Survey of Noise Attitudes 2014: Aircraft Noise and Sleep Disturbance, Further Analysis

CAP 2251

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CHAPTER 1

Introduction

1.1 This report describes results within a research study to obtain new and updated evidence on attitudes to aviation noise around airports in England (SoNA 2014[1]). The study was commissioned by the Department for Transport, and this report focuses on self-reported attitudes to sleep disturbance from aircraft noise, taken from responses to questions from within the larger SoNA study.

1.2 The main focus of the SoNA 2014 study was on annoyance responses and general attitudes to aircraft noise. However, there was also a subset of questions relating to self-reported sleep disturbance and night noise from aircraft. It is the responses to these questions that are described within this report. It should be noted that the SoNA 2014 study was not designed specifically with a view to analysing attitudes to aircraft noise at night, and therefore this is very much an exploratory examination, with the consequential limitations. In the context of this report, the night period refers to the time between 23:00 and 07:00.

1.3 This report focusses on further examination of the sleep disturbance element of the study and examines the use of additional aircraft noise-induced awakenings as the noise dose function, instead of the $L_{Aeq,8h}$ and L_{night} metrics that were investigated in the SoNA Sleep report.[2]

1.4 The overall aims of the SoNA 2014 'Sleep Study: Further Analysis' are to:

- Investigate alternative night noise metrics such as additional aircraft noise-induced awakenings.
- Explore the correlation between the number of additional aircraft noise-induced awakenings and average night noise exposure.

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1 Survey of Noise Attitudes 2014: Aircraft Noise, CAP 1506, Civil Aviation Authority, Second Edition. July 2021.

2 Survey of Noise Attitudes 2014: Aircraft Noise and Sleep, CAP 2161, Civil Aviation Authority, July 2021.

- Explore any potential relationship between additional aircraft noise-induced awakenings and self-reported quality of health.
- Examine any link between self-reported noise sensitivity and the number of additional aircraft noise-induced awakenings at night from aircraft noise.

1.5 The report is structured as follows:

- Background
- Methodology
- Social survey results
- Noise exposure: Additional aircraft noise-induced awakenings and sleep disturbance
- Health and wellbeing
- Summary and conclusions

1.6 The Glossary to the report gives definitions of the more commonly used technical terms concerning aircraft and airport operations used here.

CHAPTER 2

Background

2.1 CAP 2161 Survey of Noise Attitudes 2014: Aircraft Noise and Sleep Disturbance ("SoNA Sleep") provides a detailed background into the methodology used in sleep research in general, such as electroencephalography (EEG), polysomnography (PSG), actigraphy, and the use of self-reported responses to standardised questions on sleep disturbance.

2.2 In the SoNA Sleep study, self-reported sleep disturbance was used as the method for analysing sleep disturbance with regard to aircraft noise. The initial part of the SoNA Sleep Study had the following aims:

- Explore relationships between self-reported sleep disturbance and noise exposure.
- Explore any potential relationship between self-reported sleep disturbance and self-reported quality of health.

2.3 The SoNA Sleep study used the $L_{Aeq,8h}$ and L_{night} metrics as the noise indicators from which dose-response functions were derived for sleep disturbance.

2.4 The findings of the SoNA Sleep study included:

- The mean night-time disturbance scores correlated well with average night noise exposure defined using average summer night $L_{Aeq,8h}$, annual average night L_{night}, and average summer night N60. The r^2 for L_{night} (0.842) was slightly lower than for $L_{Aeq,8h}$ (0.883). It was considered plausible that L_{night} is inferior to $L_{Aeq,8h}$ as both Gatwick and Stansted airports experience significant seasonality with greater numbers of night flights during the summer months. N60 was found to correlate almost as well as $L_{Aeq,8h}$ and L_{night}. Based on this exploratory analysis, there was insufficient evidence to change from the current practice of using average summer night $L_{Aeq,8h}$ noise exposure for UK assessments.

- Although there was no compelling evidence for a change of practice from using average summer-night, it was recommended that future studies investigate associations with the highest noise level of either westerly or easterly mode. Mean disturbance score and the likelihood of being highly sleep disturbed were found to increase with increasing night-time noise exposure ($L_{Aeq,8h}$). The relationship found was close to linear, though disturbance levels plateaued at low and high exposure.
- For a given noise exposure, a higher proportion of respondents was found to be highly sleep disturbed compared with the Miedema pre-1990 dose-response function. At 45 dB $L_{Aeq,8h}$, 8-10% were estimated to be highly sleep disturbed compared with 5% for the Miedema curve. At 48 dB $L_{Aeq,8h}$, 10-12% were estimated to be highly sleep disturbed compared with 6% for the Miedema curve. The SoNA 2014 night-time dose response function was, however, found to be lower than the function from the post-1990 studies.
- Noise exposure and self-reported sleep disturbance were compared against the self-reported health rating (5-point scale) and the Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS), a measure of wellbeing. Poorer health ratings and lower SWEMWBS scores were found to be associated with self-reported sleep disturbance, but not with noise exposure.

2.5 This report (CAP 2251) describes results from further analysis into sleep disturbance and wellbeing using the number of additional aircraft noise-induced awakenings per night due to aircraft noise, as an additional metric.

CHAPTER 3

Methodology

3.1 Information provided here is specific to the analysis of attitudes to night noise. More detailed methodology for SoNA 2014 is provided in CAP 1506, Survey of Noise Attitudes 2014: Aircraft Noise and Annoyance, Second Edition[1], which dealt with daytime annoyance.

3.2 For analysis of attitudes to night noise, the SoNA 2014 face-to-face interview sample of 1,999 from around eight airports was reduced to 1,588 adults aged 18 and over living in residential dwellings in the vicinity of three airports in England: Gatwick, Heathrow and Stansted. This was done to focus on the three airports designated for noise control purposes where Government sets night noise controls, and with more comprehensive night noise exposure data available. Of the 1,588 residents interviewed at these airports, 100 stated they had recently moved into the area and did not live there during summer 2014 and thus were excluded from the analysis, giving a sample total of 1,488. Five of these respondents answered don’t know to the night-time noise disturbance question (CAN1vii) and were excluded from the analysis, leaving a sample of 1,483.

Sampling

3.3 Because the primary study objective was an analysis of attitudes to daytime aircraft noise, sampling was based on daytime noise exposure. Consequently, there was no direct control over selection of night noise exposure levels. Details on the distribution of night noise exposure levels were presented in Chapter 5 of CAP 2161.

Questionnaire design

3.4 The survey questionnaire, as provided in Appendix B comprised five sections:

1. A general section
2. An optional Road Traffic Noise section
3. An optional Neighbourhood Noise section
4. A Civil Aircraft Noise section
5. A Health section

3.5 The SoNA 2014 questionnaire design was both peer-reviewed and underwent cognitive testing to confirm people's understanding of the questions asked, and to identify any need for questionnaire improvement and simplification.

Survey Design

3.6 The noise survey questionnaire, the selection and sampling process are reported and covered separately in Ipsos MORI's 2014 Survey of Noise Attitudes (SoNA) technical report[3], which provides more detailed information on the sample strategy agreed, response rates, demographics of participants, survey questionnaire including show cards and diagrams showing areas sampled.

3.7 The survey was conducted via face-to-face in-home interviews with residents aged 18 and over who lived in the vicinity of nine airports in England and took approximately 35 minutes to complete. The survey employed a random probability methodology and was conducted with adults randomly chosen within their household. Although SoNA was based on respondents living in the vicinity of nine airports, this night noise survey analysis is based on a subset of respondents living near three airports.

3.8 Fieldwork was conducted between 5 October 2014 and 8 February 2015. The survey selected respondents at random, according to the populations around the sample airports.

3 The 2014 Survey of Noise Attitudes (SoNA) Technical Report, Ipsos MORI, CAP 1506a, 22 June 2015.

Additional Aircraft Noise-Induced Awakenings

3.9 CAP 2161 used average 8-hour night noise exposure as the noise dose in order to investigate associations with self-reported sleep disturbance. Despite the average night 8-hour noise dose being correlated with the number and levels of single aircraft noise events, communities have expressed concern that average 8-hour noise doses do not adequately reflect the night-time disturbance they experience.

3.10 Individuals experience different numbers of different single event noise levels, depending on their geographic location relative to a given airport and the mix of type, size and flight path direction of aeroplanes operating at night.

3.11 Basner et al[4] performed extensive laboratory and field studies on the effects of aircraft noise on sleep between 1999 and 2004. The study utilised polysomnographic measurement of sleep patterns. Polysomnography is made up of several discrete measurements of brain and body functions. It includes the electroencephalogram (EEG), which measures brain electrical activity, the electrooculogram (EOG), which measures eye movement, the electromyogram (EMG) that measures muscle tension, and the electrocardiogram (ECG) that measures heart activity. Together, the EEG, EOG, and EMG signals are called polysomnography, from which the five different sleep stages may be classified.

3.12 Basner et al defined awakenings as EEG and EMG activations that last for at least 15 seconds. In the study, subjects on average, experienced about 24 awakenings per night regardless of any noise stimulus, with the majority lasting for between 15 and 45 seconds, which were too short to be remembered the next day. However, one or more of the awakenings may have lasted longer and may have been associated with waking consciousness and may have been recalled the next day.

3.13 Basner et al then related awakening to indoor aircraft noise levels and found that the probability of additional noise-induced awakening (P_{AWR}) increased with

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

increased indoor maximum noise level, L_{ASmax} and found that the probability of additional aircraft noise-induced awakening at a given respondent location was predicted by:

$$P_{AWR} = 1.894 \times 10^{-3} {L_{ASmax}}^2 + 4.008 \times 10^{-2} {L_{ASmax}}^2 - 3.3243 \qquad \text{(Equation 1)}$$

3.14 Standard aircraft noise models predict noise levels outdoors. For this report, a value of 15 dB has been used for the noise reduction from outdoors to indoors, provided by a partially open window.

3.15 It can be seen in Equation 1 that the probability of additional aircraft noise-induced awakening (P_{AWR}) is related to a maximum noise level of each aircraft event, rather than the 8-hour average night noise exposure. Therefore, to apply the probability function requires the maximum noise level of every aircraft operation to be determined. Although computer models calculate these individual levels in order to generate average night noise exposure, the individual levels for each aircraft type and each flight track are not usually stored due to the large number of combinations involved. It is not practical to estimate the noise levels of every individual flight, so it remains appropriate to group operations of the same aircraft type on the same aircraft flight track together as they will produce the same average maximum (L_{ASmax}) noise level. Thus, the calculation does not need to be performed for every single flight, only for unique combinations of aircraft type and flight track, whilst taking into account the number of operations of each combination. A typical large airport, however, has a large number of combinations, thus the calculation is much more involved than calculating $L_{Aeq,8h}$ or L_{night}.

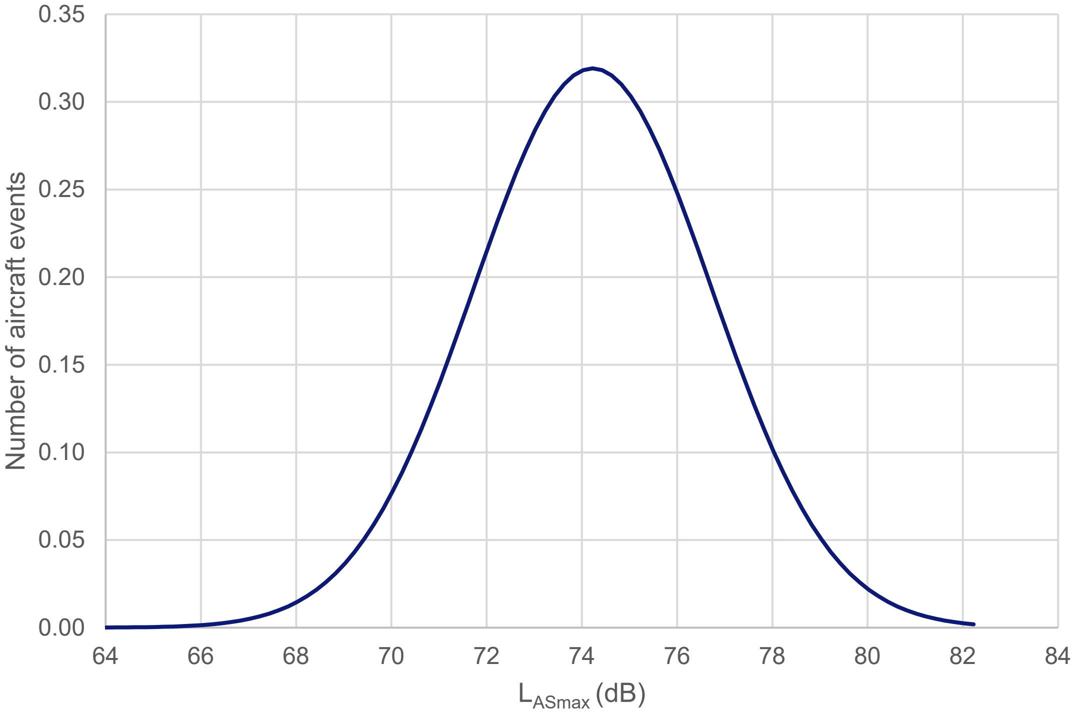
3.16 Equation 1 is a function of the maximum level, L_{ASmax}. Calculations of $L_{Aeq,8h}$ or L_{night} are based on Sound Exposure Level (SEL), which also takes into account the duration of each noise event. Because L_{ASmax} is based on a shorter measurement period than SEL, measured L_{ASmax} levels are more variable than measured SEL.

3.17 Normally variation around the mean calculated noise level is not relevant, levels slightly above or below the mean level cancel each out. However, Equation 1 reaches zero indoors at 33 dB L_{ASmax}, equivalent to 48 dB L_{ASmax} outdoors. A mean outdoor value of 47.9 dB L_{ASmax} would imply zero awakenings. However, if the average level is 47.9 dB L_{ASmax}, 50 percent of aircraft events will be louder than 47.9 dB L_{ASmax} and result in some increased risk of additional aircraft noise-induced awakenings according to Equation 1. Thus, it is necessary to take into account the variation in noise levels that occur around the average level predicted by standard calculation models.

3.18 Figure 1 shows an example redistribution of the number of discrete L_{ASmax} events that would occur representing ten events with an average L_{ASmax} of 74.2 dB and standard deviation of 2.5 dB. For this application, the average L_{ASmax} was re-distributed across a normal distribution using class widths[5], each 0.2 dB wide, as used by Basner et al[4], and a standard deviation of 2.5 dB. In Figure 1, the sum of the events occurring between 65 and 83 dB L_{ASmax} is ten events.

5 In a histogram, the entire range of the x-axis (independent variable) is divided into a series of consecutive, non-overlapping intervals of the variable. These intervals are often known as class widths, and the count of datapoints whose x-axis values that fall into each class is represented by the height of the histogram bar for each class.

Figure 1: Redistribution of average L_{ASmax} as a normal distribution for ten flights[6] with average L_{ASmax} 74.2 dB and standard deviation of 2.5 dB



3.19 The number of additional aircraft noise-induced awakenings (N_{AWR}) for, for example, an average summer night, at a given respondent location is then calculated as:

$$N_{AWR} = \sum_i P_{AWR}(L_{ASmax,i})n(L_{ASmax,i}) \qquad \text{(Equation 2)}$$

Where:

P_{AWR} is the probability of an additional aircraft noise-induced awakening (Equation 1), as a function of $L_{ASmax,i}$.

n is the number of operations generating $L_{ASmax,i}$.

$L_{ASmax,i}$ is the average A-weighted maximum noise level (slow time-constant) for the unique combination of aircraft type and flight track, i.

3.20 The calculation may be performed at household locations, for example, when predicting awakenings to associate with attitudes of sleep disturbance, or it can

6 This analysis distributes an integer number (10) of aircraft movements over a much greater number (100) class bands according to a normal distribution. Consequently, each class band is allocated with its own non-integer number of aircraft movements that is less than one. Although a fraction of an aircraft event does not make practical sense, it is necessary for modelling purposes.

be performed over a grid of locations, just like for computing contours of $L_{Aeq,8h}$ or L_{night}, except there are grids of the maximum L_{ASmax} for every combination of aircraft type and flight track which are processed to calculate the total number of awakenings at each grid point. From this, contours of the number of additional aircraft noise-induced awakenings per average night may be calculated, as occurs for $L_{Aeq,8h}$ and L_{night}.

3.21 By using the Basner relationship, the distribution of single event level and number of events at a given location can be distilled down to a single value of the number of additional aircraft noise-induced awakenings. For the remainder of this report, this is treated as a noise dose, though strictly speaking it is a measure of night-time noise impact (effect) and not a physical measure of noise exposure.

3.22 Figures 2 to 4 illustrate the $L_{Aeq,8h}$ night noise contours in gradients of grey, alongside contours for 1, 2 or 3 additional aircraft noise-induced awakenings per average summer night, for Gatwick, Heathrow and Stansted, respectively.

3.23 Whilst there is a clear correlation between the number of additional aircraft noise-induced awakenings and the average summer night $L_{Aeq,8h}$ noise dose, the additional aircraft noise-induced awakenings indicator gives more weight to the number of events. This was confirmed by Basner. Therefore, areas experiencing fewer, but louder events show comparatively fewer awakenings than areas experiencing more, but less noisy events, and fewer awakenings than the average summer $L_{Aeq,8h}$ noise dose might indicate. This is particularly visible in Figure 3 for Heathrow.

Figure 2: Average summer night additional aircraft noise-induced awakenings versus $L_{Aeq,8h}$ for Gatwick 2014 (modal split 60% west/40% east, 123.1 total movements, 78.8 arrivals and 44.3 departures)

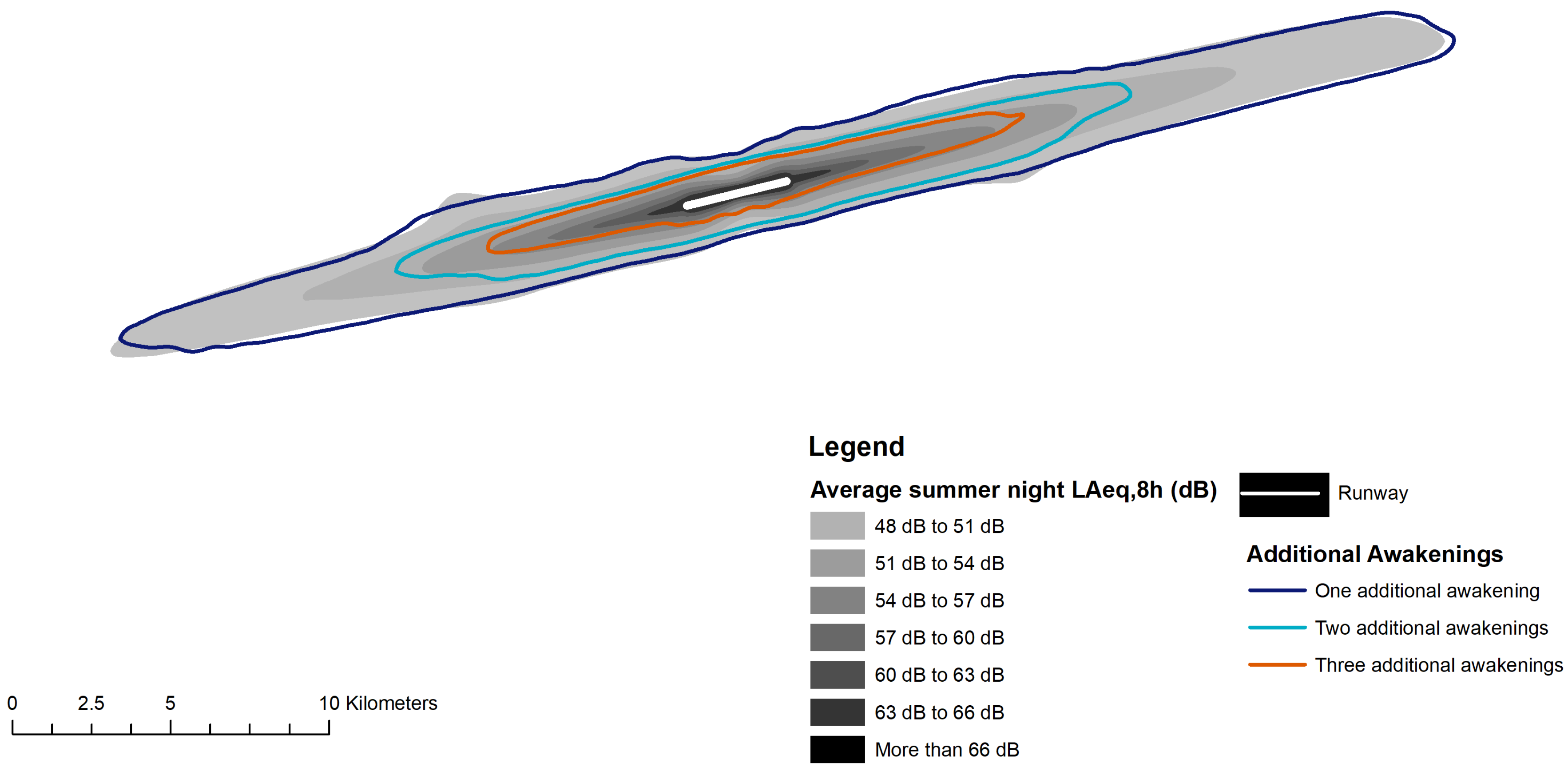


Figure 3: Average summer night additional aircraft noise-induced awakenings versus $L_{Aeq,8h}$ for Heathrow 2014 (modal split 66% west/34% east, 80.1 total movements, 56.9 arrivals and 23.2 departures)

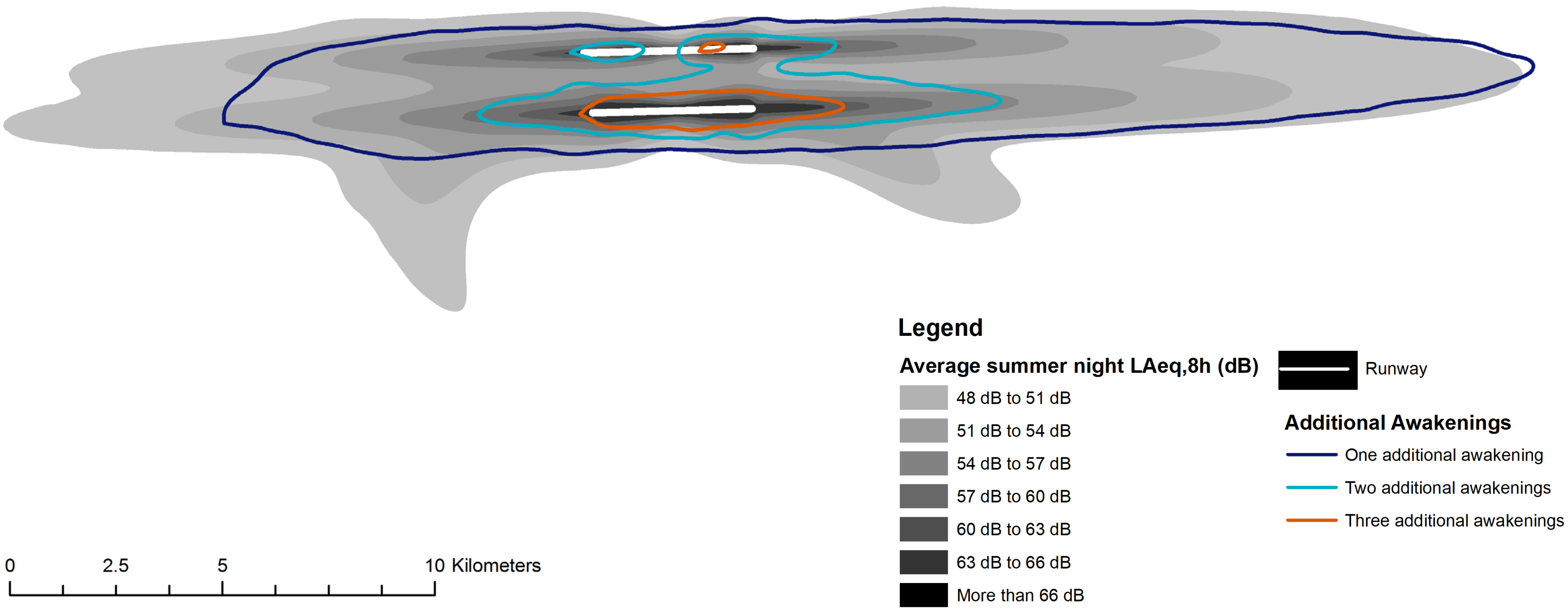
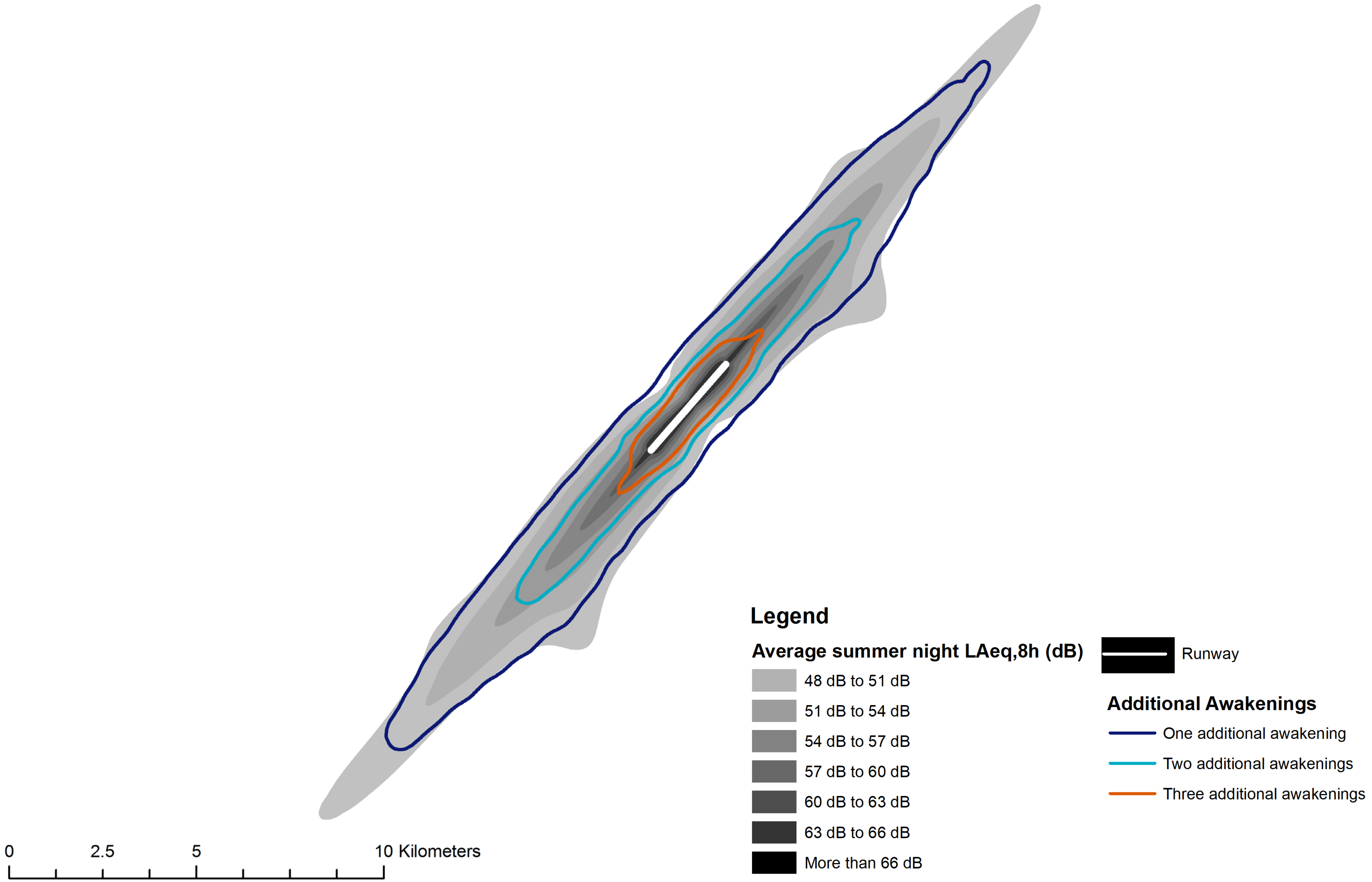


Figure 4: Average summer night additional aircraft noise-induced awakenings versus $L_{Aeq,8h}$ for Stansted 2014 (modal split 50% west/50% east, 74.4 total movements, 44.6 arrivals and 29.8 departures)



CHAPTER 4

Additional aircraft noise-induced awakenings and night-time disturbance

Introduction

4.1 Chapter 4 in CAP 2161 provides a full description of the SoNA 2014 sample used for sleep analysis. As stated in paragraph 3.2 above, a sample of 1,483 is used in this analysis.

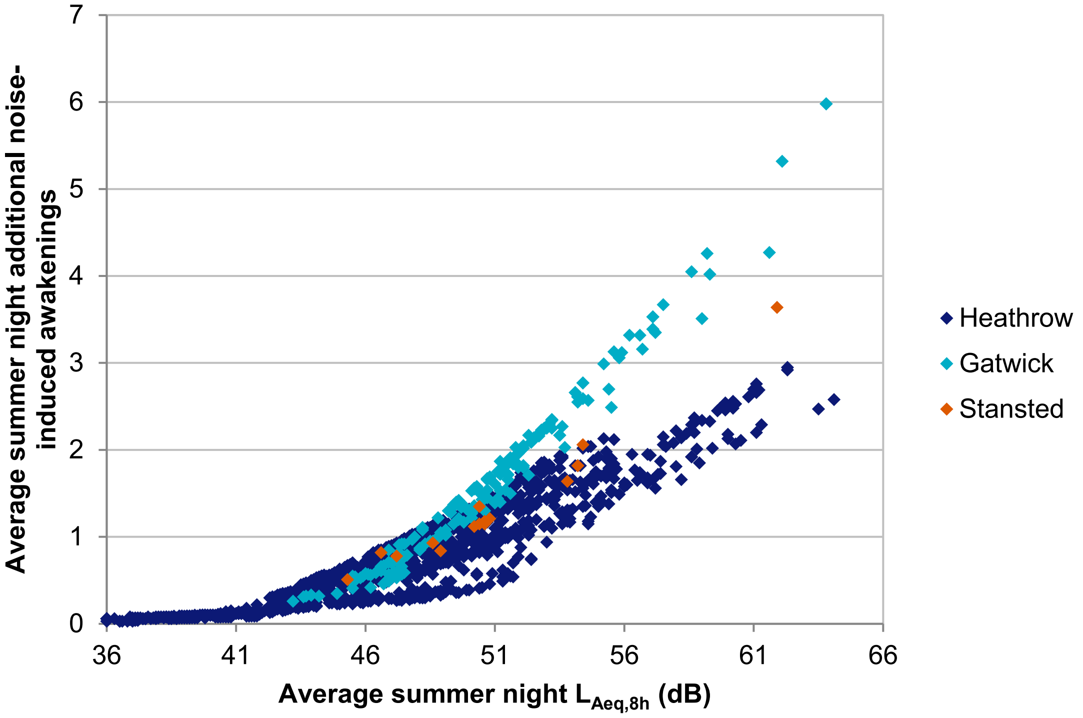
4.2 This chapter addresses the following aims of this study:

- Investigate alternative night noise metrics such as additional aircraft noise-induced awakenings.
- Explore the correlation between the number of additional aircraft noise-induced awakenings and average night noise exposure.

Additional aircraft noise-induced awakenings and noise exposure

4.3 The number of additional aircraft noise-induced awakenings for each respondent was correlated with the average summer night $L_{Aeq,8h}$ dB noise level, and is shown as a scatterplot in Figure 5.

Figure 5: Association between average summer night $L_{Aeq,8h}$ noise level and the number of additional aircraft noise-induced awakenings for each of the three airports



4.4 It should be noted that some of the higher number of additional aircraft noise-induced awakenings at higher exposures may be an over-estimate. This is because at higher noise exposure, some respondents may shut their windows to mitigate the aircraft noise. Furthermore, some may have specific sound insulation treatment to enable them to shut their windows. In both cases, the internal L_{ASmax} levels will be lower than is assumed in the results presented in Figure 5.

4.5 In summer 2014, there were 123.1 movements at Gatwick, 80.1 movements at Heathrow and 74.4 at Stansted during each average summer night period (23:00-07:00). The proportion of arrivals was 64%, 71% and 60% at Gatwick, Heathrow and Stansted respectively.

4.6 Figure 5 shows less scatter at Stansted due to the dominance of a single aircraft type, the Boeing 737-800. Gatwick also has similar types of aircraft, predominantly narrow body twin-engine aircraft types. At Heathrow there is a mix of heavier wide-body and lighter narrow body aircraft, which accounts for the spread of the data points.

4.7 Furthermore, at Heathrow, the number of additional aircraft noise-induced awakenings is approximately half of those at Gatwick for a given noise exposure, due to the presence of two runways distributing operations over a wider area and reducing the number of events at any particular location.

Survey Questions on Night-Time Disturbance

4.8 This study analysed the same question, CAN1vii, from SoNA 2014 as for CAP 2161, the difference being that this time the noise dose is the additional number of awakenings, rather than the average summer night $L_{Aeq,8h}$:

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? Sub-question vii asks specifically about disturbance at night (23:00 – 07:00).

Table 1: CAN1 response options

	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.)	○	○	○	○	○	○

Night-time Disturbance Scores

4.9 It has become standard practice to transform annoyance responses on a 5-point scale to a 100-point scale to enable future comparison with survey results using this equation:

$$Annoyance\ Score_i = \frac{100\,(i-1/2)}{m} \quad \text{(Equation 3)}$$

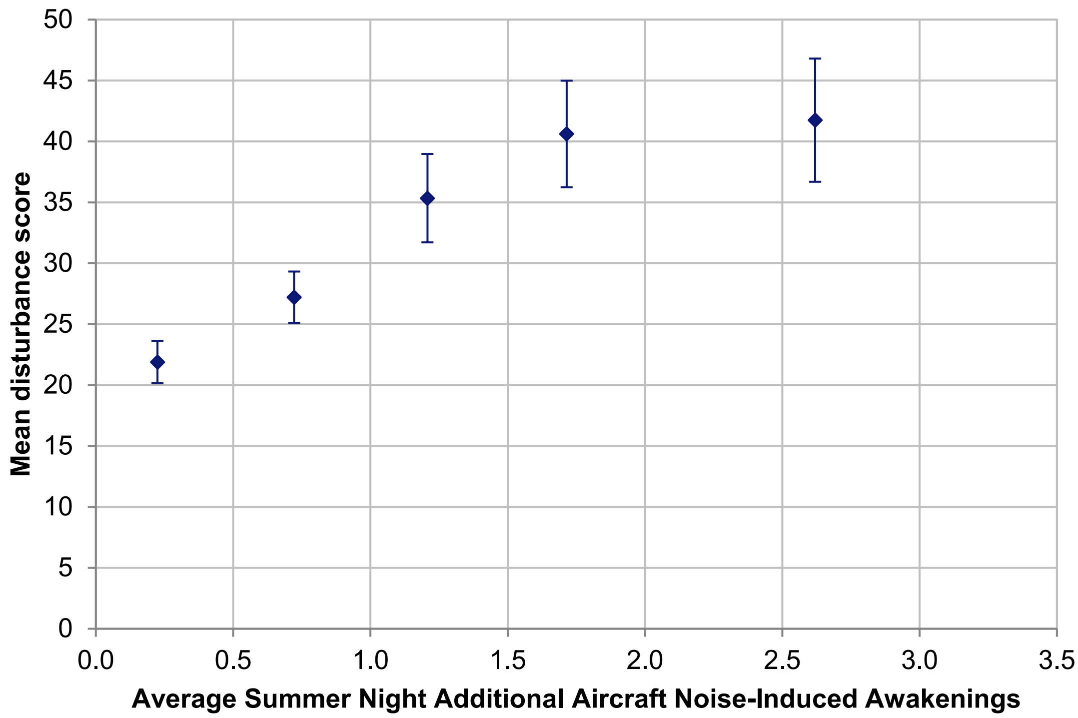
4.10 Equation 3 is used to illustrate the relationship for the 5-point scale and night-time disturbance score shown in Table 8 of CAP 2161.

4.11 Table 2 presents the CAN1vii mean night-time disturbance scores as a function of the number of additional aircraft noise-induced awakenings. The data are plotted in Figure 6.

Table 2: CAN1vii mean night-time disturbance scores as a function of the number of additional aircraft noise-induced awakenings (N=1,483)

Additional aircraft noise-induced awakenings for average summer night	N	Mean disturbance score	95% Confidence Interval
0.0-0.5	483	21.9	1.7
0.5-1.0	508	27.2	2.1
1.0-1.5	236	35.3	3.6
1.5-2.0	147	40.6	4.4
>2.0	109	41.7	5.1
Total	**1,483**	**-**	**-**

Figure 6: CAN1vii mean disturbance scores as a function of the number of average summer night additional aircraft noise-induced awakenings



Relationship between mean disturbance score and additional aircraft noise-induced awakenings

4.12 As in the previous SoNA reports, a logistic function was fitted through the mean disturbance scores. A logistic function[7] is preferred as it is naturally bounded between 0 and 100, unlike other types of functions. The correlation of determination (r^2) of a logistic function was fitted using ordinary least-squares regression for each noise indicator as shown in Table 3.

Table 3: Correlation between CAN1vii and the average summer night additional aircraft noise-induced awakenings

Night-time disturbance (CAN1vii)	N	r^2
Average summer 8-hour night additional aircraft noise-induced awakenings	1,483	0.850

4.13 The correlation between CAN1vii and average summer night additional aircraft noise-induced awakenings of 0.850, compares well with values of 0.842 to 0.883 for annual average L_{night} and average summer night $L_{Aeq,8h}$, respectively, as reported in CAP 2161. This is not surprising, since average summer night awakenings are well-correlated with $L_{Aeq,8h}$ and L_{night}.

4.14 This analysis shows that despite the concerns that are expressed that averaging the exposure at night may not properly reflect the impact of individual aircraft events, $L_{Aeq,8h}$ and L_{night} do correlate with the number of additional aircraft noise-induced awakenings arising from individual aircraft events at night and the self-reported sleep disturbance results found in the SoNA 2014 survey (CAP 2161).

4.15 Additionally, this analysis shows a high degree of association between the estimated number of additional aircraft noise-induced awakenings and the self-reported sleep disturbance rating. The association, was however, no better than that found using average summer night $L_{Aeq,8h}$ in CAP 2161. The analysis does,

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7 The data points are close to linear, and correlation does not significantly change whether a linear, polynomial or logistic function is used. A logistic function, however, avoids the situation where a linear or polynomial function predicts zero or negative annoyance at low noise exposure.

however, imply there could be scenarios where the number of awakenings may be a better estimate of impacts than $L_{Aeq,8h}$.

Percentage Highly Sleep Disturbed

4.16 Following on from Miedema's work on noise annoyance, Miedema also applied a cut-off of 72 on a 100-point scale to define being 'highly sleep disturbed'[8].

4.17 Using the 100-point scale in Table 8 in CAP 2161, the cut-off for the 5-point scale is:

- 'Extremely Sleep Disturbed' (category 5) +
  0.4 x 'Very Sleep Disturbed' (category 4) (Equation 4)

4.18 Table 4 shows the distribution of night disturbance responses to CAN1vii as a function of additional aircraft noise-induced awakenings.

Table 4: Distribution of night disturbance responses to CAN1vii question as a function of additional aircraft noise-induced awakenings

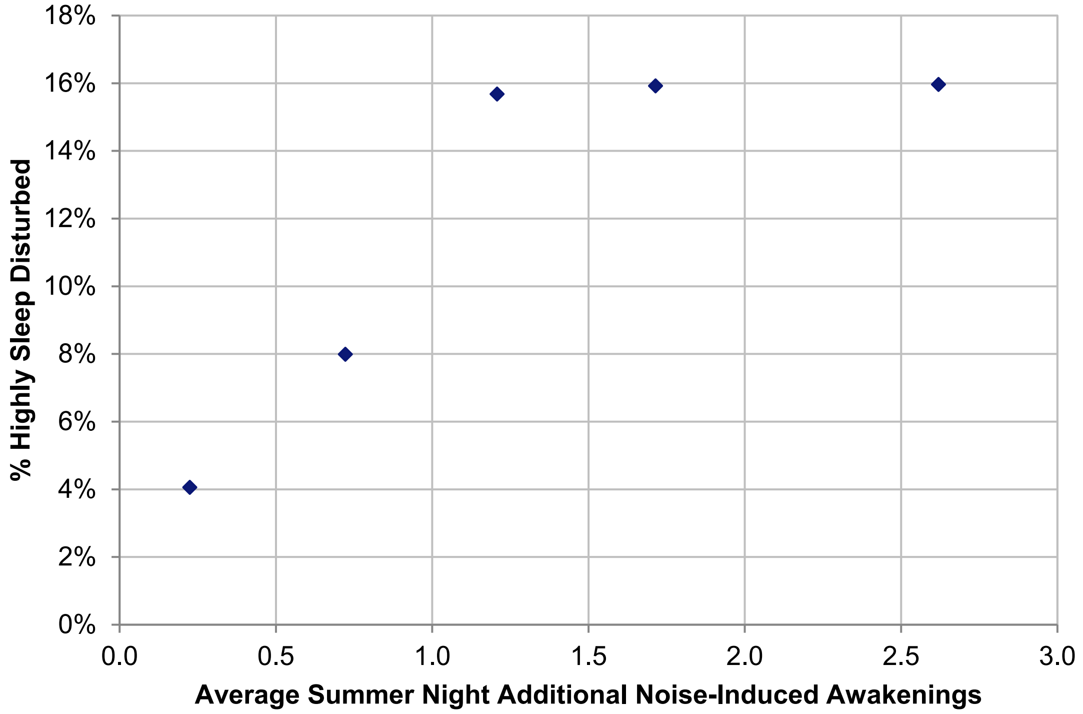
				Highly Sleep Disturbed			
Average summer night additional awakenings	**Not at all % (N)**	**Slightly % (N)**	**Moderately % (N)**	**Very % (N)**	**Extremely % (N)**	**Total**	**Highly Sleep Disturbed % (N)**
0.0-0.5	62.5% (302)	24.4% (118)	6.6% (32)	3.9% (19)	2.5% (12)	100% (483)	4.1% (19.6)
0.5-1.0	56.7% (288)	18.1% (92)	12.6% (64)	7.7% (39)	4.9% (25)	100% (508)	8.0% (40.6)
1.0-1.5	41.5% (98)	23.7% (56)	12.7% (30)	10.6% (25)	11.4% (27)	100% (236)	15.7% (37.0)
1.5-2.0	30.6% (45)	21.1% (31)	21.8% (32)	17.7% (26)	8.8% (13)	100% (147)	15.9% (23.4)
>2.0	30.3% (33)	16.5% (18)	25.7% (28)	19.3% (21)	8.3% (9)	100% (109)	16.0% (17.4)
Total	**51.7% (766)**	**21.2% (315)**	**12.5% (186)**	**8.8% (130)**	**5.8% (86)**	**100% (1,483)**	**9.3% (138)**

4.19 The results indicate that over 50% of the sample were not at all annoyed by aircraft noise at night. A third of the sample (33.7%) were slightly or moderately annoyed and just over 14% responded in the highest two categories.

[8] Miedema H.M.E. and Vos, H., 2007, 'Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies', Behavioral Sleep Medicine, 5(1) 1–20.

4.20 Figure 7 illustrates the percentage of respondents calculated to be highly sleep disturbed based on the calculated additional aircraft noise-induced awakenings for an average summer night.

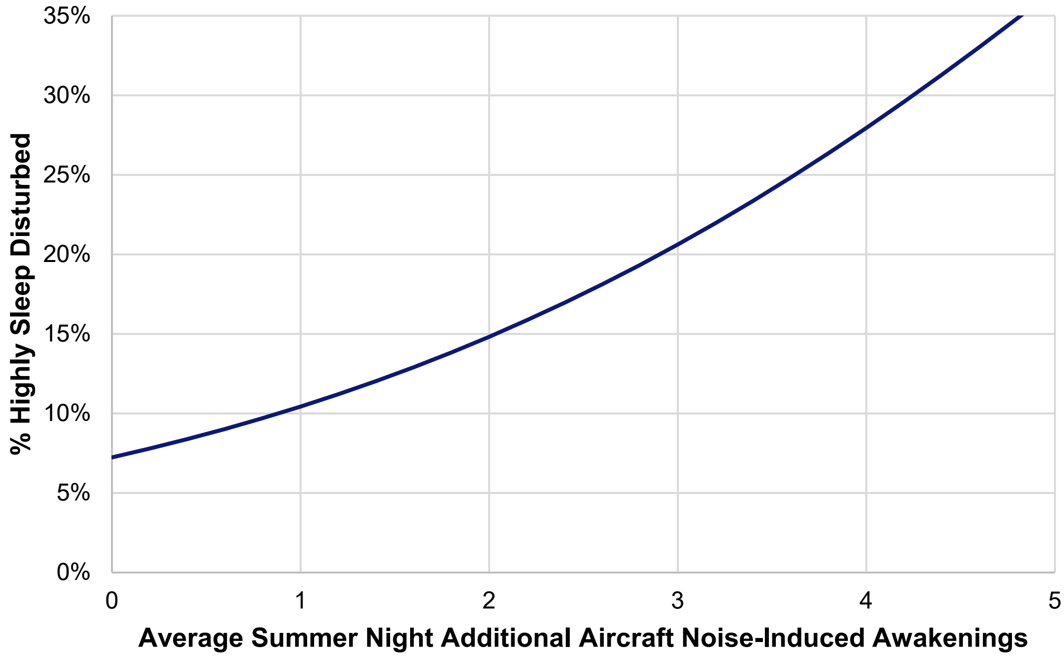
Figure 7: Percentage of respondents calculated as highly sleep disturbed as a function of the average summer night additional aircraft noise-induced awakenings (N=1,483)



4.21 The sharp rise in the proportion of residents in the SoNA 2014 survey stating that their sleep was highly disturbed (Figure 7) coincides with the first objective of the German Aerospace Centre's noise protection concept presented by Basner and Samel; this is that 'On average, there should be less than one additional awakening induced by aircraft noise' which is clarified elsewhere to mean 'per night'[4].

4.22 The corresponding dose-response function is plotted in Figure 8.

Figure 8: Logistic regression function for percent highly sleep disturbed for SoNA 2014 night as a function of average summer night additional aircraft noise-induced awakenings



4.23 One additional aircraft noise-induced night awakening is shown to associate with 10% of respondents being highly sleep disturbed. Two and three additional aircraft noise-induced awakenings per average summer night associate with 15% and just over 20% of respondents being highly sleep disturbed respectively.

CHAPTER 5

Health and Wellbeing

5.1 An objective of the SoNA 2014 Sleep survey was also to obtain evidence on the effects of noise on wellbeing and health. The scope of the wellbeing and health questions was, however, constrained by the need to limit the length of the questionnaire.

5.2 The questionnaire asked respondents a question about their general health at the time of interview and specific questions using a previously validated wellbeing scale. Question HL1 asked people to rate their health on a 5-point scale. Over half the respondents stated that their self-reported health rating was "very good" or "excellent".

5.3 As reported in CAP 2161, a Chi-Square Test of Independence was performed to examine the relationship between self-reported health ratings and self-reported sleep disturbance score (CAN1vii). There was no significant relationship found between self-reported sleep disturbance and self-reported health rating.

5.4 A Chi-Square Test of Independence was also performed to examine the relationship between self-reported health rating and the number of additional aircraft noise-induced awakenings. The relationship between these variables was found to be significant ($X^2(20) \geq 34.043$, $p<0.01$). This test suggests that there is a relationship between self-reported health rating (Question HL1) and the number of additional aircraft noise-induced awakenings.

5.5 Question HL4 asked respondents to complete the short Warwick-Edinburgh Mental Well-Being Scale (SWEMWBS), which is comprised of seven statements:

	All of the time	Often	Some of the time	Rarely	None of the time	Don't know/ refused
I've been feeling optimistic about the future	○	○	○	○	○	○
I've been feeling useful	○	○	○	○	○	○
I've been feeling relaxed	○	○	○	○	○	○
I've been dealing with problems well	○	○	○	○	○	○
I've been thinking clearly	○	○	○	○	○	○
I've been feeling close to other people	○	○	○	○	○	○
I've been able to make up my own mind about things	○	○	○	○	○	○

5.6 In relation to HL4, 43 of the 1,483 did not answer or refused to answer, therefore their SWEMWBS could not be calculated. Subsequent analysis presented here is with the remaining sample of 1,440 SoNA 2014 night respondents.

5.7 Table 5 shows a crosstabulation table of the calculated SWEMWBS and additional aircraft noise-induced awakenings. A Chi-Square Test of Independence was performed between the SWEMWBS and additional aircraft noise-induced awakenings, with no significant association found ($X^2(24)\geq 34.108$, $p=0.083$).

Table 5: Crosstabulation results for the Short Warwick-Edinburgh Mental Wellbeing Score (SWEMWBS) and additional aircraft noise-induced awakenings (N =1,440)

		Additional noise-induced awakenings					
SWEMWBS	**N**	**0.0-0.49**	**0.5-0.99**	**1.0-1.49**	**1.5-1.99**	**>2.0**	**Total**
<22	130	25%	38%	15%	13%	8%	9%
22-23	137	32%	34%	15%	9%	9%	10%
24-25	199	33%	35%	16%	10%	6%	14%
26-27	290	37%	34%	14%	8%	7%	20%
28-29	300	27%	35%	19%	9%	10%	21%
30-31	173	43%	27%	14%	8%	8%	12%
>31	211	34%	35%	15%	13%	3%	15%
Total	**1,440**	**33%**	**34%**	**16%**	**10%**	**7%**	**100%**

5.8 The Chi-Square test was repeated with respondents regrouped into two categories, less than one additional aircraft noise-induced awakening and at least one aircraft noise-induced awakening. No significant association was found between the SWEMWBS and the number of additional aircraft noise-induced awakenings ($X^2(6) \geq 7.746$, $p=0.257$).

CHAPTER 6

Summary and Conclusions

6.1 Average night-time noise doses continue to be used for night noise analysis due to the prevalence of such information. CAP 2161 showed that average summer night $L_{Aeq,8h}$ and average annual night L_{night} noise exposure correlated with the self-reported sleep disturbance as determined through the 2014 Survey of Noise Attitudes (SoNA). Notwithstanding this finding, many stakeholders argue that an average night noise dose is inappropriate for comparing against attitudes to sleep disturbance and effects on sleep, since an average night dose does not include information on the noise level of each individual event.

6.2 Based on extensive laboratory and field studies, Basner et al[4] found that the probability of night-time aircraft noise-induced awakenings may be estimated from the maximum noise level of each night-time aircraft noise event. Coupled with the number and noise level of each aircraft event occurring during a night period, an estimate of the average nightly number of additional aircraft noise-induced awakenings can be made. This number of additional aircraft noise-induced awakenings must be calculated for each aircraft type on each flight path; information that is not normally stored for an $L_{Aeq,8h}$ calculation. Consequently, this is a significantly more resource intensive calculation to perform.

6.3 The main scope of this study was to extend the analysis undertaken for CAP 2161 to estimate the number of night-time additional aircraft noise-induced awakenings for SoNA 2014 residents living in the vicinity of Gatwick, Heathrow and Stansted airports, and investigate the correlation with each respondent's self-reported sleep disturbance.

6.4 The number of additional aircraft noise-induced awakenings was estimated for a 2014 average summer night for Gatwick, Heathrow and Stansted airports. The number of additional aircraft noise-induced additional awakenings was compared with the average summer night $L_{Aeq,8h}$ noise dose. As confirmed by Basner, whilst there is a clear correlation between the two measures, the additional aircraft noise-induced awakenings indicator gives more weight to the number of events. Therefore, areas experiencing fewer, but louder, events show comparatively fewer awakenings than areas experiencing more, less noisy events, and fewer awakenings than the average summer $L_{Aeq,8h}$ noise dose might indicate.

6.5 Since SoNA 2014 did not objectively measure awakenings, it was not possible to check Basner's awakenings function or to develop an alternative function. Instead, the distribution of maximum noise level events at each SoNA respondent location around Gatwick, Heathrow and Stansted was used along with Basner's awakenings function to estimate the average number of night-time additional aircraft noise-induced awakenings for each respondent. This is no longer a measure of noise, however, it was treated as such and correlated with the respondent's self-reported sleep disturbance rating.

6.6 The analysis found that $L_{Aeq,8h}$ and L_{night} do correlate with the number of additional aircraft noise-induced awakenings arising from individual aircraft events at night and the self-reported sleep disturbance results found in the SoNA 2014 survey. Consequently, the concerns that are expressed that averaging the night-time noise exposure does not properly reflect the impact of individual aircraft noise events may be unfounded.

6.7 Additionally, a high degree of association was found between the estimated number of additional aircraft noise-induced awakenings and the self-reported sleep disturbance rating. The association was, however, no better than that found using average summer night $L_{Aeq,8h}$ in CAP 2161. The analysis does, however, imply there could be scenarios where the number of awakenings may be a better estimate of impacts than measures of $L_{Aeq,8h}$.

6.8 The SoNA 2014 survey data was then used to determine the association between the number of additional aircraft noise-induced awakenings and the percentage of respondents highly sleep disturbed. One additional night awakening was found to associate with 10% of respondents being highly sleep disturbed. Two and three additional aircraft noise-induced awakenings per average summer night were associated with 15% and just over 20% of respondents highly sleep disturbed respectively.

Appendix A

Glossary of terms

Abbreviations	
dB	Decibel
dBA	Decibel A-weighted scale
$L_{Aeq,T}$	Equivalent continuous sound level, for period of time, T
$L_{Aeq,8h}$	Equivalent continuous sound level, average summer night 11pm-7am
L_{ASmax}	Maximum single event noise level (time weighted slow)
L_{night}	Equivalent continuous sound level, average annual night 11pm-7am
N	Sample size
N_{AWR}	Number of additional aircraft noise-induced awakenings
P_{AWR}	Probability of additional aircraft noise-induced awakening
SoNA	Survey of Noise Attitudes
SWEMWBS	Short Warwick-Edinburgh Mental-Wellbeing Score