; which can be defined as a feeling of resentment, displeasure, discomfort, dissatisfaction or offence which occurs when noise interferes with thoughts, feelings or activities. The annoyance of populations exposed to environmental noise varies not only with the acoustical characteristics of the noise, but also with a range of non-acoustical factors of social, psychological or economic nature.

Transportation noise, amongst other noise sources such as that from construction, was brought to people's attention in 1963, via a report entitled "Noise", written by the Committee on the Problem of Noise, and commonly referred to as the "Wilson Report" after Sir Alan Wilson, Chairman of the committee. The Wilson Report stated that solving "noise problems must involve people and their feelings, and its assessment is a matter rather of human values and environments than of precise physical measurement". The issues raised in the Wilson Report are still, if not more, relevant today with an increasing demand for travel, 24-hour society and requirements for transport links.

Annoyance is considered to be a detriment to quality of life, well-being and ultimately, health. The Word Health Organization's (WHO) definition of health is[1]:

"Health is a state of complete physical, mental and social well-being, and not merely an absence of disease and infirmity."

Annoyance from any source represents a diminished state of well-being and noise is often referred to as the stressor that is implicated in a variety of responses (Figure 1). In their 'evidence review of annoyance' paper, (2016) the WHO described the complex annoyance response to noise as comprising three main elements:

1. An often repeated disturbance due to noise (repeated disturbance of intended activities e.g. communicating with other persons, listening to TV or music, reading, working, sleep), and often combined with behavioural responses in order to minimise disturbance.

2. An attitudinal response (anger about the disturbance, and negative evaluation of the noise source) and;

[1] World Health Organization. (2006). *Constitution of the World Health Organization* – *Basic Documents*, Forty-fifth edition, Supplement, October 2006.

3. A cognitive response (a distressful insight that one cannot do much about this unwanted situation).

Such responses are consolidated with memory of the stressor, or noise, and thus result in a long-term annoyance response to noise.

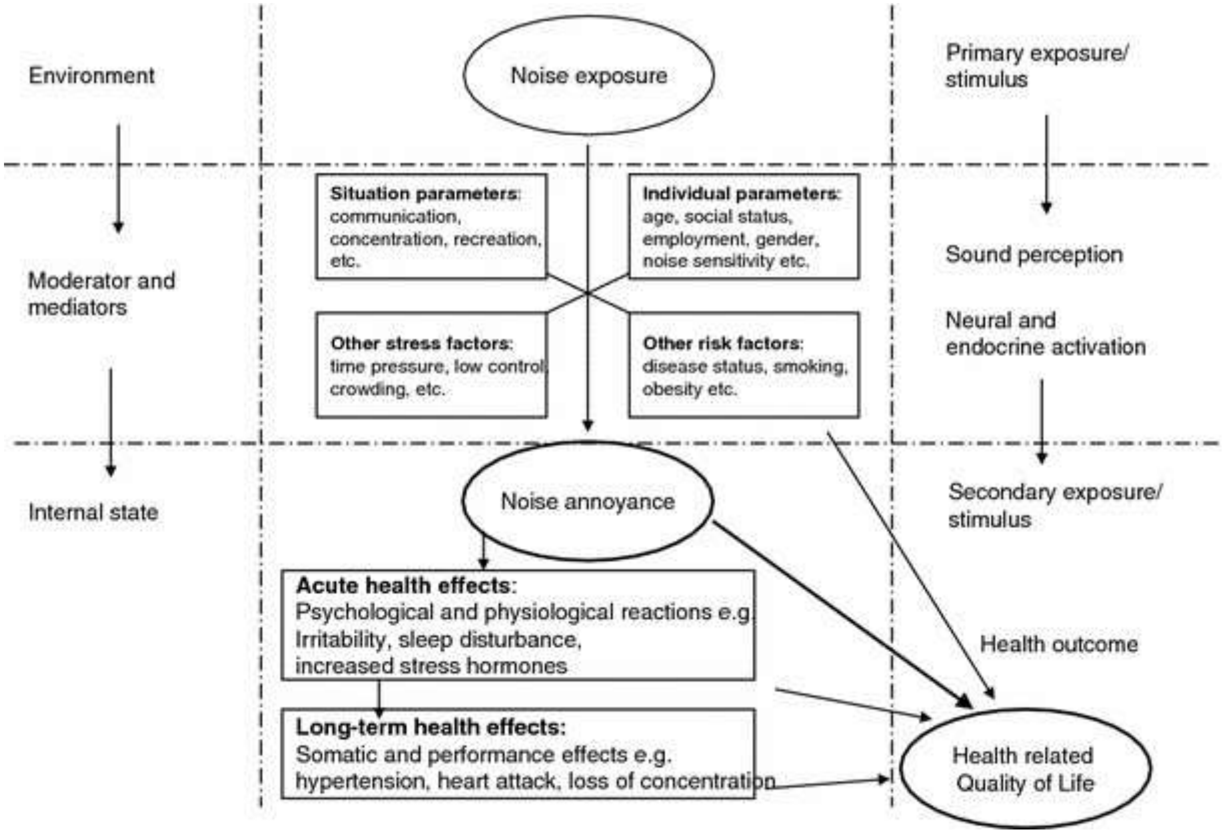


Figure 1: Conceptual model of non-auditory effects of environmental noise and noise annoyance (reproduced from Dratva et al, 2010)

Figure 1 illustrates the pathways that connect the noise exposure to the annoyance response and ultimately, health related quality of life. The diagram includes external factors, or mediators, which may contribute to the risk of annoyance and the internal state of the responder, and their subjective response. Although this diagram was taken from a paper reporting on a road traffic study, the pathways are identical for aircraft noise and the resulting outcomes. Figure 1 is a good illustration of the complexities in trying to separate out the contribution from noise annoyance alone, to health related quality of life outcomes, particularly due to the many potential moderators/mediators that must be controlled for.

In order to provide public protection from aircraft noise, an ‘annoyance threshold’ currently exists within UK policy. The time period for noise exposure used is an average summer day, from June 16th to September 15th and from 7am to 11pm. The Wilson report originally recommended the use of summer days (7am – 7pm) due to the increased likelihood of more people being outdoors and having windows open, and also because aviation levels are at their highest during summer months. The 1982 Aircraft Noise Index Study, the outcomes of which were adopted in policy in 1990, extended the reference day period from

7am to 11pm to reflect that there is a difference in terms of daytime and night-time noise exposure and consequently, annoyance reactions, resulting in the need for distinctive daytime and night-time noise exposure metrics. The noise exposure metric $L_{Aeq,16h}$, was adopted in 1990 on the basis of the ANIS findings. The UK government defined three thresholds for policy consideration: 57, 63 and 69 dB L_{Aeq16h}, representing low, moderate, and high annoyance levels.

The 2003 Air Transport White Paper subsequently defined 57dB $L_{Aeq,16h}$ as marking the approximate onset of significant community annoyance, and this was reaffirmed in the Government's 2013 Aviation Policy Framework. Critics argue that attitudes have changed since the 1982 survey. This could be because of general shifts in attitudes to annoyance, changes in the pattern of aircraft noise experienced, and/or because of changes to lifestyle that are affected by aircraft noise. This ultimately led to the UK government commissioning the Survey of Noise Attitudes 2014: Aircraft study[2]. The methods for measuring annoyance are discussed in Chapter 3.

The government published their Response[3] to their Airspace Consultation in 2017 and acknowledged the evidence from the SoNA study, which showed that sensitivity to aircraft noise has increased, with the same percentage of people reporting to be highly annoyed at a level of 54 dB $L_{Aeq,16hr}$ as occurred at 57 dB $L_{Aeq,16hr}$ in the past.

Taking account of this and other evidence on the link between exposure to noise from all sources and chronic health outcomes, the government decided to adopt the risk based approach proposed in their consultation, so that airspace decisions are made in line with the latest evidence and consistent with current guidance from the World Health Organisation.

In 2010 the Department for Environment, Food and Rural Affairs (Defra) released the Noise Policy Statement for England (NPSE), which aimed to provide clarity on noise and set out the government's long-term vision of noise policy for all noise sources. The noise policy vision was to "promote good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development."

The NPSE aims are:

Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of government policy on sustainable development:

- avoid significant adverse impacts on health and quality of life;
- mitigate and minimise adverse impacts on health and quality of life; and
- where possible, contribute to the improvement of health and quality of life.

2 CAP1506. Survey of Noise Attitudes 2014: Aircraft. Civil Aviation Authority on behalf of the DfT.

3 Consultation Response on UK Airspace Policy: A framework for balanced decisions on the design and use of airspace. Department for Transport. 2017

The phrases “Significant adverse” and “adverse” refer to the two established concepts that are applied to noise impacts worldwide, namely:

NOEL – No Observed Effect Level

This is the level below which no effect can be detected. In simple terms, below this level, there is no detectable effect on health and quality of life due to the noise.

LOAEL – Lowest Observed Adverse Effect Level

This is the level above which adverse effects on health and quality of life can be detected.

Extending these concepts for the purpose of the NPSE leads to the concept of a significant observed adverse effect level.

SOAEL – Significant Observed Adverse Effect Level

This is the level above which significant adverse effects on health and quality of life occur.

It is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times. SOAEL is therefore not specifically defined in the NPSE, for flexibility purposes in the future, with the addition of more research findings.

Annoyance from aircraft noise is a global issue, not just confined to the UK. In 2011, the WHO Europe and the Joint Research Centre published the report: Burden of Disease from Environmental Noise. The aim of this report was to provide technical support to policy-makers in the form of quantitative risk assessment of environmental noise, using the evidence available in Europe.

For each noise-induced outcome, the report estimated the number of life years that are affected by noise, defined as Disability Adjusted Life Years (DALYs). DALYs are the sum of the potential years of life lost due to premature death and the equivalent years of “healthy” life lost by virtue of being in states of poor health or disability. The outcomes included were ischemic heart disease, cognitive impairment of children, sleep disturbance, tinnitus and annoyance. It was estimated that 654,000 years were lost annually due to annoyance in the EU Member States, and other western European countries (from combined noise sources, but predominantly road traffic noise). This was only exceeded by those lost due to sleep disturbance annually, which were calculated as 903,000 years.

All transportation noise sources result in a degree of annoyance, and this remains a growing concern, particularly with the possible links to other health endpoints. This report will focus on aircraft noise-induced annoyance. Annoyance from aircraft noise and other transportation sources is often studied as part of complex pathways which may exist between acute and chronic health effects such as cardiovascular disease, disturbed sleep patterns with subsequent next-day effects, and even the cognitive performance and learning aspects in children, as detailed in the Burden of Disease Report.

The much anticipated update to the 1999 WHO Community Noise Guidelines is currently being developed, and it is expected that this document will now be published in 2018.

Chapter 3
Measuring Annoyance

Annoyance is a subjective response and therefore cannot be measured objectively, but rather through self-rated responses to survey questions as part of social survey studies that are linked to the aircraft (or other transportation source) noise exposure level of each respondent.

In this field, a widely quoted seminal dose-response relationship is the Schultz curve (Schultz, 1978). The Schultz curve (Figure 2) is a graph of percentage highly annoyed against noise exposure level; it was based on data from numerous social survey studies of public reactions to transport noise available at that time. Since 1978 there have been a number of subsequent extensions and updates of the original Schultz work.

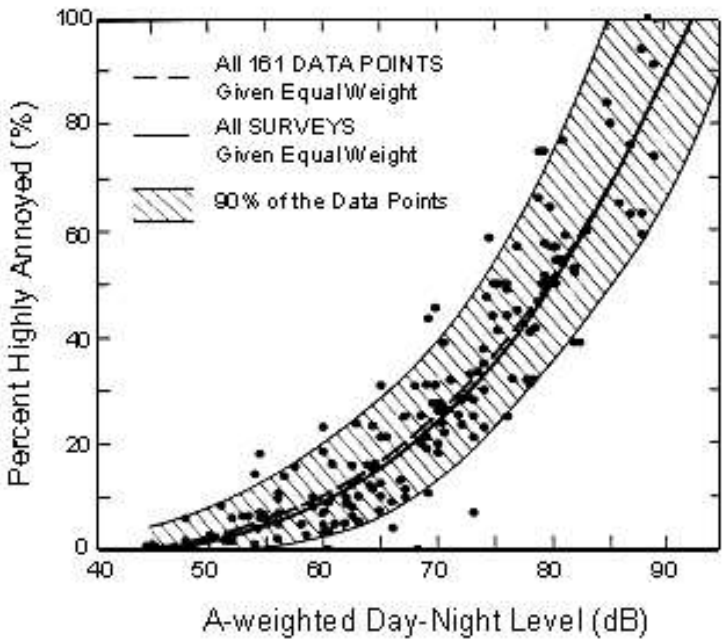


Figure 2: The original Schultz curve (1978)

Schultz used "highly annoyed" (HA) as the measure of community response and day-night average sound level (DNL)[4] as the measure of the noise environment. There is significant scatter to the data points and the 90 percent prediction intervals are quite sizeable.

Schultz identified different reactions to different noise sources, but did not make it a feature of his work. However later researchers found considerable differences in

[4] The day-night average sound level (Ldn or DNL) is the average noise level over a 24-hour period. The noise between the hours of 10pm and 7am is weighted by an increase of 10 dB. This is to take into account the decrease in background noise during this period.

annoyance for the same noise level from different sources. For example, a synthesis by Miedema and Vos (1998) (building further on the Schultz curve approach), of data for three types of transport noise (road, air, and railway) suggests that aircraft noise produced a stronger annoyance response than road traffic and that the annoyance response to rail noise was less than for road traffic.

Since the WHO Guidelines (1999) were published there have been many further studies of annoyance from transport noise, these studies provide new data on specific local circumstances and contribute to the database that can be used for developing dose-response curves. Miedema (2001) reanalysed the available international data on transport noise and annoyance (a total of 45 studies including 19 studies on aircraft noise) and produced revised curves for the relationships for the association between noise from road, rail and aircraft and annoyance using DNL (day-night level) and DENL (day-evening-night level). Figure 3 illustrates the Miedema curves for road, rail and aircraft plotted against DENL. The distribution of the annoyance scores at a given noise exposure level can be summarised in various ways. Often a cut-off point is chosen on the scale, and the percentage of the responses exceeding the cut-off is reported. If the cut-off is 72 on a 0–100 scale, then the result is called the percentage of “highly annoyed” people (%HA); with a cut-off at 50 it is the percentage “annoyed” (%A), and with a cut-off at 28 it is the percentage “(at least) a little annoyed” (%LA). An alternative to these types of measures is the average annoyance score.

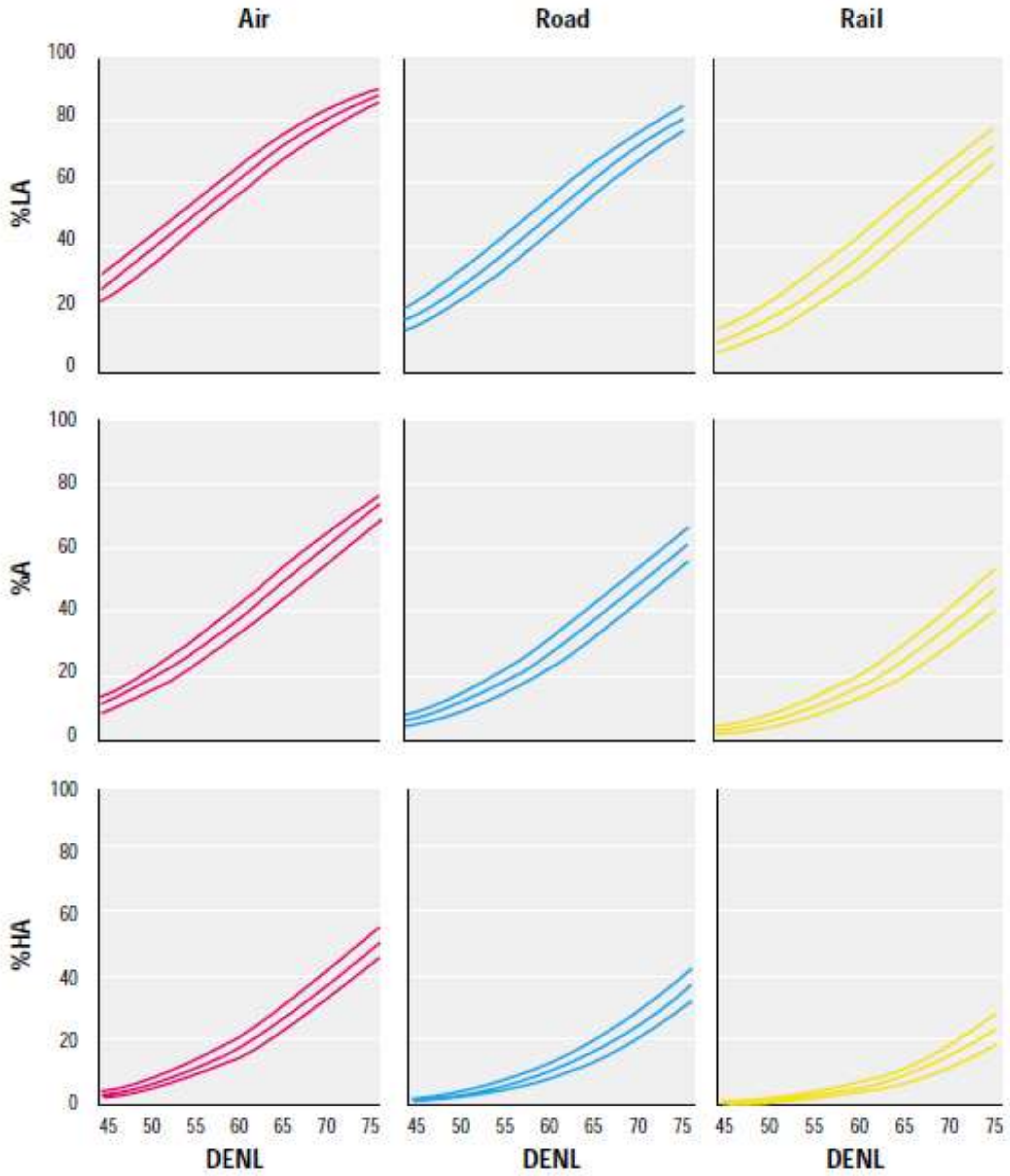


Figure 3: Miedema and Oudshoorn (2001) annoyance curves for aircraft, road and rail noise against DENL, including 95% confidence levels. LA = at least “a little annoyed”, A = “annoyed”, HA = “highly annoyed”

The above charts and DENL indicator were adopted as the European Common indicators for noise exposure for road, rail and air.

Miedema published a discussion paper on annoyance (2007), in which he proposed a model of environmental noise disturbance as a stressor, impacting on behaviour (communication, concentration) and desired state (sleep and relaxation), with the ability to cope with such disturbance being important for health and well-being. The effects of noise depend on acoustical characteristics of the noise, such as loudness, time, pattern, and on aspects of the noise situation that may involve cognitive processing, such as expectations regarding the future development of the noise exposure, lack of short-term predictability, and a feeling of a lack of control over the source of the noise. Miedema suggests that the model (Figure 4) involves four routes through which noise exerts its primary influence.

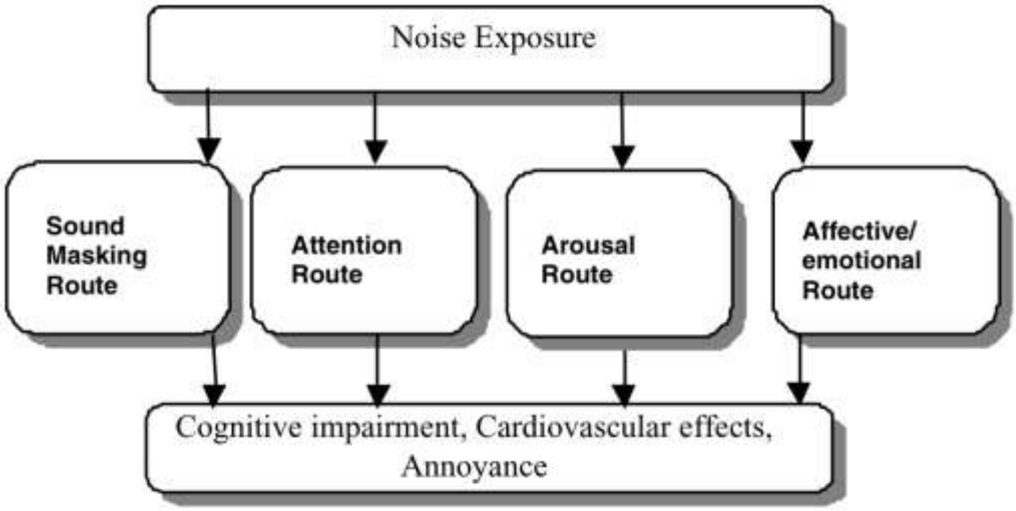


Figure 4: Miedema's (2007) model illustrating the four pathways through which the effects of noise are mediated.

Of the four pathways in Figure 4, three relate to daytime annoyance and the Arousal Route refers to night-time sleep disturbance, which will not be discussed here as this report relates to annoyance only.

Sound Masking Route

This route reduces the comprehension of speech and masks speech, signals, music or natural sounds. International standards for the assessment of speech communication say that one-to-one conversation 1 metre apart requires that the noise level does not exceed 41dBA. These are very rarely achieved in urban areas and imply that the effects of environmental noise on communication are ubiquitous, especially in cities.

Attention Route

Noise can negatively affect processes requiring attention. The effect of noise is probably most harmful when impacting on working memory, and has been found to depend on the priority and difficulty of the memory task, and type of sound. Millar (1979) indicated that it is the rehearsal of the items in working memory that is negatively affected by noise. If noise detracts from rehearsal it can have negative effects on the ability to derive implications and restructure information into more meaningful clusters.

Affective/Emotional route

As a result of noise affecting sleep, concentration, communication etc this frustration may lead to irritation or anger reactions. Fear can also be elicited with noise if it is associated with danger that threatens the individual. In this context it may be the worry of being in close proximity to an airport and therefore the concern over accidents that may induce fear, along with self-reported sensitivity to noise. People high in trait anger may be more likely to show stronger emotional reactions when noise disturbs them.

Miedema suggests that through masking, noise reduces comprehension, and through its effect on attention, noise affects the mental processing of information e.g. in reading. Also, it may elicit emotional reactions when it interferes with behaviour or a desired state and may act as a stressor, or when it is associated with fear (aircraft noise). Such primary effects may in the long-term lead to annoyance, cognitive impairment, and/or cardiovascular effects. Chronic stress is also likely to be important in some long-term effects, in particular cardiovascular effects.

Dose-Response Function for different transport sources

Annoyance is an insightful gauge of adverse noise effects and by itself means that noise affects people's quality of life as shown in Figure 1. Therefore it is often taken as an indicator of the acoustical climate. For noise annoyance, extensive research has provided relationships that give the expected noise annoyance at a given level of noise exposure. Miedema conducted a further meta-analysis of several studies examining the effects of aircraft, road and railway noise on annoyance, including the original Shultz data and that from other meta-analyses by Fidell (2001), to produce a set of dose-response relationships for each transport mode, (Figure 5). L_{den} is the yearly "average" of the daytime level (0700–1900), evening level (1900–2300) plus 5 dBA, and night-time level (2300– 0700) plus 10 dBA at the most exposed facade of a dwelling. The "A" indicates that contributions to noise from different frequencies are weighted according to the sensitivity of the ear for those frequencies.

The relationships indicate again that aircraft noise elicits a higher degree of annoyance than road or rail, though the reasons for this cannot be concluded. It is possible that due to the quiet periods between trains, annoyance is less than the constant stream of road traffic. It could be that the regularity of flights and inability to get away from the noise at a different façade of the building may be contributing factors for the response to aircraft noise being higher than the other two noise sources, along with a myriad of other hypotheses. There are also complex relationships between the annoyance response and non-acoustical factors, for example fear and individual noise sensitivity. Non-acoustical factors will be discussed in Chapter 5.

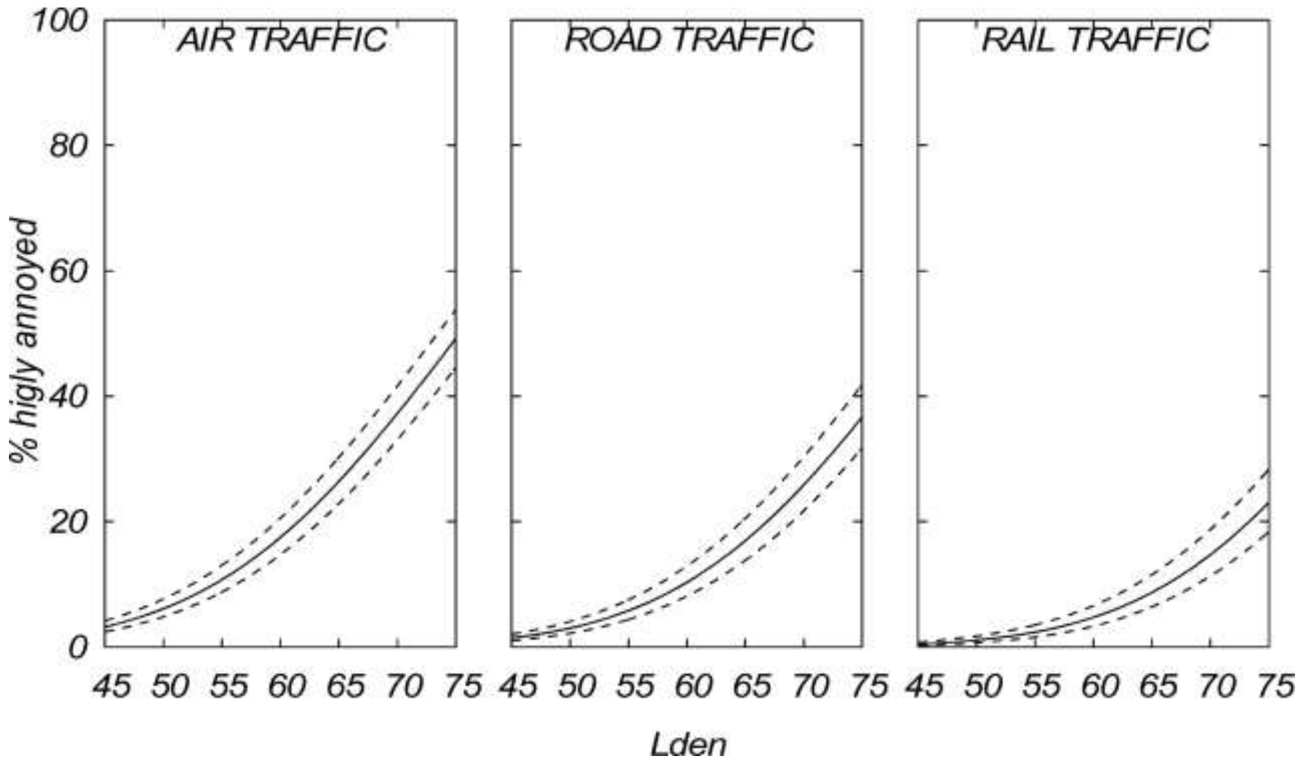


Figure 5: The percentage highly annoyed (%HA; solid lines) as a function of L_{den}, for air, road, and rail traffic noise, and the confidence interval (broken lines). Miedema (2007)

Community Tolerance Level

In 2011 Fidell et al published a paper on their model for estimating the prevalence of annoyance with aircraft noise exposure. There are issues surrounding single metric predictors of annoyance, such as DNL, in light of previous evidence suggesting that annoyance comprises both non-DNL and acoustic components in addition to the DNL metric. Debate continues about optimal metrics for predicting transportation noise impacts; and about the relative importance of acoustic and non-DNL related influences on annoyance. There are also discussions about effects of transportation modality and annoyance responses, national and regional differences, and about temporal trends in sensitivity to transportation noise. The issue of variability was discussed by Fidell, with Figure 6 illustrating how wide the variation of annoyance responses can be.

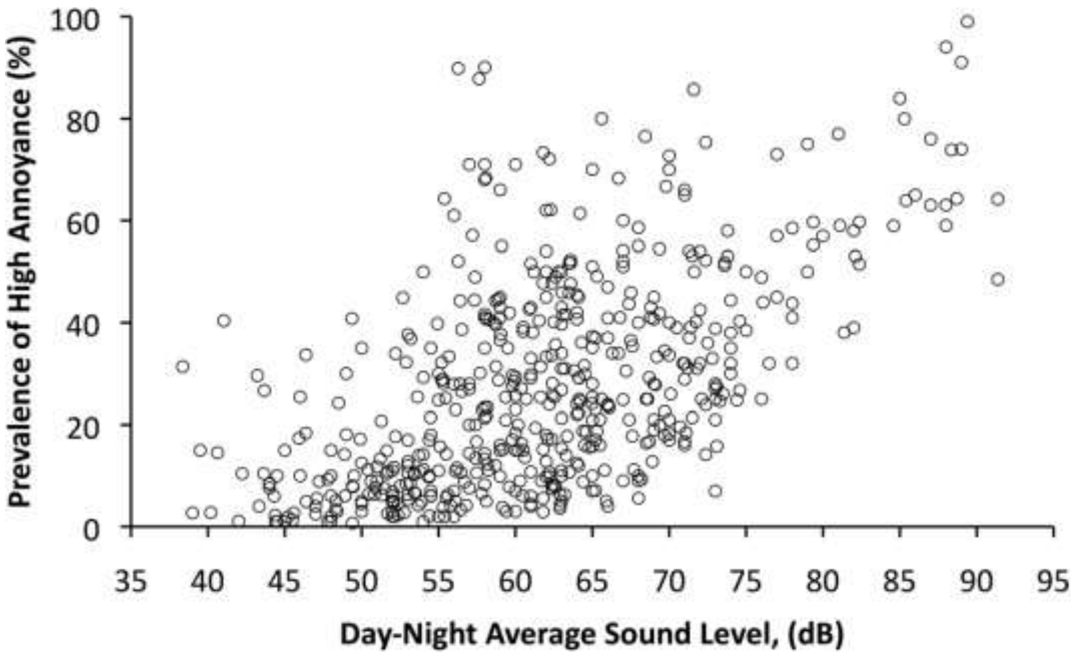


Figure 6: Illustration of variability in annoyance prevalence rates as a function of cumulative noise exposure. Each point represents an estimate of the prevalence of high annoyance at a single interviewing site.

The variability of annoyance prevalence rates can affect the usefulness of predictions developed from dose-response curves; therefore Fidell et al developed an alternate approach to prediction, based on an explanatory model which uses the findings of Stevens (1972), Fidell, Schultz (1978), and Green (1988), and Green and Fidell (1991). The model adds one predictor variable to DNL—a standardised "community tolerance level" (CTL). A "community tolerance level," is normalised to the DNL value at the middle of the best-fitting effective loudness function for each community. Figure 7 shows the calculated CTLs from the findings of six communities exposed to aircraft noise. This additional parameter enables analyses of the characteristic variability of findings in social surveys on transportations noise and annoyance. The model also accounts for more variance in annoyance prevalence rates than predictions based on DNL alone. The rate of change of annoyance with day-night average sound level (DNL) due to aircraft noise exposure was found to closely resemble the rate of change of loudness with sound level.

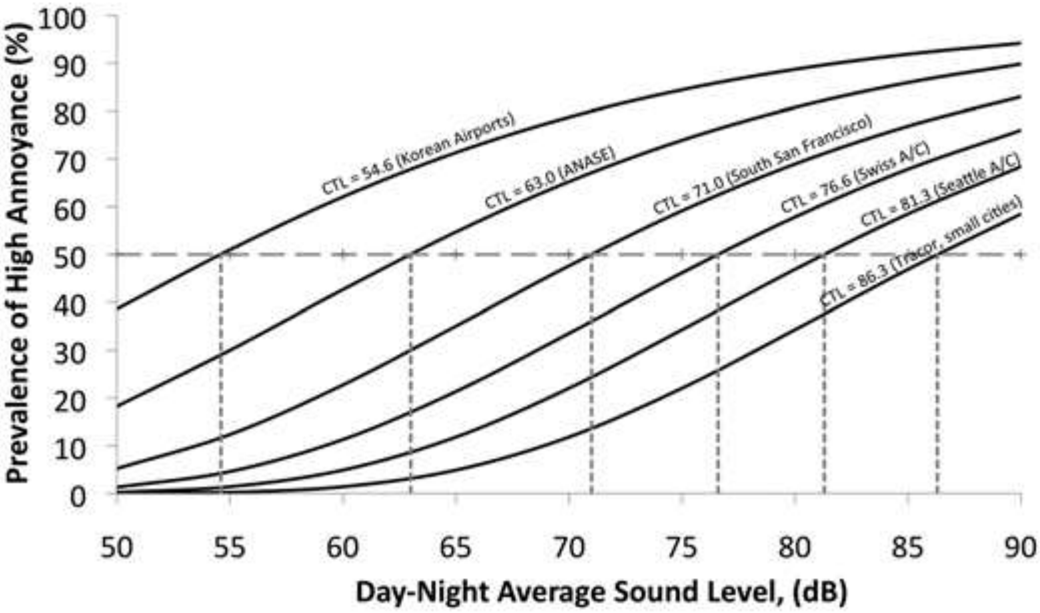


Figure 7: CTL values computed from the findings of six surveys of communities exposed to aircraft noise. Note that CTL values for the different communities shown vary over a range of 30 dB.

The authors found that there was agreement of model predictions with the findings of previous curve-fitting studies such as Miedema and Vos (1998). Even though annoyance prevalence rates within individual communities consistently grow in proportion to duration-adjusted loudness, variability in annoyance prevalence rates across communities remains great.

Fidell's analyses demonstrate that (1) community-specific differences in annoyance prevalence rates can be plausibly attributed to the joint effect of acoustic and non-DNL related factors and (2) a simple model can account for the combined influences of non-DNL related factors on annoyance prevalence rates in different communities in terms of a single parameter expressed in DNL units—a "community tolerance level." It is worth noting, however, that the CTL cannot accurately account for a wide range of outlying responses.

There are some limitations and uncertainties that arise from using this model, but Fidell concluded that using the duration-corrected loudness of noise exposure appears in most cases to link well with aircraft-noise induced annoyance responses on social surveys. This finding was derived from analyses of interviews conducted with nearly 76,000 respondents at hundreds of sites over the last 50 years, and is unlikely to change greatly as additional social survey data become available. The CTL values do not appear to be very influenced by airport size, but may be related to airport type. They also appear to be unrelated to climate variables, but may be related to economic factors such as median housing values and annual household incomes. Figure 8 shows a best-fit curve for all aircraft annoyance data to effective loudness function for a CTL of 73 dB.

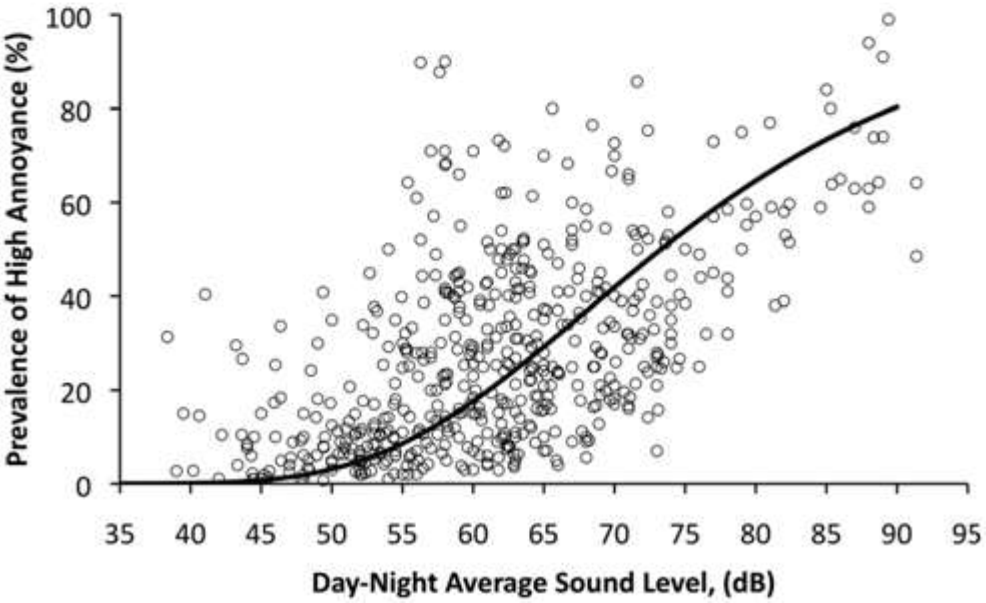


Figure 8: Fit of all aircraft annoyance data to effective loudness function for a CTL value of approximately 73 dB.

UK Aircraft Noise Annoyance Studies

ANIS

In the UK, there have been several aircraft annoyance studies that have produced dose-response relationships. The first was the UK Aircraft Noise Index Study- ANIS (1982). At that time the noise exposure metric that had been used since the 1960s was the Noise Number Index (NNI), which was criticised for being out of date. This aim of the ANIS study was to both substantiate the NNI and disentangle the effects of noise level versus number of aircraft events, or to devise a more appropriate metric that would better reflect the level of disturbance experienced. The findings suggested that NNI gave too much influence to the number of aircraft noise events, and a more appropriate metric to correlate disturbance responses to was the 24 hour L_{eq} – a measure of average sound energy received over the 24 hours.

The annoyance questionnaire used in ANIS was a modified version of a questionnaire used in an earlier study in 1967, using the Gutman annoyance scale, and comprised three sections of questions. An introductory section asked questions about general attitudes to the area without being aircraft specific; the second section included questions focussed on disturbance, and then finally came questions about potential confounding factors.

The ANIS study concluded that an appropriate threshold to reflect disturbance would be 55 dB L_{Aeq}, which could be used to mark the onset of community annoyance, and 70 dB L_{Aeq} would mark the onset of high disturbance. 70 dB L_{Aeq} would correspond to 55 NNI, and represents aircraft noise exposure which was:

- “Very much” annoying to two-thirds of the exposed population
- “Not acceptable” to three quarters of the population, and

- The “most bothersome” noise to nine out of ten people.

The noise exposure metric $L_{Aeq,16h}$ was adopted in 1990 following the results of the ANIS study. $L_{Aeq, 16h}$ refers to the equivalent continuous sound level between 0700-2300.

ANASE

The Attitudes to Noise from Aviation Sources in England (ANASE) study was commissioned by the Department for Transport in 2001 and was published in 2007. The aims of the study were to re-assess attitudes to aircraft noise in England, re-assess their correlation with the $L_{Aeq,16h}$ noise index and examine willingness to pay in respect of annoyance from such noise, in relation to other elements, on the basis of stated preference survey evidence.

In addition to interview questions, respondents at some of the study sites were played audio recordings of aircraft noise and were also asked to rate their “willingness to pay” to avoid aircraft noise. The study concluded that “levels of annoyance were higher than expected from previous surveys and that the relationship between L_{Aeq} and annoyance was not stable over time:

- the proportion of respondents who are at least very annoyed is less than 10% for areas with L_{Aeq} less than 43dB;
- the proportion of respondents at least very annoyed generally increases with L_{Aeq} for values of L_{Aeq} over 43dB, although there is a relatively large spread in percentages for most L_{Aeq} values; and
- at least 40% of respondents were at least very annoyed for all except one of the areas with L_{Aeq} greater than 57dB.”

Although the researchers concluded there was no clear threshold between 43 and 57dB $L_{Aeq,16h}$, the study suggested that for the same proportion of highly annoyed people as found in ANIS at 57dB $L_{Aeq,16h}$ (10%), the corresponding $L_{Aeq,16h}$ level would be approximately 10-13 dB lower.

The independent peer review by Havelock (CAA) and Turner (Bureau Veritas) raised concerns over the use of and calibration of noise playback equipment prior to the social survey being undertaken. Restricted sites, where no noise playback equipment was used appeared to show differences in attitudes to those from the main study, where noise playback equipment was used. There were also concerns over the estimation of aircraft noise at survey sites. Consequently the peer review concluded that “there were sufficient technical and methodological uncertainties still remaining with the study… [that] the reviewers would counsel against using the results and conclusions in the development of government policy”.

SoNA 2014

In 2014 the Department for Transport commissioned the Survey of Noise Attitudes (SoNA) – Aviation study[2], which built on previous noise attitudes surveys by Defra with the addition of an aircraft noise section.

The overall aims of SoNA 2014 were to:

- Obtain new and updated evidence on attitudes to aviation noise around airports in England, including the effects of aviation noise on annoyance, wellbeing and health.
- Obtain new and updated evidence on what influences attitudes to aviation noise, and how attitudes vary, particularly how attitudes vary with LAeq, but also other non-acoustic factors that may influence attitudes, such as location and time of day, and socioeconomic group of respondents.
- Examine whether the currently used measure of annoyance, LAeq, is the appropriate measure of annoyance for measuring the impact on people living around major airports.
- Consider the appropriateness of the policy threshold for significant community annoyance from aviation noise.
- Provide baseline results that can be used for a programme of regular surveys of attitudes to aviation noise.

The findings included that $L_{Aeq,16h}$ was still deemed to be the most appropriate noise indicator to correlate with annoyance. In terms of supplementary metrics to help residents understand noise exposure, it was found that N65 was the most suitable, describing the number of aircraft noise events over 65 dB L_{Amax}.

Mean annoyance score and the likelihood of being highly annoyed were found to increase with increasing noise exposure ($L_{Aeq,16h}$). The relationship found was close to linear, though annoyance levels plateau at low exposure and do not reach zero annoyance.

Annoyance scores were found to be comparable with those found for the ANASE restricted sites, but lower than found by the full ANASE study, and higher than found by ANIS. For a given noise exposure, a lower proportion of respondents was found to be highly annoyed than compared with ANASE, the results of which were considered unreliable.

For a given noise exposure, a higher proportion of respondents was found to be highly annoyed than compared with ANIS. The same percentage of respondents said by ANIS to be highly annoyed at 57 dB $L_{Aeq,16h}$ now occurs at 54 dB. Comparing with the results, the ‘Miedema’ dose response function, predicts 12% highly annoyed at 54 dB and 16% at 57 dB.

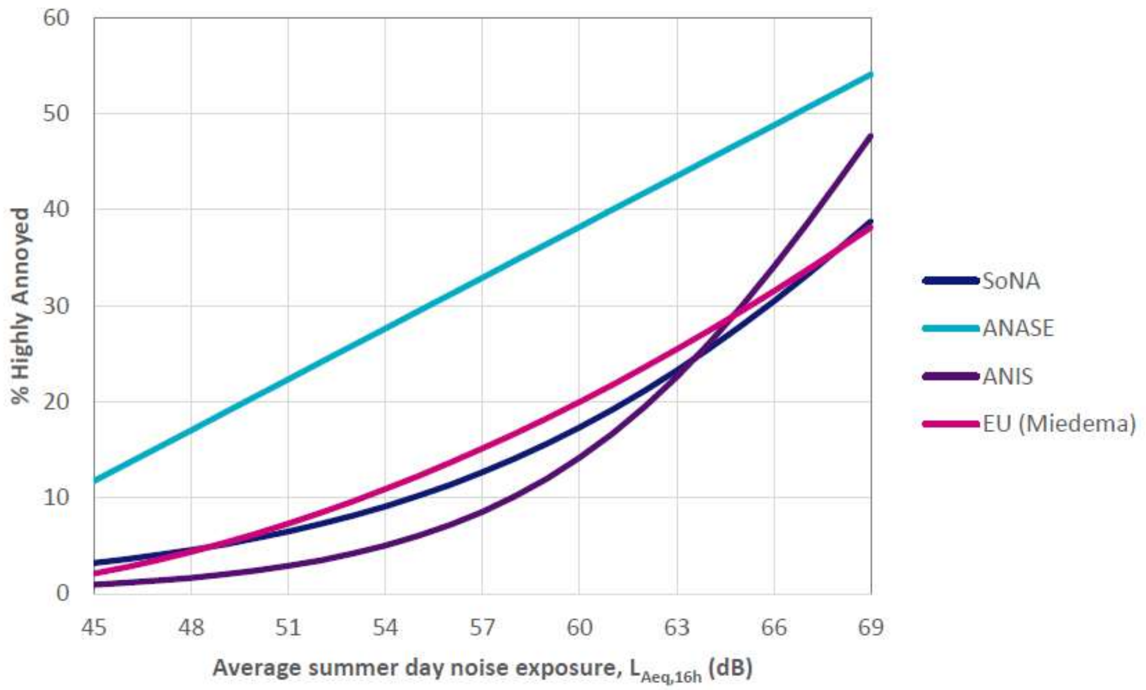


Figure 9: Comparison of % highly annoyed for SoNA, ANASE, ANIS and Miedema

It is apparent in Figure 9 that for values below 60 dB $L_{Aeq,16h}$, the SoNA 2014 results lie between ANASE and ANIS. At levels above 63 dB $L_{Aeq,16h}$ the SoNA 2014 estimates lie below ANIS. This may be due to small sample sizes at higher exposure levels for SoNA 2014 not being representative – early charts showed mean responses with relatively large uncertainties due to small sample sizes. The SoNA 2014 results are somewhat similar to the Miedema curve.

Standardisation of Questions

Data on aircraft noise-induced annoyance is obtained through surveys conducted either by post, in person face-to-face, or via telephone. Clearly face-to-face interviews are more expensive, though elicit a better response rate than postal surveys or those conducted by telephone. Postal and telephone surveys result in lower response rates of the order 15 - 20% compared to around 60% for face-to-face.

There are two standardised ISO scales that are used in social surveys on annoyance. The first is a 5-point scale that was recommended by the International Commission on the Biological Effects of Noise (ICBEN) and is shown in Figure 10 in the form presented to respondents in the SoNA study:

CAN1: So, thinking about this summer, when you were here at home, how much did each of these different types of noise from aeroplanes bother, disturb or annoy you?

		Not at all	Slightly	Moderately	Very	Extremely	Don't know
i	Overall noise of all kinds, from aeroplanes	☐	☐	☐	☐	☐	☐
ii	Noise from aeroplanes on the ground at an airport (e.g. taxiing planes, engine testing)	☐	☐	☐	☐	☐	☐
iii	Noise from aeroplanes taking off and climbing	☐	☐	☐	☐	☐	☐
iv	Noise from aeroplanes descending and landing	☐	☐	☐	☐	☐	☐
v	Noise from aeroplanes in flight	☐	☐	☐	☐	☐	☐
vi	Noise from aeroplanes during the day (7 a.m. – 11 p.m.)	☐	☐	☐	☐	☐	☐
vii	Noise from aeroplanes during the night (11 p.m. – 7 a.m.)	☐	☐	☐	☐	☐	☐

Figure 10: ISO 5 point annoyance scale as used in SoNA 2014.

The second is an 11-point scale and shown in Figure 11:

CAN34: Thinking about this summer, what number from 0 to 10 best shows how much you were bothered, disturbed or annoyed by noise from aeroplanes.

Not at all **Extremely**

0	1	2	3	4	5	6	7	8	9	10	Don't know
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 11: ISO 11 point annoyance scale, taken from SoNA 2014.

For both questions annoyance is characterised as 'being bothered, disturbed or annoyed', however throughout this document such responses are simply referred to as annoyance responses. CAN1 was presented as a matrix question, seeking views on overall annoyance from civil aircraft, but also views on noise associated with specific types of operation and specific times of day.

Such standardisation in how the questions are asked allows for direct comparisons between studies, for example between SoNA and ANASE, and also enables the responses to be transformed to mean annoyance scores for statistical analysis purposes. At the ICBEN Congress in 2017, Truls Gjestland presented a paper on the standardisation of the 5 and 11-point annoyance scales. These have now been translated into 17 further languages to enable standardisation worldwide when obtaining annoyance responses.

A report on environmental noise and health, published by the Health Protection Agency (2009) includes a section on annoyance, and the difficulties associated with analysing annoyance responses. The conclusions from this report were that generally the risk and strength of annoyance increases with the degree of sound level exposure, and such a relationship can be expressed mathematically and graphically. The report suggests that dose-response curves could be used for policy development, but they need to be studied closely due to the amount of scatter of individual responses occurring around the average response for any specific sound level. Caution should be observed due to the reasons behind such variation being not yet well understood, and that the slope of dose-response relationships may be unstable due to possible change in annoyance reactions. It was concluded that repeated surveys may still be required to establish reliable dose-response annoyance curves.

In recent years, the use of social media has become prolific and it has been suggested that this platform may be employed to gather large amounts of data in an efficient and cost effective manner in social studies. A study around Brazil’s Guarulhos airport (Silva et al, 2017) used Facebook advertisements and web-based forms to examine annoyance at various noise levels measured in DNL. 560 questionnaires were completed, and the advertisement shown to over 124,000 people, though it is impossible to know what percentage of that number actually saw the advertisement.

When compared to responses from the general population of Guarulhos regarding aircraft noise, the survey respondents’ attitude to noise was generally similar, although the survey respondents’ responses were lower for lower noise levels and higher than the general population for higher noise levels. This may be due to the recent operational changes at the airport, with an aircraft noise movement increase of 45% five years prior to the survey, making it a “high rate of change” airport. The data suggests that an increase in aircraft movements has influenced the reported annoyance of respondents.

It is important to bear in mind that with sampling techniques such as this, there is a lack of proof that the sample is representative of a noise-exposed population. In this instance, the CTL level of 65 dBA DNL suggested that the population is about 8 dB less tolerant than the average community as described by Fidell (2011). There is also a bias towards technology savvy respondents who are on Facebook, which may not be fully representative of the overall sample, and the possibility of self-selection bias, meaning that highly annoyed people will be more likely to complete the survey. The authors argue that self-selection bias is unlikely due to the low number of complaints regarding aircraft noise.

Although this method of sampling is open to certain biases, this study did not demonstrate any clear bias or distortion of results as such. The authors suggest that this method is a useful means of data collection on aircraft noise-induced annoyance in developing countries and in future to minimise bias, a postal or telephone study could be run alongside the social media method, to validate results.

Chapter 4

Recent findings

This chapter will describe and discuss a selection of the most significant findings regarding aircraft noise and annoyance since 2010. The scope of this report does not allow for a comprehensive literature review of all studies in that time period, due to the high number of annoyance studies worldwide, but instead will focus on a range of issues such as changes over time, evening and night-time studies and vulnerable groups.

The findings are grouped under the following headings:

- Changes in annoyance over time
- Psychological factors
- Night-time annoyance
- Children and vulnerable groups
- Other annoyance findings

Changes in annoyance over time

NORAH

In late 2015 some of the results of the much-awaited NORAH (NOise-Related Annoyance, cognition and Health) study were published. This was a large-scale, longitudinal German study that commenced in April 2011 and continued until 2014 and included 43 researchers from 11 institutes. In order to get more insight into the effects of transportation noise, the state-owned Environment & Community Center (ECC) of the Forum Airport and Region (FFR) commissioned the researchers to conduct a noise effects monitoring program at Frankfurt Airport before and after the opening of a fourth runway. Three Work Packages (WPs) were included in the study:

1. Annoyance and quality of life
2. Sleep and health
3. Children's cognition

Annoyance and quality of life was part of the first work package, and examined:

- Aircraft noise annoyance and health related quality of life (HQoL) before and after the opening of the fourth runway in comparison to annoyance at other airports;
- Comparison of HQoL and annoyance due to aircraft, railway and road traffic noise; effects of combined transportation noise exposure on annoyance and HQoL;

Dirk Schreckenberg, who was a lead researcher of the NORAH study, authored a paper on the effects of aircraft noise on annoyance and sleep disturbances before and after the expansion of Frankfurt airport, which were the results of Work Package 1. The study was centred on the opening of a new runway at Frankfurt Airport in 2011, along with the introduction of a new airport night curfew from 2300-0500. The study examined the impact of aircraft noise on annoyance before and after these changes by surveying residents living near the airport before the runway opening and in follow-up studies in 2012 and 2013. Over 3,500 residents participated in all three phases of the study. Surveys were conducted via telephone or optional online methods.

The operations predictions for the time after the new runway opening were that some areas would experience an increase in aircraft noise, some would experience less noise and some areas would see no significant difference in noise exposure. For each residential address, the source-specific equivalent sound level, and mean maximum sound level of aircraft, road and railway noise were calculated for the preceding 12 months of each survey study, at different times of the day.

Residents selected randomly for the study were stratified according to continuous aircraft noise level and by predicted change in aircraft noise exposure for 2020 in relation to 2007 sound levels (increase of > 2 dB $L_{Aeq, 24h}$; decrease of > 2 dB $L_{Aeq, 24h}$; no significant change i.e. a change less than or equal to ± 2 dB $L_{Aeq, 24h}$).

The surveys used the ICBEN 5-point annoyance scale and in addition to aircraft noise-induced annoyance included self-reported measurements of sleep disturbance, noise sensitivity, coping capacity/perceived control, attitudes towards aircraft, positive expectations of the change in air traffic on the economic development of the region and quality of life, and demographics such as age, gender, socioeconomic status etc.

The results suggest that the exposure-response curve for annoyance versus LAeq, 24 hour shifted following the opening of the runway, depending on changes in local sound levels. Figure 12 shows that there was a shift in % Highly Annoyed (HA) between 2011 prior to the opening of the new runway, and 2012 and 2013. This difference is especially marked for noise levels of 55 dB $L_{Aeq,24h}$ and below. The curve for 2013 lies in between those for 2011 and 2012 suggesting that there has been a settling effect of the new runway in terms of people’s attitudes and annoyance responses. In comparison to the RDF study at Frankfurt in 2005, also shown in Figure 12, there is a much larger shift in annoyance reactions for all noise levels, between these two studies.

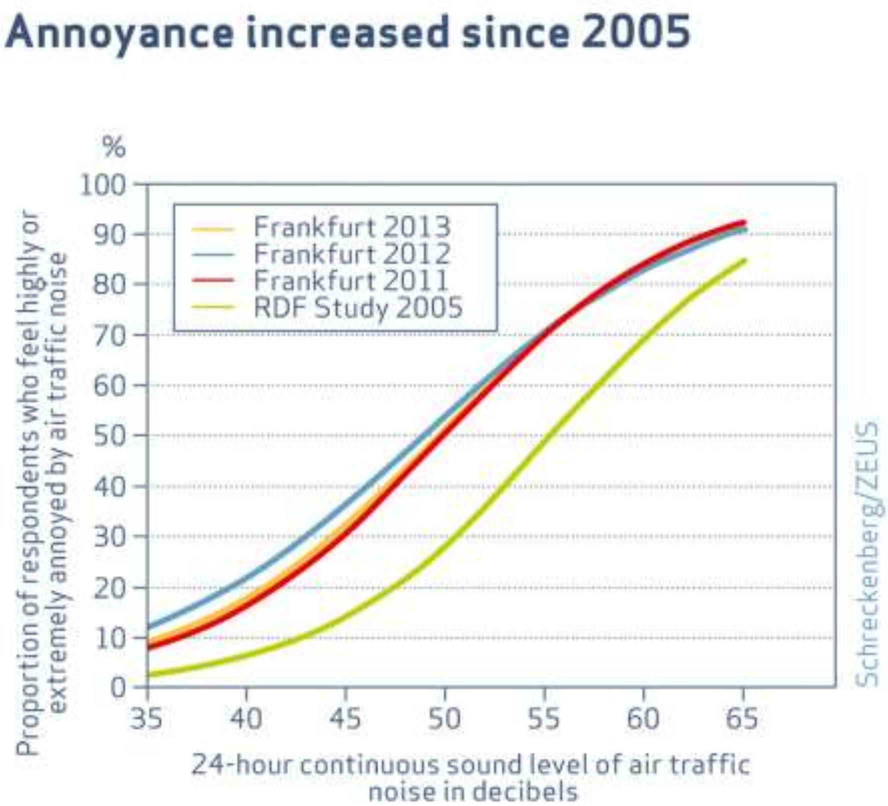


Figure 12: Percentage HA in the NORAH Study for 2011, 2012 and 2013.

For the group of participants who experienced a reduction in aircraft noise exposure, there was also a reduction in the magnitude of annoyance responses in 2012 and 2013 as seen in Figure 13. Aircraft noise annoyance in 2011 was explained by the aircraft sound level. In addition, railway sound level, survey mode, coping capability, positive expectations and judgement of air traffic as environmentally harmful were associated with aircraft noise annoyance in 2011. Participants interviewed by telephone were more annoyed than those who completed the online survey. The changes in aircraft noise annoyance in 2012 and 2013 were predicted by aircraft sound levels, coping capability, air traffic related expectations and the judgement that air traffic is dangerous.

Figure 14 shows the annoyance reactions over the three years in those residents who experienced no significant change to their aircraft noise exposure. House owners reported higher annoyance levels than tenants in this group, and sound level and noise sensitivity were also associated with annoyance levels. In this group in general the annoyance reactions increase in 2012 and then decrease again in 2013. In additions to aircraft sound levels, coping capacity and positive expectations towards the air traffic contribute to the explanation for the change in annoyance reactions.

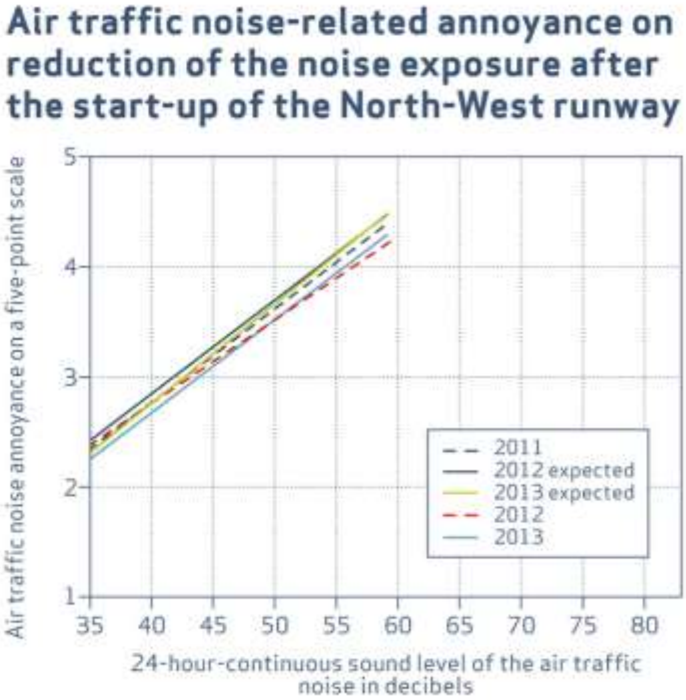


Figure 13: Annoyance reactions in the subset of the NORAH sample who experienced a reduction in aircraft noise following the opening of the new runway in 2011.

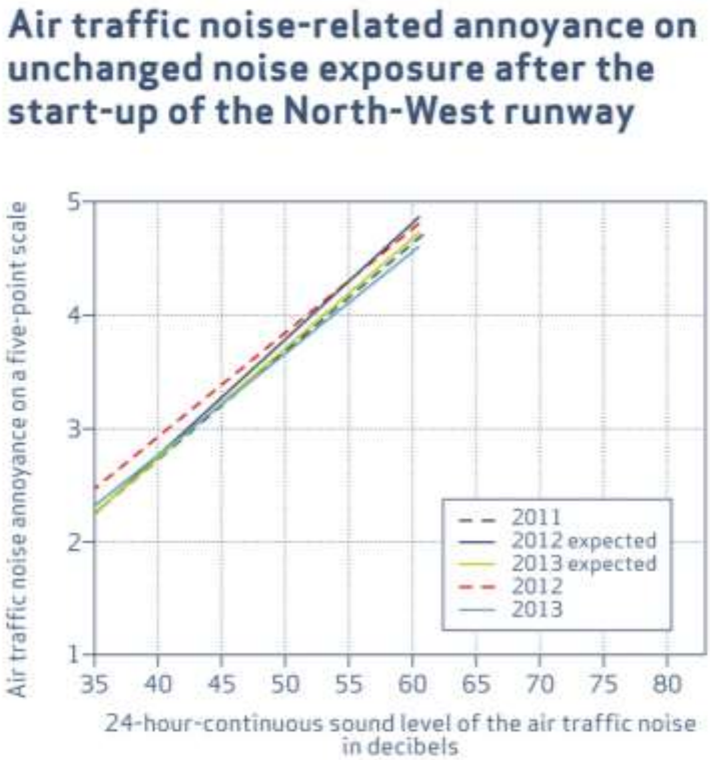


Figure 14: Annoyance reactions in the subset of the NORAH sample who experienced no change in aircraft noise following the opening of the new runway in 2011.

Figure 15 shows the change in annoyance reactions in the group who experienced an increase in aircraft noise following the opening of the runway. The change in annoyance over time is not explained by the changes in the average aircraft sound level $L_{Aeq, 24h}$. Instead, in this group annoyance changes are predicted by coping capacity, positive expectations concerning air traffic, and judgements of the airport as dangerous and environmentally harmful. In 2012 and 2013 the curve moves up and down again but is still higher than in 2011.

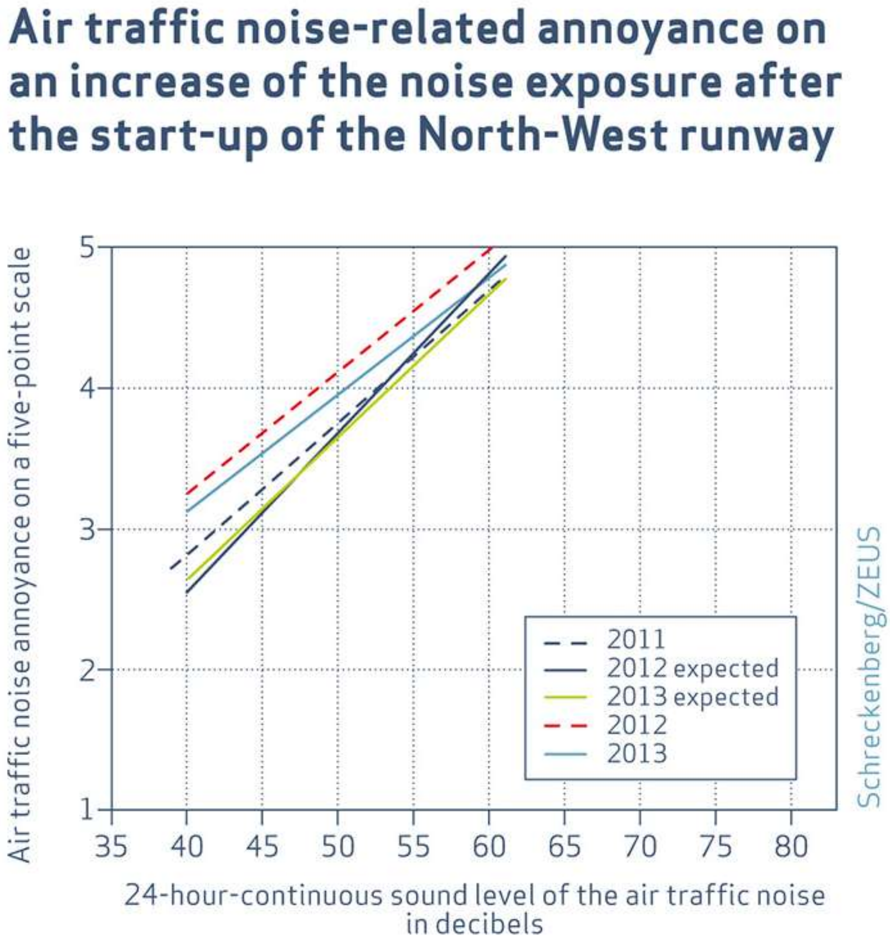


Figure 15: Annoyance reactions in the subset of the NORAH sample who experienced an increase in aircraft noise following the opening of the new runway in 2011.

It was concluded that the change effect for aircraft noise levels and annoyance responses over the three years was particularly strong:

- In lower levels of $L_{Aeq,24h}$ (below 55 dB).
- For those participants experiencing an increase in aircraft noise levels in 2012 following the opening of the new runway compared to 2011.
- In 2012 compared to 2013.

Importantly, there are several non-acoustic factors which partly explain the changes in aircraft noise reactions observed. In the group of participants experiencing an increase in aircraft noise levels, only the non-acoustic factors contributed to the change effect in aircraft noise annoyance. Those non-acoustic factors relate to coping mechanisms and attitudes, expectations and noise sensitivity. This highlights the need for the appropriate attention and controls that should be given to non-acoustic factors in aircraft annoyance studies to avoid misleading results.

Trends in annoyance over time

Janssen et al (2011) examined trends in aircraft noise annoyance and discussed the role of study and sample characteristics. Previous research has suggested annoyance levels have risen for a given aircraft noise level over the years, and it was the aim of this study to test whether there is a change over time in annoyance due to aircraft noise and if so, whether this trend may be explained in terms of study or sample characteristics.

The authors updated the previous annoyance database from Miedema and Oudshoorn (2001), with several recent cross-sectional surveys. This updated database included 34 original datasets from separate airports from 1967 to 2005. The variance of the effect estimates could be determined based on the individual data, allowing more profound statistical analysis of the trend. No extrapolation was needed for determining the effect estimates, and the problem of differences between studies in cut-off criteria for high annoyance was avoided. An adapted version of a multilevel grouped regression as described by Groothuis-Oudshoorn and Miedema (2006) was used to determine effect estimates (and their variance) of the relationship between annoyance and exposure to aircraft noise for each airport. This method allowed for correction of the effect on the exposure–response relationship of possible differences among study samples in individual characteristics. The authors then performed a meta-regression to investigate whether characteristics of the study may explain the variation in effect estimates between airports. While the main factor of interest was year of the study, the study also investigated whether other study characteristics (type of contact, type of annoyance scale applied), sample characteristics (age, number of persons in the household, use or economical dependency of the airport, insulation, noise sensitivity, fear), and acoustical characteristics of the study (number of events) may explain variability in annoyance response.

The results suggested that a significant increase in expected annoyance at a given level of aircraft noise was observed over the years. Instead of a gradual increase, annoyance appeared to show increased levels particularly from 1996 onward, although the authors explain that this could be due to the limited number of studies included in the preceding years.

It was suggested that various study characteristics can possibly explain the reason for the increased levels of annoyance based on the analysis used. The annoyance scale used, in particular the 11-point scale versus 4 or 5 point scale, was found to be an important source of variation in annoyance responses, which stressed the importance of using a standard single annoyance question. However, while the scale factor could statistically account for the year effect, a sensitivity analysis, and other previous research findings have ruled it out as a satisfactory explanation. In the SoNA 2014 study, no significant difference was found between the 5 and 11-point scales.

There were two further study characteristics that were associated with differences in annoyance, namely the type of contact, with postal surveys showing higher annoyance ratings than telephone or face-to-face surveys, and the response percentage, with higher annoyance in surveys with lower response percentages. The SoNA 2014 study specifically used face-to-face interviews in order to address these concerns. However, neither of these factors could explain the effect of the year of the study in Janssen et al. Another possible explanation for the year effect, the presumed higher rate of expansion of airports in recent years, could neither be confirmed nor ruled out due to uncertainty in attributing the change-status to an airport.

In addition, there was no evidence found for a sensitisation to noise within the population under study as reflected in self-report measures of noise sensitivity. The authors explained that a limitation of meta-regression analysis is that some of the characteristics which differ between studies can be highly correlated, making it hard to differentiate between their effects. Therefore it was suggested that caution should be taken in the interpretation of the effects, especially since several of the study characteristics discussed appear to have changed around the same time. A further limitation is that not all of the included surveys provided information on certain individual characteristics that have been shown to importantly influence annoyance, such as noise sensitivity, fear, or other attitudinal characteristics, preventing proper adjustment for these. However, the authors concluded that despite the uncertainty with regard to its explanation, it is clear from the observed trend that the applicability of the exposure–annoyance relationship for aircraft noise (Miedema and Oudshoorn, 2001) should be questioned. It is worth noting that an alternative view is that because the change over time is not consistent, it doesn't necessarily follow that a 2001 curve is actually out of date. Given the large part of the variation explained by year of the study, it does not seem justifiable to pool recent and older studies into one single relationship. While this could imply that the relationship needs to be updated on the basis of recent studies using similar methodologies, it is important to obtain further insight into the factors responsible for the change and the large variation found in the annoyance response.

A Japanese study presented at Internoise 2016 by Nguyen from Kumamoto University looked at community response to a change in aircraft noise exposure before and after the operation of the new terminal building in Hanoi Noi Bai airport in Vietnam. Following opening of the new terminal building in December 2014, there was a 20% increase in the number of daily flights, thus changing the pattern of noise exposure in surrounding areas. Social surveys were conducted in September 2014, March 2015 and September 2015. L_{den} levels had increased from 44-66 dB during the first survey, to 45-66 dB and then 49-69 dB during the last survey, and the exposure-response increased by approximately 5% for the second survey and then very steeply for the third survey. All three curves are noticeably steeper than the EU annoyance curve, particularly for noise values above 55 dB L_{den}, indicating that residents around this airport are generally more annoyed by aircraft noise than those in Europe. Logistic regression indicated that there were significant increases in high annoyance responses between each survey. An update on this study (ICBEN 2017) reported that there were significantly higher levels of annoyance at the arrivals side of the airport for all three phases of the study, and in particular for the second survey. There were considerable gaps between exposure-response curves for general annoyance and activities interference, as well as sleep disturbances at arrival and departure sides of the airport. The excess responses at the arrivals side of the airport was possibly explained due to the corresponding level of sleep disturbance in that area, or other non-acoustical factors.

Truls Gjestland et al (2016) examined the use of noise surveys at five Norwegian airports in 2014 and 2015. The study focused on the difference between ‘high rate of change’ (HRC) and ‘low rate of change’ (LRC) airports. LRC is classified as those airports where there is no indication of a sustained abrupt change of aircraft movements, or the published intention of the airport to change the number of movements within three years before and after the study. If the typical trend is disrupted significantly and permanently, the airport is classified as HRC. The Community Tolerance Level (CTL) method (see Chapter 2) was used in this study for ease of cross-study comparison and to provide a single-number parameter to describe the annoyance level in the particular community i.e. the noise level at which half of the population is highly annoyed.

In this study, Oslo Airport was classified as HRC, and the other four airports (Stavanger-Sola, Trondheim, Bodø, Tromsø) were classified as LRC. 300 participants were chosen from each airport population, and the surveys were conducted via telephone. The annoyance questions used were the two ICBEN recommended 11-point and 5-point scales.

The results indicated that residents living near the four LRC airports tolerate 7-10 dB higher noise levels than is suggested by the EU curve and had a higher CTL than the average value given by Fidell. Residents near the HRC airport were more annoyed than the average, equivalent to a shift of about 5 dB compared to the EU curve and had a lower CTL of 68 dB compared to the average of 73 dB.

The study also found a positive correlation between annoyance and the number of noise events above 55 dBA per day, with approximately 25% of the population being Highly Annoyed at 250 events per day. In contrast the UK SoNA 2014 survey found 18% and 20% Highly Annoyed for 200-399 events per day above 65 and 70 dB L_{Amax} respectively. Night-time aircraft annoyance was strongly correlated with overall noise annoyance, which suggested that night noise is not specifically problematic at the studied airports. Noise during the summer was experienced as more annoying, irrespective of seasonal differences in noise level.

The notion of HRC and LRC airports formed part of the WHO systematic review on environmental noise and annoyance from 2000-2014, which was presented by Rainer Guski from Ruhr University in Germany at the Internoise 2016 Congress. The main noise sources considered were aircraft, road traffic, railway noise and wind turbines, with the aims to assess the strength of association between exposure and long term noise annoyance, to quantify the increase of annoyance with an incremental increase in noise exposure, and to present an exposure-response relationship for each noise source.

The paper discusses the criteria used for the literature search, and definitions of annoyance. It was agreed by the WHO group that noise annoyance as seen in surveys is a complex response, comprising three elements:

1. An often repeated disturbance due to noise often combined with behavioural responses in order to minimise disturbances. (repeated disturbance of intended activities e.g. communication, watching TV, reading, sleep)
2. An attitudinal response (anger about the disturbance, and negative evaluation of the noise source)
3. A cognitive response (the realisation that one cannot do much against this unwanted situation).

This multi-faceted reaction is seen by many researchers as a stress-reaction, involving an environmental threat and individual physiological, emotional, cognitive and behavioural responses which can partly be remembered and integrated into a long-term annoyance response. The results from the aircraft noise element to this review comprised data from 15 aircraft annoyance studies which occurred between 2000 and 2014. All of the studies except one defined “highly annoyed” by the upper 27% of the response scale i.e. HA ≥ 73%.

In terms of dose-response curves, the more recent studies appear to have shifted above the Miedema/Oudshoorn curve from 2001, and closer to Janssen and Vos’ annoyance curve from 2009, especially in the 40-50 dBA L_{den} (Figure 16). This result is in line with the often reported trend that aircraft noise has increased over recent years, and aircraft noise today is higher than shown in the Miedema/Oudshoorn 2001 curve. In addition, airports that were deemed to have a HRC elicit a higher degree of annoyance than those classified as steady state or LRC for the same or comparable noise levels.

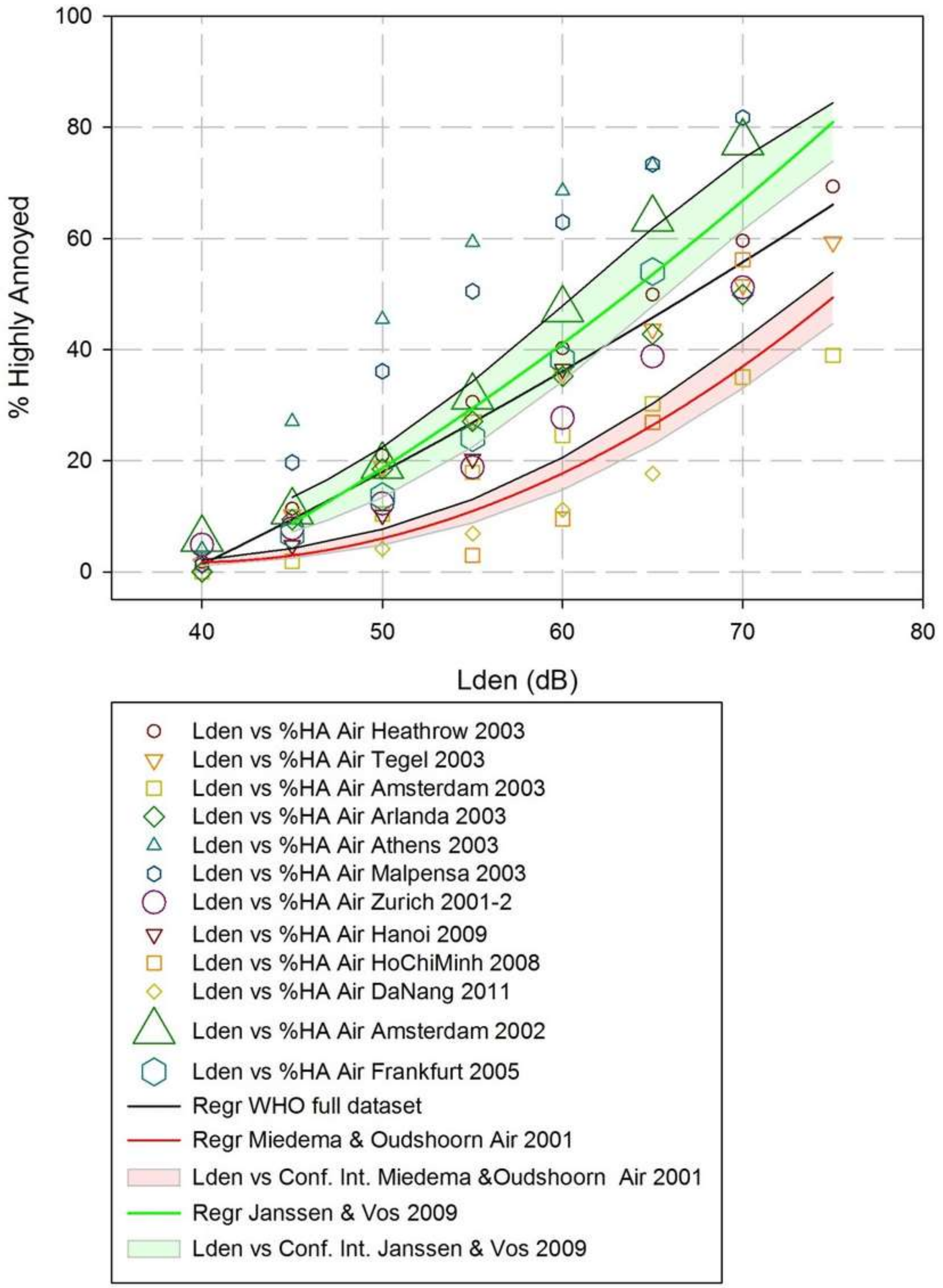


Figure 16: Scatterplot and quadratic regression of the relationship between Lden and the calculated % Highly Annoyed for 12 aircraft noise studies (black), together with exposure-response functions by Miedema & Oudshoorn (2001, red), and Janssen & Vos (2009, green). Taken from WHO (Internoise 2016).

Psychological factors

Kroesen et al (2010) investigated the direction of causality between psychological factors and aircraft noise annoyance using a structural equation modelling approach. Data was used from two surveys conducted in 2006 and 2008 using the same residents living within the 45 L_{den} contour of Schiphol airport (n=250). The model used in this study was a cross-lagged panel model, where the dependent variables at time 2 are predicted by their previous values as well as the time 1 values of the other variable of interest. The authors found surprisingly that none of the paths from the twelve subjective socio-psychological factors that were included, to aircraft noise annoyance were found to be significant. However, two effects were found to be significant in the opposite direction. The first was from ‘aircraft noise annoyance’ to ‘concern about the negative health effects of noise’, and the second was from ‘aircraft noise annoyance’ to ‘belief that noise can be prevented.’ Hence aircraft noise annoyance measured at time 1 contained information that can effectively explain changes in these two variables at time 2, while controlling for their previous values. Secondary results show that aircraft noise annoyance is very stable through time and also that changes in aircraft noise annoyance and the identified psychological factors are correlated.

The authors suggest that establishing the direction of causality between aircraft noise annoyance and possible social-psychological factors is important for noise policy. Policies specifically aimed at these factors can only be effective if the causality indeed ‘flows’ from such factors to aircraft noise annoyance. A second and related issue, is whether individual differences can be attributed to social or psychological variables and processes. If, for instance, personality traits appear to be dominant in the explanation of individual differences, more individually ‘tailored’ noise policies would be preferable. If, on the other hand, social representations are dominant in structuring noise perception and evaluation, a closer examination of the collective noise policy and the message it brings across would be more appropriate.

Evening/ night noise and lack of annoyance studies

Elmenhorst et al (2012) examined nocturnal railway noise and aircraft noise in the field with respect to sleep, psychomotor performance, and annoyance. This study was conducted using participants living alongside railway tracks around Cologne/Bonn. Previous research has suggested that railway noise is less annoying than aircraft noise in surveys, which was the reason for a so called 5 dB railway bonus regarding noise protection in many European countries. This study investigated railway noise-induced awakenings during sleep, night-time annoyance and the impact on performance the following day. Comparing these results with those from a field study on aircraft noise allowed for a ranking of traffic modes concerning physiological and psychological reactions. Thirty three participants (mean age 36.2 years (±10.3 standard deviation); 22 females) living alongside railway tracks around Cologne/Bonn (Germany) were polysomnographically investigated. These data were pooled with data from a field study on aircraft noise (61 subjects) directly comparing the effects of railway and aircraft noise in one random subject effects logistic regression model. Annoyance was rated on the ICBEN 5-point scale in the morning, regarding the previous night’s railway noise in the first study, and compared with those from the aircraft noise study. Results of the regression model indicated that nocturnal aircraft noise was more annoying than nocturnal railway noise though statistically not significant. Annoyance ratings were independent from gender but increased with age.

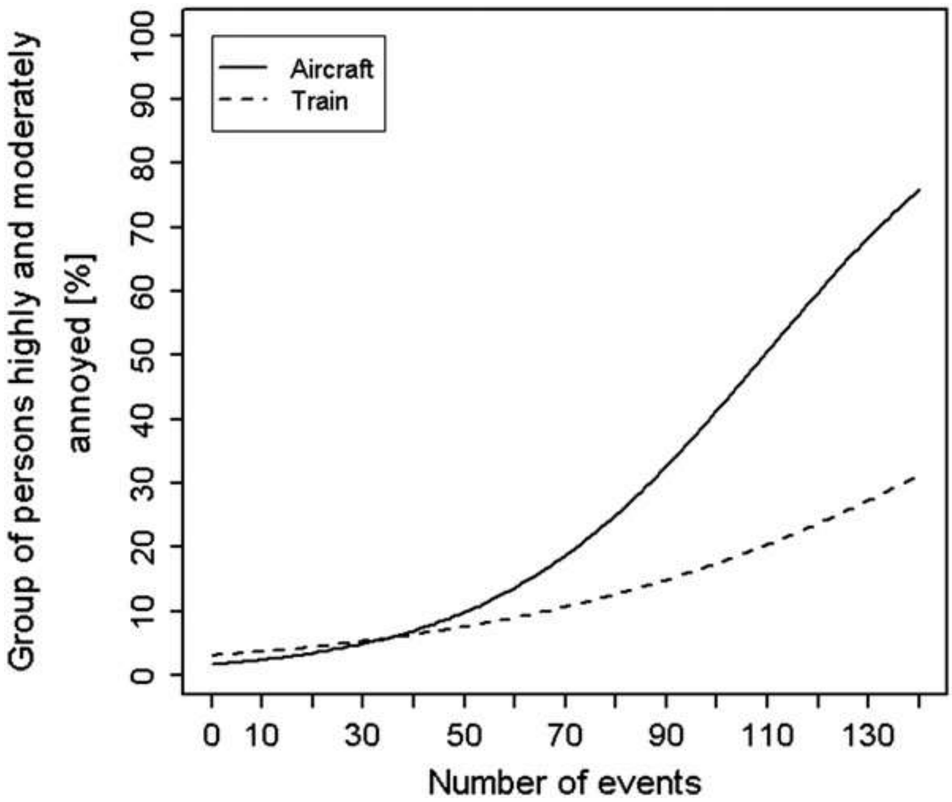


Figure 17: Comparison of railway and aircraft noise effects and annoyance against number of nocturnal events. Assumptions: age = 34 years (median), gender = male; noise levels at the sleeper's ear.

The results suggested that probability of sleep stage changes to wake/S1 from railway noise increased from 6.5% at 35 dBA to 20.5% at 80dBA L_{AFmax}. Rise time of noise events had a significant impact on awakening probability. Nocturnal railway noise led to significantly higher awakening probabilities than aircraft noise, partly explained by the different rise times, whereas the order was inversed for annoyance. Freight train noise compared to passenger train noise proved to have the most impact on awakening probability. Nocturnal railway noise had no effect on psychomotor vigilance. The authors concluded that nocturnal freight train noise exposure in Germany was associated with increased awakening probabilities exceeding those for aircraft noise and contrasting the findings of many annoyance surveys and annoyance ratings.

Maria Foraster from the Swiss Tropical and Public Health Institute from Basel investigated annoyance reactions and the risk of physical inactivity (2016). The theory behind this work was that annoyance from transportation noise, and resulting sleep disturbance may then in turn lead to a reduction or lack of physical activity. Perceived stress and unconscious stress resulting from noise can both lead to sleep deprivation. In addition, annoyance with the neighbourhood due to noise may reduce the willingness to go outside and exercise locally. The study had two aims: 1. to investigate whether there is an association between noise annoyance at home and physical activity, and 2. Is there any effect modification by gender and noise sensitivity?

3,622 participants aged 30-38 years were assessed as part of a large study cohort in Switzerland between 1991 and 2011. Annoyance was assessed on the 11-point annoyance scale. Sufficient physical activity was defined as at least 150 minutes of exercise per week. The results indicated that 60% of the study population were active, and there were fewer tendencies towards high annoyance scores in those that were physically active. Road traffic noise was responsible for the highest degree of annoyance, followed by aircraft noise and then railway noise. There was a significant association between long-term annoyance to transportation noise (on average 20 years) and being physically inactive at the end of that period.

Physical inactivity was strongest amongst those people who had reported sleep deprivation, particularly for night-time annoyance to road traffic noise. No effect modification was observed for gender or noise sensitivity, so these factors do not explain the association. Foraster concluded that noise annoyance at night may contribute to cardiovascular diseases through a decrease in physical activity, and this relationship may be stronger in those people with impaired sleep, especially due to road traffic annoyance at night. This is the first study to investigate transportation noise and physical activity with relation to cardiovascular health endpoints. Further studies are needed to confirm these results and to ascertain the pathways that may be responsible for decreased activity. In 2014 a Swedish study by Eriksson et al was published that claimed a link between aircraft noise and obesity. The study was part of the longitudinal study on hypertension (Eriksson, 2010) and aimed to investigate effects of long-term (up to 10 years) aircraft noise exposure on body mass index (BMI), waist circumference, and Type 2 diabetes in over 5,000 residents in Stockholm County. The main finding was that there was an association between aircraft noise exposure and increased waist circumference after adjustment for individual and area-level confounders. The authors found that this association appeared particularly strong among those who did not change their home address during the study period, which may be a result of lower exposure misclassification. Although this association was considered to be a physiological association, Foraster's results suggest it could be more of a behavioural outcome of lack of physical activity.

There is a lack of studies on night-time aircraft noise and annoyance; studies tend to focus on sleep disturbance which is a pre-cursor to annoyance, but an earlier study by Quehl and Basner (2006) examined the dose-response curves in laboratory and field settings for aircraft noise and annoyance responses.

Data for the study was used from questionnaire surveys with 128 subjects in a laboratory study performed at the DLR Institute of Aerospace Medicine over a period of 13 nights. One control group experienced no aircraft noise for the duration of the study, and three other experimental groups experienced varying degrees of loudness and rate of presentation of the aircraft noise. The A-weighted maximum noise levels L_{ASmax} in the noisy nights ranged from 45–80 dB, and the frequency of occurrence varied between 4 and 128 events per night.

Annoyance was measured using the ICBEN 5-point scale, 15 minutes after waking, and non-acoustic factors were assessed also using 5 point scales on areas such as noise sensitivity, adaptation to noise, attitudes to aviation and the level of annoyance at home, prior to the study. Age and gender were also measured.

The field study was conducted around Cologne/Bonn airport, using 64 participants over nine consecutive nights. The aircraft noise was recorded inside and outside of the bedroom, and numbers of events were measured as well as L_{Aeq} event. The L_{Aeq} event concerns the aircraft noise-specific, A-weighted energy equivalent noise level in the bedroom during individual sleep times, where only aircraft noise events exceeding 35 dBA were taken into account.

Dose–response curves regarding the annoying impact of nocturnal aircraft noise were calculated for the (1) maximum noise level L_{ASmax} combined with the number of aircraft noise events and for the (2) energy equivalent noise level LAeq event by means of random effects logistic regression. Logistic regression is a mathematical model used in statistics to estimate the probability of an event occurring having been given some previous data. Logistic Regression works with binary data, where either the event happens (1) or the event does not happen (0). The laboratory results were compared to the results of the field study.

In the laboratory setting there was a significant increase in the number of annoyed people relating to L_{ASmax} and the frequency of fly-overs. The percentage annoyed by aircraft noise also increased with L_{ASmax} during those nights with fewer than 16, but louder aircraft noise events. The group of annoyed subjects also significantly increased with the L_{Aeq} event; however, above 50 dBA it decreased again since fewer but louder events were presented in the underlying combinations of noise level (45–80 dBA L_{ASmax}) and number of noise events per night (4 to 128). Data from the field study confirmed the trend of the laboratory dose–response relationships. However, the dose-response curve from the laboratory study lay above the field-study curve, i.e. subjects felt more annoyed by aircraft noise in the laboratory setting than in their home environment. This was most probably caused by the increased number of awakenings in the laboratory compared to field conditions. Other studies have also found much higher responses in laboratory settings, and have suggested that habituation is a significant factor. Quehl and Basner suggest that the findings of the studies indicate that not only the energy equivalent noise level ($L_{Aeq,night}$), (as often used in European noise policy) but also the number of aircraft events are a major source of nocturnal aircraft noise-induced annoyance. This could be due to people reacting more to single event noise characteristics rather than average noise levels, and that people often complain about the frequency of flights (even though the individual events may be quieter than in previous years) and a lack of respite between them.

In terms of non-acoustic moderating factors, the results from the laboratory models showed that one factor (‘‘necessity of air traffic’’) and three personal variables (gender, age, pre-annoyance due to aircraft noise) proved to be significant. In other words, the predicted number of people annoyed by aircraft noise was significantly higher for those people who did not regard air traffic as necessary, women rather than men, older people versus younger people and those who were highly annoyed due to aircraft noise in their homes prior to the study.

Children's annoyance/vulnerable groups

Children's annoyance reactions to aircraft and road traffic noise have also been studied (van Kempen et al, 2009). Annoyance in children has rarely been studied outside of the school environment, and the aim of this work was to investigate annoyance reactions and exposure-response relationships to aircraft and road noise in both home and school. Data from the Road Traffic and Aircraft Noise Exposure and Children's cognition and Health (RANCH) study was used (RANCH study is described in detail in ERCD Report 0908) with a secondary aim to compare children's annoyance reactions with those of their parents. Both parents and children's reactions were measured using self-administered questionnaires. The study was carried out on 2,844 children, aged 9-11 from primary schools in areas surrounding Heathrow, Schiphol and Madrid-Barajas airports. Aircraft noise exposure at home and school was significantly related to severe annoyance, in both cases where the noise exposure from aircraft was higher, the proportion of severely annoyed children was higher also. At school, the percentage of severely annoyed children was predicted to increase from 5% at 50 dB $L_{Aeq,16h}$ to about 12% at 60 dB $L_{Aeq,16h}$ (Figure 18). At home these figures were 7% and 15% respectively (Figure 19). Road traffic noise at school was also significantly related to severe annoyance, with the percentage severely annoyed children predicted to increase from 4% at 50 dB $L_{Aeq,16h}$ to about 6% at 60 dB $L_{Aeq,16h}$. The authors' view was that the association between annoyance and aircraft noise is stronger in children than road noise, probably due to the intensity, variability and unpredictability of aircraft noise in comparison to road noise. Children's annoyance reactions were found to be comparable to their parent's reactions, but with children having lower response frequencies of severe annoyance than their parents at higher noise levels of 55 dB and above.

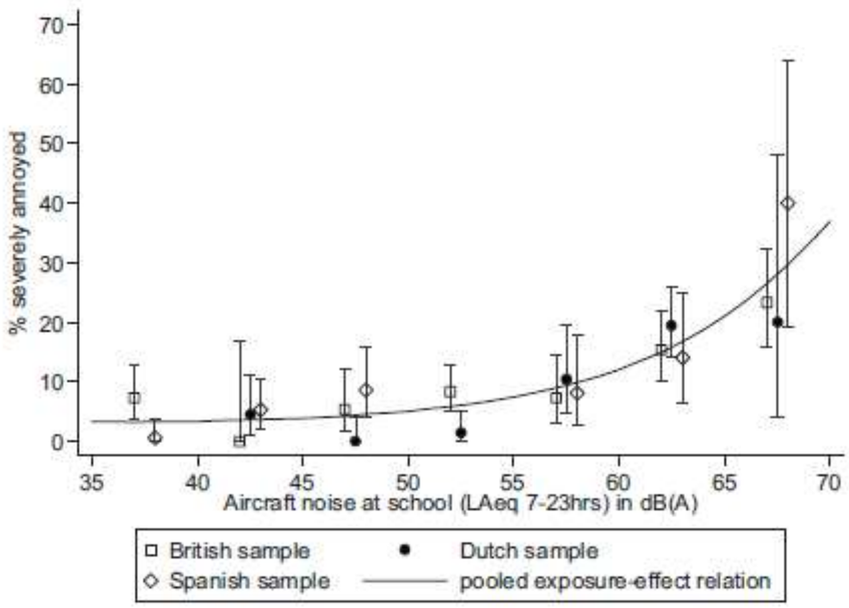


Figure 18. The country-specific percentage of severely annoyed children by 5 dB bands of aircraft noise ($L_{Aeq,16h}$) at school and the relationship between aircraft noise at school and the percentage of children severely annoyed derived after pooling the data and adjustment for confounders. The vertical lines correspond to the 95% confidence interval.

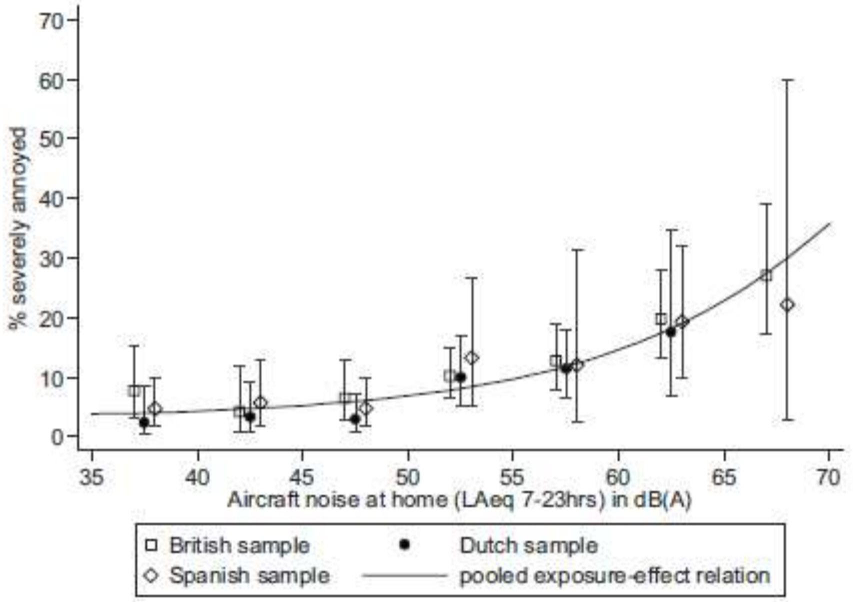


Figure 19. The country-specific percentage severely annoyed children by 5 dB bands of aircraft noise ($L_{Aeq,16h}$) at home and the relationship between aircraft noise at home and the percentage of children severely annoyed derived after pooling the data and adjustment for confounders. The vertical lines correspond to the 95% confidence interval.

Another study examining annoyance reactions to aircraft noise in children (Seabi, 2013) was conducted in South Africa and also included measures of health. Known as RANCH-SA, this was one of the only studies on aircraft noise induced-annoyance in South Africa to date, and was intended to observe whether the results were comparable to those from Western Countries where there has been far more research in this area. The study was designed around the relocation of Durban Airport to an area 35 km north of the city and included children from a selected “High Noise Group” (HNG) with a range of baseline noise levels between 63.5 to 69.9 dB L_{Aeq} and “Low Noise Group” (LNG) with a range of baseline noise levels between 54.4 to 55.3 dB L_{Aeq}, for participation in three waves of the study. 732 children with a mean age of 11.1 (range = 8-14) participated at baseline measurements in Wave 1 (2009). 649 (mean age = 12.3; range = 9-15) and 174 (mean age = 13.3; range = 10-16) children were reassessed after the relocation of the airport in Wave 2 (2010) and Wave 3 (2011), respectively. Noise measurements during Waves 2 and 3 when aircraft were gone from the area, produced results at the formerly noise exposed schools of 55.2 dB L_{Aeq}. Aircraft noise levels at the quieter schools had noise levels between 50.5 to 57.9 dB L_{Aeq}.

Questionnaires were given to the parents and children, and used to obtain information on the children’s age, gender, and socio-economic status as well as the children’s annoyance reactions which were given on a 4-point Likert scale in seven specially adapted questions. Questions on self-reported general health and specific conditions such as headaches, stomach aches, vomiting, and difficulty sleeping were also included.

The findings revealed that the children who were exposed to chronic aircraft noise continued to experience significantly higher annoyance than their counterparts in all the waves at school, and only in Wave 1 and Wave 2 at home. This was an interesting finding as the annoyance persisted even after the relocation of the airport and subsequent decrease in noise levels. It is possible that non-acoustic factors that were not measured are accountable for this result. Aircraft noise exposure did not have adverse effects on the children's self-reported health outcomes. Taken together, these findings suggest that chronic exposure to aircraft noise may have a lasting impact on children's annoyance, but not on their subjective health rating.

It should be noted, however, that in this study there was a relatively small sample of participants in Wave 3 (less than 25% of the original Wave 1 sample) which may have influenced the results. Also, only aircraft noise was measured, and other noise sources such as road or railway noise were not included which may have led to bias.

Other annoyance findings

Military versus civil aircraft noise

Gelderblom from Norway (Internoise 2014) presented research findings on the impact of civil versus military aircraft noise on annoyance. Civil aircraft traffic tends to be spread out relatively evenly over a day, whereas military training operations can often be characterised by short periods of high activity followed by long periods of comparative silence. The study aimed to examine which acoustic properties a noise metric should depend on to be as strongly related to annoyance as possible.

Annoyance responses from airports that are operationally, and therefore acoustically, very different from another, were compared. An aircraft noise annoyance survey was conducted via telephone at two locations: near a civil airport and near a runway that is used for both military and civil air traffic. Various acoustical and operational variables were examined, together with reported annoyance and answers to questions that attempted to identify causes of annoyance.

The results indicated that at both locations, annoyance due to aircraft noise was significantly lower than predicted by the Miedema curve. The percentage highly annoyed at a certain Ldn was found to be significantly different for the different types of airports, but comparison of annoyance scores did not support this conclusion. The clearest difference between locations was an increased percentage of highly annoyed at lower levels of Ldn for the airport with mixed traffic. The authors explain that this may be due to the presence of fighter jets in this area, which are responsible for relatively high noise levels per event in areas where Ldn was low in comparison.

The results suggested that when given a choice, respondents tend to separate airport activities by the type of aircraft involved. Interestingly, the aircraft that contributes most to the Ldn was not necessarily the most annoying. An example of this is very loud events such as fighter jets are remembered as specifically annoying, even if they are relatively infrequent. The study also investigated impact of time of day, with most respondents not reporting a specific time of day that increased annoyance. In those that did, the majority specified the time period 0900-1200 for the mixed airport, and 1200-1800 for the civil aircraft airport. Descriptors of the noisiest events, like L_{Amax} and the number of loud noise events, were more strongly related to the observed annoyance than the energy-weighted units $L_{Aeq\ 24h}$, L_{dn} and L_{den}.

Novel indicators

A Swiss study, authored by Wunderli et al (2016), examined the use of a new acoustic descriptor called Intermittency Ratio (IR) , which reflects the 'eventfulness' of a noise exposure situation with the possibility of use alongside the common metrics such as L_{Aeq}. Regarding noise effects on health and wellbeing, average measures often cannot satisfactorily predict annoyance and health effects of noise, particularly sleep disturbances. It has been hypothesised that effects of noise can be better explained when also considering the variation of the level over time and the frequency distribution of event-related acoustic measures, such as for example, the maximum sound pressure level. However, it is unclear how this is best measured in a metric that is not correlated with the L_{Aeq}, but takes into account the frequency distribution of events and their emergence from background. The study looked at whether the intermittent characteristics of noise correlated with subjectively perceived intermittency of noise exposure at the homes of Swiss residents, and whether IR could actually contribute to the explanation of noise annoyance and self-reported sleep disturbance.

The preliminary results suggested that the de-correlation of the IR from L_{Aeq} in the survey sample studies worked relatively well with road traffic noise but less well with railway and aircraft noise, which is surprising given the intermittent nature of aircraft noise. IR was not strongly associated with self-reported perception of intermittency, and does not seem to increase or decrease self-reported annoyance or sleep disturbance responses. It was suggested that the situations with high IR, such as an aircraft overflights, have more and longer noise-free intervals, but also more obvious single events, which could trigger physiological responses at night. The authors suggest a possibility for future epidemiological studies on long-term health effects and sleep disturbances may be to consider the use of IR as a supplementary tool to help explain variance.

Mitigation/Intervention measures

Kroesen and Shreckenberg (2011) published analysis on a new model for general noise reaction in response to aircraft noise. In this paper a measurement model for general noise reaction (GNR) in response to aircraft noise was developed to assess the performance of aircraft noise annoyance and a direct measure of general reaction as indicators of this concept. For this purpose GNR was conceptualized as a superordinate latent construct underlying particular manifestations. This conceptualisation was empirically tested through estimation of a second-order factor model. Data from a community survey at Frankfurt Airport were used for this purpose (N = 2206). The data fit the hypothesised factor structure well and supported the conceptualisation of GNR as a superordinate construct. It was explained that noise annoyance and a direct measure of general reaction to noise capture a large part of the negative feelings and emotions in response to aircraft noise but are unable to capture all relevant variance.

The authors concluded that the results of this present study are in line with the previous findings and indicate that general measures are more valid indicators of negative reaction to (aircraft) noise than specific dimensions such as annoyance or disturbance. The developed model provides insight into the overall experience of aircraft noise. Based on the results it is apparent that this experience is multi-faceted and includes at least three, but possibly many other, dimensions. In addition, from the factor loadings on GNR it can be inferred that dimensions such as noise annoyance and activity disturbance lie at the core of GNR, while the anxiety and fear dimension operates at a more distant level.

The authors suggest several possibilities for future research, including the analysis of additional dimensions of general negative reaction, such as perceived control or the attitude towards noise source authorities to investigate whether such factors are an integral part of general reaction to aircraft noise, or whether these should be thought of as independent variables.

USA Annoyance Study

In the USA, a new Civil Aircraft noise annoyance study is underway. The aim of the study is to produce an up-to-date nationally applicable aircraft noise dose-annoyance response relationship. Given that US aircraft noise policy was first established in the 1970s, there is a need for an updated knowledge base on community noise in the US in the form of a large-scale social survey.

Twenty airports are being surveyed simultaneously over the course of one year, to capture seasonal effects and minimise the chance of bias as the names of the airports have not yet been disclosed. The selected airports meet the following criteria:

- At least 100 jet operations per day.
- At least 100 households exposed to aircraft noise of 65 dB DNL or above.
- Have at least 100 households exposed to levels between 60 dB and 65 dB DNL.

Airport characteristics that may affect how people react to aircraft noise were also taken into account such as:

- Average daily operations – a need to reflect both small and large airports.
- Percentage of night-time operations.
- Average daily temperature – warmer climates result in higher annoyance
- Fleet mix ratio.
- Population within five miles of the airport.

The sample size is approximately 10,000, with the reported annoyance related to the computer modelled noise exposure level at that respondents’ location. The study will collect survey data by post and by a computer-assisted telephone interview, although the postal survey elicits a higher response rate (35% compared to 12% for phone) so the majority of data will be collected in this way. The aim is to produce a cumulative national civil airport annoyance curve from responses to the postal survey, using a logistic regression analysis.

Annoyance and mental health

Noise-induced annoyance measures are often included as part of larger studies on health endpoints, but there has been a paucity of studies examining the potential link between annoyance reactions to aircraft noise, and mental health. A German observational study (Beutel, 2016) examined the link between annoyance and depression and anxiety in a sample of over 15,000 people who were included in the cohort Gutenberg Health Study between 2007 and 2012 and in the vicinity of Frankfurt airport.

Annoyance was measured by asking "How annoyed have you been in the past years by . . ."? for six sources of noise (road traffic, aircraft, railways, industrial/construction, neighbourhood indoor and outdoor) and were separately rated "during the day" and "in your sleep". Ratings were given on the five-point scale ("not, slightly, moderately, strongly, and extremely").

The results suggested that mean depression (measured by the Patient Health Questionnaire) and anxiety (measured by the Generalised Anxiety scale) scores increased steadily from 3.5 to 5.1, and 0.7 to 1.1, respectively, with the degree of annoyance. A sum score of 3 and more (range 0–6) out of these two items indicates generalized anxiety with good sensitivity and specificity. In order to determine the associations between noise annoyance, depression and anxiety, a logistic regression controlling for gender, age and socioeconomic status was performed. Compared to no annoyance, the odds ratio for depression increased steadily starting from moderate (1.22; 95% CI 1.00 to 1.49) to extreme annoyance, which had a 2.12 fold (95% CI 1.71 to 2.64) likelihood of depression. Correspondingly, the likelihood of anxiety increased from moderate (1.45 fold; 95% CI 1.16 to 1.81) to extreme annoyance (2.28 fold; 95% CI 1.79 to 2.91).

The proportion of annoyance was highest from aircraft noise, with nearly 60% of the population reporting it affected them to some degree, and over 6% reporting they were extremely annoyed by it. Aircraft noise was the major source of annoyance in this study, and exceeded the other sources in terms of being strongly annoyed. Strong noise-induced annoyance was associated with a two-fold increase in incidence of depression and anxiety; however, aircraft noise could not directly be related to depression and anxiety outcomes. A major weakness of this study was that there were no objective measurements of noise and it relied solely on self-reported measures of annoyance to perceived noise levels.

Floud et al (2011) also examined the effect of aircraft noise on mental health, and reported on medication use in relation to aircraft noise of populations surrounding six European airports, as part of the HYENA study. Differences were found between countries in terms of the effect of aircraft noise on antihypertensive use. For night-time aircraft noise a 10 dB increase was associated with an odds ratio of 1.34 (95% CI 1.14 to 1.57) for the UK and 1.19 (CI 1.02 to 1.38) for the Netherlands but no significant associations were found for other countries. There was also an association between aircraft noise and anxiolytic (anti-anxiety) medication, OR 1.28 (CI 1.04 to 1.57) for daytime and OR 1.27 (CI 1.01 to 1.59) for night-time. It should be noted that these confidence intervals are considerable in variation. This could indicate an association with symptoms of anxiety. However, it could also indicate sleep disturbance because anxiolytics can be prescribed for sleep problems.

This effect was found across countries. The authors concluded that although results suggested a possible effect of aircraft noise on the use of antihypertensive medication, the effect did not hold for all countries. The data was more consistent for anxiolytics in relation to aircraft noise across countries. No associations were found between noise levels and hypnotics, antidepressants or antasthmatics.

Chapter 5

Non-acoustic factors

As can be seen from the studies in Chapter 4, investigating the effects of aircraft noise and annoyance is not entirely straightforward and the relationship is often affected by other, non-acoustic factors i.e. all those factors other than noise level which contribute to annoyance. Non-acoustic factors encompass a broad spectrum, including age, gender, socioeconomic status, attitudes to aviation, to name but a few. This chapter will explore some of the recent research that focuses on non-acoustic factors within aircraft noise-induced annoyance studies.

In 2010 Schreckenberg et al investigated the associations between noise sensitivity, reported physical and mental health, perceived environmental quality, and noise annoyance. The aim of the study was to test whether noise sensitivity reflects partly general environmental sensitivity and is associated with an elevated susceptibility for the perception of mental and physical health. Annoyance due to environmental noise is influenced by several non-acoustic factors such as personal traits and attitudes toward the noise source. The study explains that previous research has shown that noise sensitivity is regarded as a moderator or mediator of noise annoyance and other effects such as subjective sleep disturbance, or impaired mental performance. Noise sensitivity has also been found to be associated with physical and mental health complaints, irrespective of noise exposure, personality traits such as introversion/extraversion, neuroticism and negative affectivity.

190 participants living around Frankfurt airport were interviewed, with the aim of assessing their residential situation, health-related quality of life, annoyance and disturbances due to noise, in particular to aircraft noise. $L_{Aeq,16h}$ was calculated for air traffic and road traffic, and ranged from 41 to 62 dB for aircraft noise, which was the predominant noise source.

The results indicated that noise sensitivity was associated with self-reported physical health but not with reported mental health. Noise sensitivity contributed to the prediction of the evaluated environmental quality in the residential area, in particular with regard to air traffic (including noise, pollution, and contaminations). Other aspects of perceived quality of the environment were not associated with noise sensitivity. Little evidence was found that suggested that noise sensitivity affects the perception of general environmental quality. The authors concluded that noise sensitivity is more specific, and therefore a reliable predictor of responses to noise rather than a predictor of the way in which people perceive the environmental quality in their residential area as a whole.

Schreckenberg also authored a paper on aircraft noise annoyance (2012) and residents' acceptance and use of sound proof windows and ventilation systems. Residents of Raunheim, which is a town 8km west of Frankfurt, are exposed to high levels of aircraft noise (>60 to 70 $L_{Aeq,16h}$ for easterly operations) and are included in the night protection zone and therefore the noise protection plan implemented by the airport. A telephone survey was conducted on 765 residents, covering annoyance, sleep disturbance and perceived room climate. The results indicated that sleeping with usually closed windows and active ventilators in bedrooms is associated with negative perception of indoor climate, increased aircraft noise annoyance and self-reported sleep disturbance. Schreckenberg suggested as a result, that insulation measures cannot replace operational measures to reduce aircraft noise, such as night flight limitations, optimized take-offs and landing procedures.

Van den Berg et al authored a paper (2012) on the relationship between worry and annoyance with respect to aircraft noise.

Health surveys are carried out periodically in The Netherlands by regional or local Public Health Services. Every four years the GGD (Municipal Health Service) Amsterdam sends questionnaires to a representative part of the population of Amsterdam and, separately, five other municipalities in its work area. In the most recent survey in those five municipalities a number of questions addressed the local environment and its perceived effects. One of the important issues is the effect of Amsterdam Schiphol Airport in terms of noise, air pollution and safety. 70% of the respondents stated that they lived close to the airport. Previous research from Miedema and Vos has suggested that fear is correlated to annoyance, and the aim of this study was to investigate the relationship between worry and aircraft-induced annoyance. The survey results showed a strong correlation between worry about safety or health because of the airport or passing aircraft and annoyance (from noise and odour) of aircraft. 11% of those not worried about living close to a route were highly annoyed by the sound and 1% by the odour of aircraft. For those that are highly worried these percentages are 74% and 23%. This is not a new insight: fear or worry has long been known to be an important determinant of annoyance. Men and young adults (19-34 years) were significantly less annoyed. In relation to self-reported health (symptoms), respondents with anxiety/depression complaints and those with bad health were significantly more worried. A correlation between worry from living in a busy street and noise and odour annoyance from road traffic was also found. Here less people were involved, but of those living in a busy street, approximately the same proportion was worried.

These findings concur with those from Miedema and Vos: fear or a perception of risk is an important factor in relation to noise annoyance. It is interesting that this also appears to be true for odour annoyance.

Noise from air routes and, to a lesser degree, from road traffic, causes most annoyance when compared to noise from the airport and odour from aircraft and road traffic. However, the increase in annoyance score is comparable: when the worry score increases from 4 to 8, the average annoyance score in all relations increases with two to three score points. Worry about health and safety risks is apparently related to both signals coming from the source of worry and though noise creates more annoyance, the signals have approximately the same differential effect on noise as well as odour annoyance.

Charlotte Clark from Queen Mary University of London (2014) authored a paper on the factors associated with noise sensitivity in the UK. The study used data from the 2012 National Noise Attitude Survey (NNAS 2012), and examined whether certain sub-groups of the UK population are more or less sensitive to noise. NNAS 2012 had 2,747 respondents that answered questions relating to attitudes towards environmental noise. Data relating to a range of socio-demographic, dwelling, and geographic factors was also collected. Respondents rated how sensitive they were to noise on a seven-point scale ranging from ‘not at all sensitive’ to ‘very sensitive’.

Overall, noise sensitivity was more strongly associated with socio-demographic factors than with dwelling or geographic factors. Age; gender, homeownership, children, employment status, social class, and interviewer rating of hearing problems were associated with noise sensitivity after adjustment for dwelling and geographic factors. The analyses suggest that certain sub-groups of the population may be more or less noise sensitive compared with the UK population as a whole.

Considered individually, several socio-demographic factors were significantly associated with noise sensitivity: age; gender, homeownership, children, employment status, working at home, shift work, social class, and interviewer rating of hearing problems. These factors remained associated with noise sensitivity scores, after taking other statistically significant socio-demographic, dwelling, and geographic factors into account.

The analysis also revealed that older respondents (aged mid-forties and upwards) had higher noise sensitivity scores, whilst younger respondents (aged 16-24 years) had lower noise sensitivity scores. There was also a significant gender difference in noise sensitivity, with males having lower noise sensitivity scores and females having higher noise sensitivity scores. These findings suggested that within the population, younger respondents and male respondents may be less sensitive to environmental noise exposure than older respondents and female respondents.

Interestingly, those respondents who had a mortgage on their property were found to report themselves as more noise sensitive than those people who owned their home outright. Respondents who had children less than 17 years of age living in the household had significantly lower noise sensitivity scores and respondents without children under 17 years of age in the household had significantly higher noise sensitivity scores. These findings might be explained by higher internal noise exposure within houses with children less than 17 years of age, associated with activities within the home and more residents, making respondents less sensitive to noise.

Respondents who were working full-time or who were retired had significantly lower noise sensitivity scores. This may reflect the fact that respondents who work full-time probably spend less time at home compared to the general population. It is unclear why retired respondents might be less noise sensitive. The authors suggested that it may be due to changes in the auditory system due to aging, but is more likely to be explained by other attitudes and behaviour, as the association between retirement and noise sensitivity remained after taking hearing problems into account.

There was a social gradient in noise sensitivity, with noise sensitivity being higher in respondents with a head of household with a high social class (A) and lower in respondents where the head of household had a lower social class (C2 or D). Future research could examine what other individual or situational factors might explain this social gradient. The results also suggest that hearing ability might be related to noise sensitivity:

respondents without hearing problems had significantly higher noise sensitivity and respondents with hearing problems had significantly lower noise sensitivity scores.

Bauer (2014) authored a paper on findings from the COSMA study. One aim of the EU-project COSMA (Community Oriented Solutions to Minimize aircraft noise Annoyance) was to identify commonalities of the most important non-acoustic factors contributing to aircraft noise annoyance around three different important European airports (London Heathrow, Cologne/Bonn, Stockholm Arlanda) and therewith prepare further studies aiming at updating and more differentiating the current EU dose response relationship. Therefore around 1,200 residents were interviewed by telephone, and 50 residents at each airport were supervised for four consecutive days including continuous sound pressure level recordings and hourly annoyance ratings. The results show that working on other, mostly non-acoustic, influential factors possibly carry a higher potential to reduce aircraft noise annoyance in the medium term than acoustic factors are able to do due to long-term technical implementation times. This is consistent with the findings of the SoNA 2014 study.

In the COSMA study the following influences increased long-term annoyance around the study airports:

- annoyance at night or in early/late hours of the day
- disturbed mental work or relaxation
- noise felt as a health hazard
- coping measures necessary
- personal noise sensitivity

The following influences reduced long-term annoyance around the study airports:

- feeling fairly treated by airport authorities
- belief in getting used to aircraft noise in the future
- belief that the airport is economically important
- satisfaction with noise insulation
- satisfaction with residential area

Bauer explains that in the case of Cologne/Bonn airport, when these non-acoustical variables were included more than 55% of the variance for noise annoyance ratings was accounted for, and thus they are important factors that need to be included when attempting to determine aircraft noise-related annoyance. Increased communication and transparency between airports and residents is clearly an important step in helping to address attitudes towards aircraft noise, and could be assisted by external mediation experts that have a thorough knowledge of noise and associated factors.

The paper discusses the ranking of importance of these non-acoustical factors, and the possibility that they may differ from airport to airport. The COSMA study airports indicate that there are some that presumably matter at every airport. Based on these results, the author recommends that future studies at selected cluster airports should start concentrating on understanding the underlying effects of annoyance reactions at night or in early/late hours of the day, residents' attitude towards possible health effects and examinations about their satisfaction with the installed noise insulation. Is it, for example, important to guarantee for day and night in at least one room each of the airport residents' homes that they always can retire from aircraft noise if they wish to?

These are interesting findings, as although there may be a geographical and cultural bias when assessing aircraft noise-induced annoyance in the UK, these factors are all relevant and should probably be considered in future design of questionnaires and field studies.

Babisch et al (2013) examined whether noise annoyance is a modifier of the association between noise level and cardiovascular health. Effect modification is a biological phenomenon in which the exposure has a different impact in different circumstances. Different models were used to either, include the noise level and noise annoyance variables separately, simultaneously, or together with an interaction term referring to the same noise source for the noise level and the noise annoyance for hypertension data obtained during the HYENA study.

The results suggested that the noise level (objective exposure) as well as the noise annoyance (subjective exposure) may serve as explanatory variables for the assessment of cardiovascular diseases due to chronic noise exposure. There was some indication from the HYENA study that the noise level might have a stronger predictive meaning for the relationship between noise exposure and hypertension than the reported noise annoyance. However, no general conclusion can be drawn as to whether one of the two exposures (noise level and noise annoyance) is a "better" predictor of cardiovascular risk than the other.

Regarding effect modification, the results of the HYENA study support the findings from a Swedish cohort study showing that subjects that are more annoyed by aircraft noise are at a higher risk of hypertension with increasing exposure to aircraft noise (level).

At the 2017 ICBEN Congress, an emerging theme was to attempt to separate out the non-acoustic factors that contribute to the annoyance response. Schreckenberg et al authored a paper on the development of a Multiple Item Annoyance Scale (MIAS). The aim was to incorporate the different dimensions to the annoyance response in terms of a multiple item annoyance scale. Data from the NORAH Work Package 1 was used, which looked at annoyance and quality of life across four airports. Factor analysis[5] was used to separate out those variables which are responsible for the most variance within the annoyance response. For this study, different models were examined, with the best one being the one that included the two factors, Factor 1 (F1): 'Experience of aircraft-related Disturbances' and Factor 2 (F2) 'Lack of coping ability', and correlated error terms. The second best

[5] A statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. The values of observed data are expressed as functions of a number of possible causes in order to find which are the most important.

model was this one with the addition of the ICBEN annoyance item. Table1 shows the 21 variables included in the measurement of aircraft noise-induced annoyance.

Experience of aircraft noise-related disturbances	Affective evaluation, attitudes	Perception of loss in control, lack in coping capacity
In the last 12 months aircraft noise has disturbed … I-1. during communication, when using the phone at home I-2. when listening to the radio and watching TV I-3. when reading and concentrating I-4. when having visitors at home I-5. when staying and/or recovering outdoors I-6. when falling asleep I-7. during the night I-8. when awakening (1) not at all, (2) slightly, (3) moderately, (4) very, (5) extremely	I-9. ICBEN 5-point aircraft noise annoyance Expectations concerning impact of air traffic on residential quality of life: *Response scale: agree (1) not, (2) a little bit, (3) moderately, (4) rather, (5) very* I-10. The air traffic leads to fall in value of residence and properties I-11. The air traffic spoils residents' outdoor stay in the garden, on the terrace or on the balcony. Attributes of air traffic: *Response scale: agree (1) not, (2) a little bit, (3) moderately, (4) rather, (5) very* Air traffic is … I-12. useful I-13. dangerous for me I-14. comfortable for users I-15. environmental harmful	Perceived capability to cope with noise: *Response scale: agree (1) not, (2) a little bit, (3) moderately, (4) rather, (5) very* I-16. I know that I can protect myself quite well against noise. I-17. If it is too loud outside, I simply close the windows, and then I am no longer disturbed. I-18. Sometimes, I really feel at the mercy of the noise. I-19. If it is very loud, I just mentally switch off. I-20. I do not hear the noise anymore. I-21. I have accepted the fact that the noise is here.

Table 1: Initial list of 21 items for the assessment of aircraft noise annoyance

The statistical tests indicated a good model fit for both models (MIAS with two factors and MIAS with two factors plus the ICBEN scale) at each airport studied, indicating adequate construct validity beyond the initial Frankfurt sample.

Correlations of the MIAS, ICBEN 5-point scale, F1 and F2 separately with indicators of aircraft noise exposure, and non-acoustic factors showed that the MIAS and ICBEN scale produced very similar correlation results, with the ICBEN scale being slightly higher in most cases. In terms of the aircraft noise exposure indicators ($L_{Aeq,06\text{-}22h}$, $L_{Aeq,22\text{-}06h}$, $L_{Aeq,24h}$ and L_{den}), the highest correlation coefficients were seen for F1 'disturbances' and the lowest were for F2 'lack of coping capability'. The ICBEN indicator correlates slightly higher than MIAS for the aircraft sound level indicators, and MIAS is slightly higher correlated than ICBEN with the non-acoustic factors including degrees of sleep disturbance, trust in authorities, noise sensitivity, views that air traffic is useful/dangerous/environmentally harmful etc.

The results indicated that F1 'disturbances' correlated higher with sleep, with the judgement that air traffic is dangerous, and with physical health related quality of life than F2. The F2 'coping ability' correlated higher with other judgements and expectations concerning the impact of air traffic, mental HQol and noise sensitivity than F1.

Schreckenberg recommended that F1 and F2 should be calculated before summarising these scores together with the ICBEN annoyance item to MIAS. Statistically, a higher order factor of annoyance consisting of F1 and F2 would already be a reliable and valid parsimonious[6] construct. However to continue the internationally standardised assessment of noise annoyance, the inclusion of the single annoyance item suggested by ICBEN is still recommended by the authors. In addition, the ICBEN 5-point scale was found to be an assessment of noise annoyance with good criterion validity, and the correlations with acoustical and non-acoustical factors are of expected size and quite similar to those of MIAS.

The advantages of using a MIAS include:

- It helps to understand the interrelations between different noise effects and therefore might be more effective in the assessment of the impact of noise-related interventions.
- Using multiple items to assess annoyance means response bias is reduced and different causes of different components of annoyance are more explicit.

The limitations to this study include:

- The questionnaires were not specifically developed for the purpose of the study; this was an ad hoc analysis of pre-existing data from the NORAH study.
- No emotion-related item concerning aircraft noise was assessed – the ICBEN item was used as its own proxy for affective reaction.
- The ICBEN 11-point scale was not used, and it is not certain how this would fit in to the factorial structure of MIAS.
- This study was aircraft-noise specific. Whether it could also be generalised to other noise sources has not been tested.
- The items referring to F2 were non-source specific and should be related to the specific noise source of interest.

Marquis-Favre and Gille (2017) authored a paper at ICBEN 2017 on how to test noise annoyance models based on psychoacoustic indices using socio-acoustic survey data. The models used were proposed by Gille et al and were based on noise sensitivity and psychoacoustic indices for aircraft noise studied in laboratory conditions. The psychoacoustic indices account for annoying auditory sensations such as sensations due to tonal components and amplitude fluctuations present in aircraft flyover noise.

This paper describes a methodology that is proposed in order to estimate values of psychoacoustic indices. The methodology is assessed using data collected during a French socio-acoustic survey carried out in 2012. The database is constituted of noise annoyance and noise sensitivity responses as well as Lden values for each respondent.

A methodology proposed to estimate the psychoacoustic index values at respondents' dwellings is presented. Then, the methodology is assessed comparing in situ measured

---

[6] A model that accomplishes a desired level of explanation or prediction with as few predictor variables as possible.

annoyance and annoyance predicted from model using the estimated psychoacoustic index values.

The results suggested that a model based on psychoacoustic index and noise sensitivity enabled better prediction of measured noise annoyance responses than the L_{den} index alone did. Results also highlighted that the methodology proposed to approximate psychoacoustic index values for each survey respondent allowed further enhancement of models for a better prediction of noise annoyance felt by inhabitants. More work in this area is required to eliminate approximations and gain more accurate results, but it is possible that consideration of psychoacoustic factors will enable in situ annoyance responses to be better understood and therefore predicted in future.

Also at the ICBEN 2017 Congress, Dirk Shreckenberg presented work on attitudes towards authorities and aircraft noise annoyance, with sensitivity analyses on the relationship between non-acoustical factors and annoyance.

The study used survey data from the three waves of the NORAH study, in 2011 prior to the opening of the new runway at Frankfurt airport ,in 2012 and 2013 (one and two years after the runway opening, respectively). In order to clarify the potential of non-acoustical factors to reduce annoyance, sensitivity analyses of attitudinal and annoyance data from the NORAH study were carried out. Considerable differences in exposure-response curves for aircraft noise annoyance were found depending on 'trust in authorities', ‘perceived procedural fairness’ and 'expectations regarding the air traffic's impacts'. The aim of this study was to explore the causal direction of noise annoyance and ‘trust in authorities’ as an indicator of people’s attitudes towards authorities.

Within the questionnaire, aircraft noise annoyance was measured on the ICBEN 5-point scale, “trust in authorities” was measured as an indicator of attitudes towards the aviation community and authorities, residents' belief about authorities' efforts for reducing the aircraft noise annoyance in communities around the airport was measured using a 5-point scale (endeavours (1) not at all – (5) very). The perceived fairness of the decision process regarding the air traffic operations and noise management at Frankfurt Airport was assessed only in the first survey wave (2011). A summarised mean score of 'perceived procedural fairness' was calculated from responses on a 5-point scale (agree (1) not – (5) very) to the following four items: (1) I think that aircraft noise is distributed fairly amongst all residents; (2) When decisions concerning aircraft noise are being made, I have opportunities to express my views to the relevant people; (3) I have the chance to appeal decisions that I consider to be wrong; (4) Decisions concerning aircraft noise are explained and justified to me in detail. The variable 'Positive expectations concerning the impact of air traffic on the regional development and the residential life' was assessed by a mean score of the following items on a 5-point scale (agree (1) not – (5) very): (1) The airport improves the regional development; (2) The air traffic leads to fall in value of residence and properties; (3) The air traffic brings new jobs to the region; (4) The air traffic spoils residents' outdoor stay in the garden, on the terrace or on the balcony.

Figures 20- 22 display the percentage of people highly annoyed by aircraft noise (%HA) in 2013 by $L_{Aeq,24h}$, and by discrete values of attitudes assessed previously such as trust in authorities, perceived procedural fairness and positive expectations of the impact of air traffic.

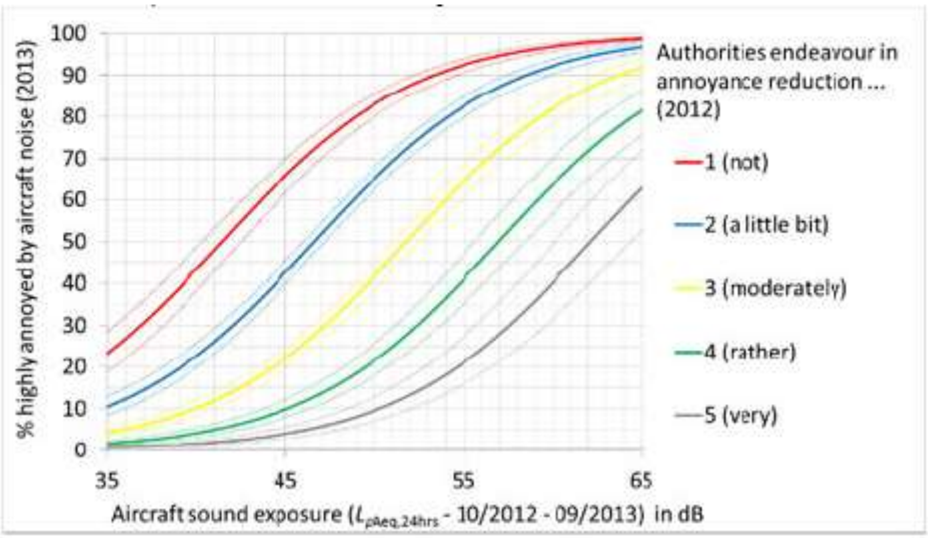


Figure 20: Percentage Highly Annoyed by Aircraft Noise and 'Trust in Authorities' (2012)

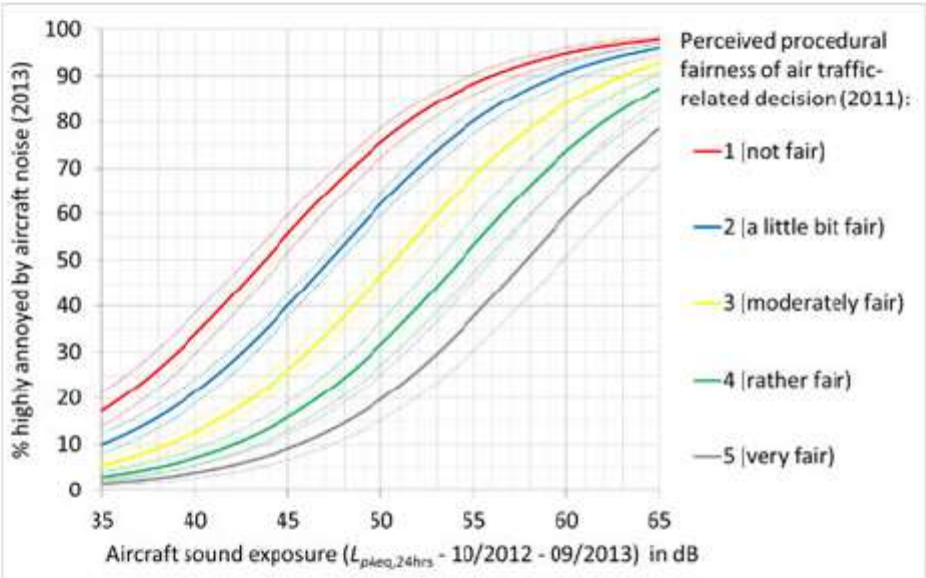


Figure 21: Percentage Highly Annoyed by Aircraft Noise and 'Perceived Procedural Fairness of decisions relating to air traffic and noise management' (2011)

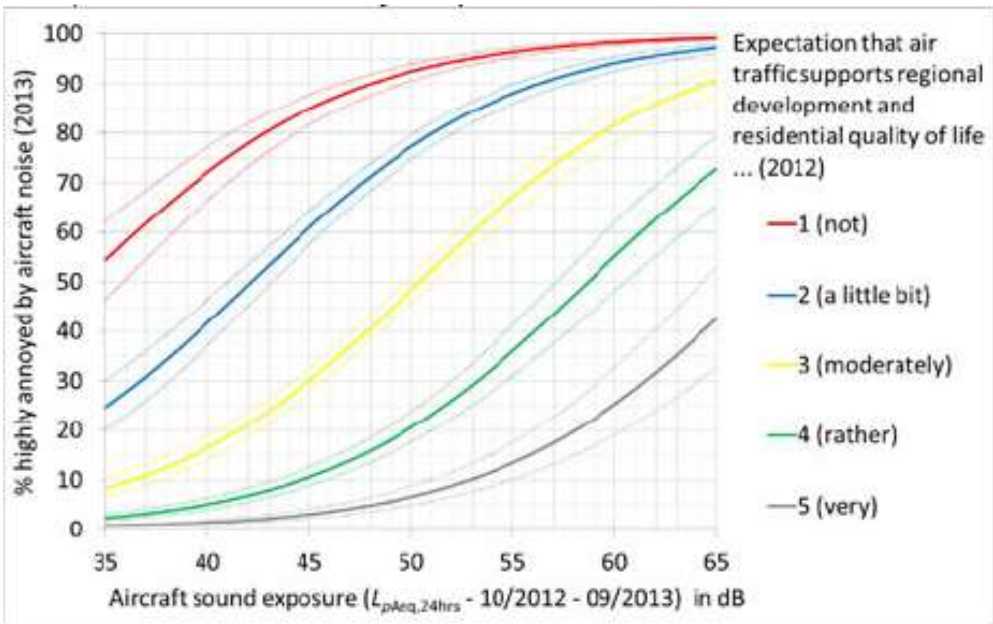


Figure 22: Percentage Highly Annoyed by Aircraft Noise and expectations of air traffic on regional development and residential quality of life. (2012)

Taking the example of 'trust in authorities', different hypothesised causal directions between annoyance and attitudes ('trust in authorities' contributes to the prediction of annoyance and vice versa) were analysed using longitudinal data of the NORAH study. The relationship between trust and annoyance seems to be reciprocal with changing strength of one of the two causal directions depending on whether there is a change in noise exposure (e.g. airport expansion) or not. The relationships are complex in nature and it is suggested by the authors that in future noise abatement projects the attitudes related to the source or to authorities should be considered in addition to the acoustical and operational measures. The impact of such a noise management on exposed people should then be evaluated in intervention studies in order to get a better understanding of noise effects and of how to minimise noise effects.

Non-acoustic factors are an important consideration when undertaking research on aircraft noise-induced annoyance, and indeed other sources of environmental noise. There is an emerging drive to separate out the relative contribution of non-acoustic factors to the annoyance response and address the importance of understanding the complexities of the relationships between such factors and annoyance.

Chapter 6
Summary and Conclusions

This report has provided an overview of the background to, methodologies surrounding and recent research into aircraft noise-induced annoyance. Several themes have emerged in the literature, and can be summarised as:

- Briefly, there has been a change in annoyance responses; people are more highly annoyed now by aircraft noise than 30 years ago, but it is important to take into account confounding factors.
- With regard to annoyance changing over time, there remain questions around whether this is due to survey methods and/or non-acoustic factors rather than a shift in attitudes towards aircraft noise.
- The NORAH Study has utilised a natural opportunity for the exploration of annoyance responses following the opening of a new runway, and implementation of a night curfew, and found that annoyance responses were particularly strong for lower noise levels (below 55 dB $L_{Aeq,24h}$); for those people experiencing an increase in noise levels in the year following the opening of the runway, and for the first year after opening compared to the following year, which saw a decrease in annoyance and levelling-out effect.
- The examination of ‘high rate of change’ (HRC) and ‘low rate of change’ (LRC) airports revealed that residents around LRC airports are able to tolerate 7-10 dB higher noise levels than the suggested EU curve, and in terms of Community Tolerance Level (CTL). Those people living around HRC airports exhibit a lower Community Tolerance Level (CTL) level, and were more annoyed by approximately 5 dB on the EU curve.
- There is the potential for longitudinal studies in order to obtain a clear timeline of attitudes over time in the UK. This could be possible with repetition of the SoNA Study.
- Several attempts are being made at trying to explain the variance within the annoyance response, using modelling to calculate the weight of non-acoustic factors. This is important work, and should lead to improved methodologies for annoyance studies, and a greater insight into the annoyance response characteristics.
- A question remains around annoyance at night. It is very difficult to separate the sleep disturbance response from the annoyance response at night and it could be questioned as to whether this even matters to some extent?
- It is recommended that the inclusion of questions on trust in authorities and perceived fairness in air traffic related decisions should be included in future surveys, given the importance of these aspects to the annoyance response.

Chapter 7
References

ANASE – Attitudes to Noise Aviation Sources in England. (2007) MVA Consultancy.

Aviation Policy Framework (2013) presented by the Secretary of State.

Babisch, W. et al. (2013) Noise annoyance — A modifier of the association between noise level and cardiovascular health? Science of the Total Environment 452–453:50–57

Bauer, M. et al. (2014) COSMA – A European Approach on Aircraft Noise Annoyance Research. Internoise Congress. Melbourne.

Beutel, M.E. et al. (2016) Noise Annoyance Is Associated with Depression and Anxiety in the General Population- The Contribution of Aircraft Noise. PLoS ONE 11(5): e0155357. doi:10.1371/journal.pone.0155357

Brooker, P. et al. (1985) United Kingdom Aircraft Noise Index Study. Prepared on behalf of DfT by the Civil Aviation Authority.

Clark, C. et al. (2014) What factors are associated with noise sensitivity in the UK population? Internoise Congress. Melbourne.

Department for Transport (2003) The future of air transport: White paper.

Dratva, J.et.al. (2010) Impact of road traffic noise annoyance on health-related quality of life: results from a population-based study. Qual life Res. 19(1):37-46

Elmenhorst, E-M. et al. (2012) Examining nocturnal railway noise and aircraft noise in the field: Sleep, psychomotor performance, and annoyance. Science of the Total Environment 424: 48–56

Eriksson, C., Hilding, A., Pyko, A., (2014) Long-Term Aircraft Noise Exposure and Body Mass Index, Waist Circumference, and Type 2 Diabetes: A Prospective Study. Environmental Health Perspectives online.

Fidell, S. Silvati,L. (2011) Social survey of community response to a step change in aircraft noise exposure. The Journal of the Acoustical Society of America. 111, 200

Fidell, S. et al. (2011) A first-principles model for estimating the prevalence of annoyance with aircraft noise exposure. J Acoust Soc Am. Aug;130(2):791-806

Floud, S. et al. (2010). Medication use in relation to noise from aircraft and road traffic in six European countries: results of the HYENA study. Occup Environ Med ;68:518e524.

Foraster, M. et al. (2016) Long-termtransportation noise annoyance is associatedwith subsequent lower levels of physical activity. Environment International 91: 341–349

Gelderblom, F.B. et al. (2014) The impact of civil versus military aircraft on noise annoyance. Internoise Congress. Melbourne.

Gjestland, T. et. al. (2016) Noise surveys at five Norwegian airports. Internoise Congress. Hamburg.

Gjestland, T. (2017) Standardized general-purpose noise reaction questions. ICBEN Congress, Zurich.

Guski, R. Schreckenberg, D., Schuemer, R. (2016) The WHO evidence review on noise annoyance 2000-2014. Internoise, Hamburg.

Janssen, S. et al. (2011) Trends in aircraft noise annoyance: the role of study and sample characteristics. J Acoust Soc Am. Apr;129(4):1953-62

Jones, K. (2010) Aircraft noise and children's learning. ERCD Report 0908. Civil Aviation Authority.

Kroesen M, Molin EJ, Wee Bv. (2010) Determining the direction of causality between psychological factors and aircraft noise annoyance. Noise and Health;12:17-25

Kroesen M, Schreckenberg D. (2011) A measurement model for general noise reaction in response to aircraft noise. J Acoust Soc Am. Jan;129(1):200-10.

Marquis-Favre, C., Gille, L-A. (2017) How to test noise annoyance models based on psychoacoustic indices using socio-acoustic survey data? The case of aircraft noise annoyance models. ICBEN, Zurich.

Maynard,R. Et al (2009) Environmental Noise and Health in the UK. http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1246433634856

Miedema, H. Vos, H. (1998) Exposure-response relationships for transportation noise. J Acoust Soc Am. 104(6):3432-45.

Miedema HM, Oudshoorn CG. (2001) Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Environ Health Perspect.109(4):409-16.

Miedema, H.M.E. (2007) Annoyance caused by environmental noise: Elements for evidence–based noise policies. Journal of social issues. (63) 41-57.

Miedema, H.M.E.(2007) Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. Behavioural sleep medicine. (5) 1-20.

Miller, N.P. et al (2014) Research Methods for Understanding Aircraft Noise Annoyances and Sleep Disturbance Airport. ACRP.

Nguyen, T.L., et al. (2016) Social surveys on community response to a change in aircraft noise exposure before and after the operation of the new terminal building in Hanoi Noi Bai International Airport. Internoise Congress, Hamburg.

Noise Policy Statement for England (2003) Department for the Environment, Food and Rural Affairs.

Quehl, J., Basner, M. (2006) Annoyance from nocturnal aircraft noise exposure: Laboratory and field-specific dose–response curves. Journal of Environmental Psychology 26 :127–140

Schreckenberg, D. et al. (2010) The associations between noise sensitivity, reported physical and mental health, perceived environmental quality, and noise annoyance. Noise Health. Jan-Mar;12(46):7-16

Schreckenberg, D. (2012) Aircraft noise annoyance and residents' acceptance and use of sound proof windows and ventilation systems. Internoise Congress. New York.

Schreckenberg, D. et al. (2016) Effects of aircraft noise on annoyance and sleep disturbances before and after the expansion of Frankfurt Airport – results of the NORAH Study WP1 ‘Annoyance and Quality of Life’. Internoise Congress, Hamburg.

Schreckenberg, D. et al. (2017) First results of the development of a multiple-item annoyance scale (MIAS). ICBEN, Zurich.

Schreckenberg, D. et al. (2017) Attitudes towards authorities and aircraft noise annoyance: Sensitivity analyses on the relationship between non-acoustical factors and annoyance. ICBEN, Zurich.

Schultz, T. J. (1978). ‘‘Synthesis of social surveys on noise annoyance,’’ J.Acoust. Soc.Am. 64, 377–405.

Seabi, J. (2013) An Epidemiological Prospective Study of Children’s Health and Annoyance Reactions to Aircraft Noise Exposure in South Africa. Int. J. Environ. Res. Public Health, 10, 2760-2777

Silva, B. et al. (2017) Annoyance survey by means of social media. J Acoust Soc Am. Feb;141(2):1019

Survey of Noise Attitudes 2014: Aircraft. Civil Aviation Authority on behalf of the DfT.

Van den Berg, F. et al. (2015) The Relation between Self-Reported Worry and Annoyance from Air and Road Traffic. Int. J. Environ. Res. Public Health, 12, 2486-2500

van Kempen, E. M., van Kamp, I., Stellato, R.K., et al. (2009) Children’s annoyance reactions to aircraft and road traffic noise. J. Acoust. Soc. Am. 125:2

World Health Organization (2011) Burden of disease from environmental noise – quantification of healthy life years lost in Europe.

Wilson, A; Ferguson, T.R; Fogg, A. et al. (1963) Noise – Final Report. Report of the committee on the problem of noise. Her Majesty’s Stationary Office.

Wunderli, J.M. et al. (2016) Intermittency ratio: A metric reflecting short-term temporal variations of transportation noise exposure. Journal of Exposure Science and Environmental Epidemiology 26, 575–585

Reference 7

ICCAN review of airport noise insulation schemes March 2021

ICCAN

Independent Commission on Civil Aviation Noise

ICCAN review of airport noise insulation schemes

March 2021

Contents

About ICCAN

The Independent Commission on Civil Aviation Noise (ICCAN) was established in 2019 and operates as an independent and impartial body on matters related to civil aviation noise and how it impacts communities. The first aim of our two-year programme has been to improve public trust and confidence in the management of aviation noise by developing expert knowledge and understanding of the challenges associated with aviation noise. Our expert knowledge base has resulted in a range of research and publications which we continue to build on, all of which are available on ICCAN's website.

Foreword

It is widely accepted that high-quality noise insulation is an effective way to mitigate the impacts of aviation noise inside people's homes. Future growth at many UK airports has rightly been conditional on airports providing funding to insulation schemes for the homes of people most impacted. I am sure that airports genuinely believe they are providing insulation of high enough quality to meet these conditions.

The question is how to ensure that the quality and effectiveness of the insulation used in airports' schemes is sufficient.

When ICCAN was established in January 2019, the Aviation Minister asked us to look into this very issue and recommend some ways forward. We wanted to examine what airports offer, and have promised through their schemes, and how the insulation providers have responded. So, we commissioned the Building Research Establishment (BRE) to conduct a technical review. This document summarises their key findings and sets out our initial recommendations.

We recognise that the Covid-19 pandemic has brought significant challenges for the aviation industry and we have revised our timescales on this work to take account of this. Though I also know that prior to the pandemic there was no shortage of willingness from airports to work with ICCAN on this issue, and we anticipate that many would welcome further guidance on what constitutes 'good' quality and 'fair' distribution.

We hope this report is a first step towards creating best practice to ensure consistency, clarity and fairness in the way insulation is used to mitigate aviation noise impacts in the future. In our recommendations we commit to working in partnership with manufactures, installers, and airports to support new standards in the future.

[redacted]

Rob Light

ICCAN Head Commissioner

Rationale

Noise insulation schemes created by UK airports are not subject to central legislation, so airports are free to create their own insulation policy, resulting in a variation of noise insulation schemes. In the consultation paper Aviation 2050 – The Future of UK Aviation (UK Government, 2018), the Government proposed that new guidance be issued to airports on best practice for noise insulation schemes, to improve consistency. ICCAN's first Corporate Strategy, therefore, had a commitment to review the performance and consistency of airports approaches to noise insulation schemes and provide guidance on best practice (ICCAN, 2019).

ICCAN recognises that since its formation in 2019 and the start of its work on insulation schemes, the aviation landscape has been dramatically altered by the Covid-19 pandemic with far fewer aircraft in the sky. While this is an uncertain time for airports and aviation, with their focus understandably on survival and economic sustainability, once aviation recovery is underway noise will return, and insulation schemes will come under the spotlight again.

Given the current situation regarding Covid-19, and the associated challenges the commercial aviation industry face, this document contains a summary of the key findings from our technical review. It sets out our initial recommendations, which future, more detailed guidance should address if consistent airport insulation schemes are to be provided. We will continue to work on more detailed recommendations and standards, consulting with industry and experts in the field.

ICCAN's approach

The overall aim of this study is to develop a detailed review of the components required to implement noise insulation schemes that deliver optimal standards for noise reduction in affected household properties. To gain a better understanding of how noise insulation schemes could deliver optimal standards, ICCAN commissioned the Building Research Establishment (BRE) to conduct a technical review. The comprehensive review considers the following key issues affecting insulation schemes designed to mitigate aircraft noise in existing residential properties:

1. Insulation products and systems
2. Testing of properties
3. Installation of insulation
4. Building Regulations
5. Quality management

Insulation products and systems: this was achieved by conducting a detailed review of products and systems which can be retrofitted to properties and mitigate the noise ingress from aircraft noise. The review examines key acoustic attributes of products and systems and highlights typical performance values. To give an idea of what is achievable in terms of the performance of acoustic insulation and the resultant internal noise levels, BRE examined different ranges of sound insulation in a what-if model.

Testing of properties: this involved a robust review of testing methods used to determine the level of noise intrusion entering properties from aircraft noise before and after the installation of acoustic insulation. This approach identified the most effective methods, including advantages and disadvantages, from a practical perspective.

Installation of insulation: this reviewed different existing approaches to the installation of acoustic insulation used in the UK and overseas, highlighting the benefits and disadvantages of these approaches from the perspective of the occupants and the airports that implement the measures.

Building Regulations: this examined current Building Regulations 2010, relating to the retrofitting of products and systems that improve sound insulation properties of a household. This review also examined any unintended consequences for the building or occupants that would not be addressed through existing compliance of the Building Regulations.

Quality management: this reviewed different approaches to measuring the quality of work conducted by installers of acoustic insulation products and systems. This included examining different approaches by quality assurance schemes and their applicability to airport noise insulation schemes.

Key findings and initial recommendations

1: Insulation products and systems

1. The review found that for each of the acoustic insulation product types examined, there is already a published framework for testing, reporting and declaring acoustic performance, except for secondary glazing. However, having reviewed industry documents and centrally issued guidance, it found that very few relevant industry standards exist in relation to the mitigation of aircraft noise and the required insulation products.

2. A lack of consistency and/or detail in terms of insulation product standardisation between different airports was identified. This makes it difficult to determine whether all UK airports currently offer products of an appropriate standard.

3. There is the potential that noise insulation schemes may include products that have not been tested for acoustic performance.

4. A model of what-if scenarios, created by BRE, demonstrated that a number of acoustic insulation treatments with a range of different insulation products should be capable of resulting in internal noise levels during the daytime that achieve current (WHO) guidelines (Berglund, Lindvall, & Schwela, 1999).

ICCAN's initial recommendations

1. ICCAN is committed to improving standards related to mitigating the effects of aircraft noise and recommends that a set of guidance should be created directly related to mitigating aircraft noise including the required product standards. This would include examining current British Standards (BS) to determine how effective they are at covering aviation noise.

2. In order to create a more consistent approach to the selection of acoustic insulation products, ICCAN aims to develop a best practice toolkit that can help airports to identify an appropriate range of insulation products.

3. Given the risk of untested insulation products not providing appropriate levels of indoor noise reduction, ICCAN will only recommend the use of products that meet standards for acoustic insulation.

4. To help with the selection process for choosing insulation packages, the toolkit mentioned in recommendation 2 will consider the many different factors and requirements based on noise reduction requirements. This will include performance-based outputs for chosen acoustic insulation products.

2: Testing of properties

1. Establishing the effectiveness of installed acoustic insulation products requires testing the indoor sound levels. The review found that, between industry guidance and standards published by the British Standards Institution (BSI), there are clear protocols for testing properties for levels of noise pollution, determining current acoustic performance of the building envelope, and assessing the effectiveness of mitigation deployed.

2. The Association of Noise Consultants (ANC) guidelines provides detailed and useful information necessary for measuring sound levels within properties due to internal and external sources. This, however, is only based on internal measurements of pre and post works. The review suggests that the ANC's methodology could be improved by including the measurement of external noise over the pre and post work time period, to ensure the variation in the external noise is accounted for.

3. The most accurate approach for in-situ testing of sound insulation characteristics would require using BS EN ISO 16283-3 methods. This approach helps to better understand all noise transmission paths allowing for an optimal insulation package to be delivered. Testing of a property by an experienced acoustician has been estimated to take around half a day but it may not be practical to test all properties surrounding an airport.

4. If it is desirable to understand the noise levels within a home over a long duration e.g. over the course of a year or more, the more reliable method may be to determine the sound insulation performance of the building envelope in conjunction with long term, predicted external noise levels using noise contours. Contours can provide a picture of the long-term external noise environment and so deal with the variability of external aircraft noise. However, these noise contours need to be accurate.

5. Only one airport was found to set indoor noise reduction targets. London City Airport set a target for their noise insulation works at the 57 dB noise contour and state the work must achieve "*an average sound reduction not less than 25 dB averaged over 100 to 3150 Hz in accordance with BS EN ISO 16283-3:2016*" (BRE, 2020).

ICCAN's initial recommendations

1. ICCAN recommends that external noise monitoring is conducted in parallel to internal noise measurements and we will work with ANC to offer advice on updating their current guidelines.

2. It is important to develop an effective sampling strategy to test sound insulation in-situ. This could include testing a sample of properties of the same build type and surveying individual properties with more unique attributes, such as old stand-alone cottages.

3. The use of accurate and appropriate noise contours should be used for understanding noise levels and insulation performance over long time periods. ICCAN will be using our own forthcoming noise metrics best practice guidance to determine the best approach to the use of noise contours for estimating long-term external noise.

4. Setting a performance based indoor noise reduction target is a good approach to setting realistic expectations with property owners. ICCAN welcomes this approach; however, more work needs to be done to determine the criteria used in setting such targets throughout UK airports.

3: Installation of insulation

1. Having studied a number of UK airports' approaches to the installation of acoustic insulation (BRE Report, Appendix A), BRE found that while airports often conducted home surveys prior to the installation of properties, there was no mention of prior testing. A detailed understanding of the pathways of noise ingress into a building is required to help provide the best approaches to installation of insulation.

2. There are two key approaches to the provision of sound insulation packages i.e. pre-determined solutions and tailored solutions. The pre-determined approach uses noise contours to determine the insulation products supplied. This is similar to insulation schemes mentioned in the Noise Insulation Regulations (NIR 1975), used for sound insulation addressing road and rail noise. A tailored approach, based on testing of properties, allows for a more specific range of insulation products to be used for individual properties, which could be more costly due to greater expert input and more insulation products used.

3. Airports sometimes give property owners the option to select their own insulation products and/or appoint a contractor to conduct the installation work. BRE determined that the homeowner may not necessarily be the correct, or indeed competent, person to make decisions regarding product and contractor selection due to their lack of expertise.

4. There are generally two approaches to the installation of insulation: individual rooms or the perimeter approach. UK insulation schemes generally target the insulation of habitable rooms rather than the entire property as in the perimeter approach e.g. Sydney Kingsford Smith Airport (Burgess, Cotton, & Butler, 2000). BRE adopts the view that the room approach is fit for purpose since the concept features in the NIR 1975 specification.

ICCAN's initial recommendations

1. ICCAN recommends property inspections and testing, in line with a detailed sampling strategy as mentioned in ICCAN principle 2 of Testing of Properties above.

2. A balance of both pre-determined solutions and tailored solutions should be used, depending on the attributes of the building. The noise contour approach will generally be acceptable for a range of properties with identical build qualities. The tailored approach should be used for unusual build types.

3. ICCAN recommends that airports should appoint approved contractors to install insulation products, but householders should be given the option to make non-technical decisions such as colour or style of window frames.

4. ICCAN recognises that in the majority of cases the 'room' approach to insulation will be appropriate. The 'perimeter' approach can be used at the discretion of the airport, depending on the build type and noise levels experienced.

4: Building Regulations

1. There are Building Regulations requirements that will come into force when acoustic insulation products/packages are installed, as relevant to the product or works undertaken. It is specifically the responsibility of the person undertaking the works to demonstrate compliance with the Building Regulations, rather than the homeowner.

2. BRE identified examples of unintended consequences of installing insulation for the building and/or occupants that were not addressed through the compliance of the Building Regulations. Overheating may occur where closed windows and loft insulation may reduce heat loss. It was found that there are no specific requirements relating to overheating in the Building Regulations (Association of Noise Consultants, 2020). Whilst NIR 1975 provides details of ventilation options, these were primarily aimed at maintaining indoor air quality (Committee on the Problem of Noise, 1963).

3. Without correct detailing, condensation can build up either between the primary and secondary units or on the inside (room side) face of the secondary glazing unit (Pickles, 2016). Either situation could lead to damage to the building or represent a health risk to the building occupant if left unchecked.

ICCAN's initial recommendations

1. ICCAN recommends a best practice approach is developed to address overheating. It will also explore the possibility of including an amendment to the Building Regulations, ensuring aviation noise is factored into any acoustic insulation works, including its impact on overheating.

2. The issue of condensation and how to mitigate it should be considered during the early stages of product selection for noise insulation schemes. Details of potential condensation issues and which specialists to contact for advice will feature in the toolkit as mentioned in ICCAN principle 2 under Insulation products and systems.

5: Quality management

1. The review was unable to establish whether there is a consistent approach to quality management for airport acoustic insulation schemes in the UK. This is not to say that individual schemes do not have their own quality management systems or requirements, but this information was not available for a detailed review.

2. There are centrally endorsed competent persons schemes covering installation of many products that may be used to provide acoustic insulation to properties. The schemes are directly concerned with satisfying Building Regulation requirements. However, noise ingress into a building from aircraft noise is not currently addressed by the Building Regulations so the relevant competent persons schemes do not specifically address sound insulation.

3. The review concluded that the use of a contractor or supplier who is a member of a competent person scheme or professional body does ensure benefits relating to quality including sound insulation.

4. BRE's findings determined that there could be an opportunity for collaboration between airport operators, schemes and professional bodies to develop a guide, code of practice or a certification scheme relating to the installation of sound insulation products.

ICCAN's initial recommendations

1. ICCAN recommends that only certified contractors should be used for the installation of noise insulation products.

2. ICCAN would look forward to adopting the role of a facilitator for the collaboration of relevant stakeholders to ensure the development of robust quality management standards relating to installation of acoustic insulation products.

ICCAN’s next steps

Our review confirms the lack of any standardised approach to noise insulation schemes across UK airports and an apparent lack of pre and post insulation testing of properties that would determine the effectiveness of noise insulation products. Some aspects of product installation may require scrutiny by amendments to the Building Regulations and quality management should be more focused on the installation of acoustic insulation products.

The Government has already suggested some changes to insulation policy in the Aviation 2050 consultation paper. At the time of writing, it is unclear how the Government intends to progress the proposals in the Aviation 2050 consultation document in light of the Covid-19 pandemic. However, we look forward to working with them on the future strategy once the recovery has started.

We will continue to work on more detailed recommendations and standards, in parallel with our work on metrics best practice, on which some of our future insulation standards will rely.

ICCAN plans to work in collaboration with industry experts to ensure the most accurate technical advice regarding standards is incorporated into the development of our recommendations.

Similarly, we intend to work with other industry experts and airports to help develop new, standardised approaches to the installation of noise insulation products. Our standards will be proportionate, practicable and reflective of the current challenges facing the aviation industry.

References

Association of Noise Consultants. (2020). *Acoustics Ventillation and Overheating Residential Design Guide Version 1.1.* Northallerton: Association of Noise Consultants.

Berglund, B., Lindvall, T., & Schwela, D. (1999). *Guidelines for Community Noise.* Geneva: World Health Organisation.

BRE. (2020). *A review of insulation standards, building regulations and controls related to airport noise insulation schemes.* Watford: © Building Research Establishment Ltd.

Burgess, M., Cotton, M., & Butler, K. (2000). Residential Insulation Scheme around Sydney Airport. *The 29th International Congress and Exhibition on Noise Control Engineering.* Nice: InterNoise 2000.

Committee on the Problem of Noise. (1963). *Noise Final Report.* London: HMSO.

ICCAN. (2019). *Corporate Strategy 2019 - 2021.* © Crown copyright 2019. Retrieved 02 11, 2021, from https://iccan.gov.uk/wp-content/uploads/2019_07_25_ICCAN_Corporate_Strategy-2019_2021.pdf

Pickles, D. (2016). *Energy efficiency and older buildings, Secondary glazing for windows.* UK: Historic England.

UK Government. (2018). *Aviation 2050:The Future of UK Aviation, a consultation.* London: © Crown copyright 2013.

Contact ICCAN:
01484 240457 | ContactICCAN@iccan.gov.uk