

ANASE

Attitudes to Noise from Aviation Sources in England

Executive Summary for Department for Transport
In Association With John Bates Services, Ian Flindell and RPS
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Executive Summary

1.1 Background and Objectives

- 1.1.1 The last major survey of attitudes to aircraft noise in the UK was carried out in 1982 and reported in 1985; this was known as the 'ANIS study' (United Kingdom Aircraft Noise Index Study¹). The results informed current policy that the daytime index for measuring people's exposure to aircraft noise should be the LAeq index measured over 16hrs, and that the 'onset of significant annoyance' is assumed to occur at around 57 LAeq.
- 1.1.2 Since 1982, however, the overall amount of air traffic has increased significantly whilst the sound levels generated by individual aircraft events have been significantly reduced as older, noisier aircraft types have been replaced by more modern aircraft types with quieter engines and much improved climb performance. In addition, it is possible that attitudes to aircraft noise might have changed along with social changes in the population, and that the aircraft noise indicator adopted after the 1982 ANIS study (Leq) might be less appropriate for present day conditions. It was therefore considered timely to see whether the current understanding of the links between reported annoyance and aircraft noise levels still held.
- 1.1.3 The study objectives were to:
- re-assess attitudes to aircraft noise in England;
 - re-assess their correlation with the Leq noise index; and
 - examine (hypothetical) willingness to pay in respect of nuisance from such noise, in relation to other elements, on the basis of stated preference survey evidence.
- 1.1.4 Studies in recent years have investigated the value put on marginal changes in noise from transport sources including aircraft noise. Most have used revealed preference techniques (hedonic pricing studies) but far fewer have used hypothetical methods such as contingent valuation (which ask directly about how much they are willing to pay) or SP (which ask people to express their preferences between a set of alternatives). Note, the term stated preference is sometimes used in a generic sense and encompasses any hypothetical trade-off exercise. In this report we use the term specifically in relation to hypothetical choice-sets that are described in attribute form that enables valuations to be indirectly inferred – sometimes known as stated choice or contingent choice.
- 1.1.5 Meeting the third objective in the ANASE study was potentially the most challenging because of the necessarily innovative nature of research in this area. Generic techniques for studying attitudes to aircraft noise and for measuring aircraft sound levels have been in existence for many years, but there are few precedents for studying aircraft noise using SP methods and no large scale studies had been carried out previously in the UK using this method. It was therefore necessary to carry out a considerable amount of pilot study testing to develop and confirm an appropriate methodology before starting the main study.
- 1.1.6 A Contingent Valuation item was also included in the survey. This technique provides a more direct approach to assessing 'willingness to pay'. For example, respondents might be asked

¹ United Kingdom Aircraft Noise Index Study: Main Report (DR Report 6402) January 1985, prepared on behalf of the Department for Transport by the Civil Aviation Authority

to state how much money they would be prepared to pay for removal of all aircraft noise from their place of residence.

1.2 Methodology

- 1.2.1 The research to investigate attitudes to aircraft noise in England comprised two main phases. Phase 1 examined a number of issues relating to the study scope, in the form of a series of pilot studies. Phase 2 comprised a national survey to explore the attitudes and values of a representative sample of residents in close proximity to some of the major airports around England.
- 1.2.2 The main issues investigated as part of Phase 1, and the main technical tasks involved in planning and executing Phase 2 are illustrated in Figure 1.

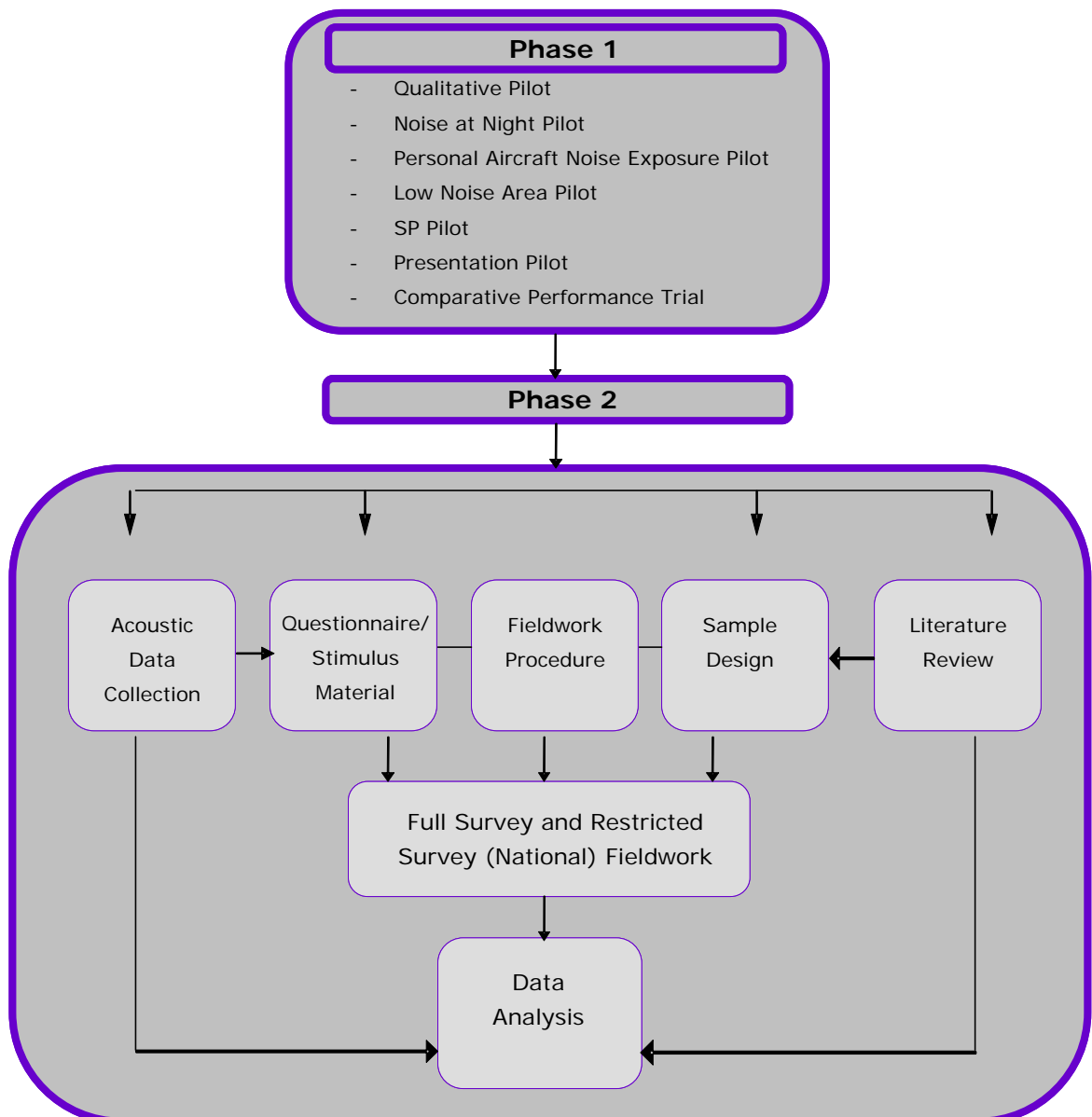


Figure 1 ANASE Study Programme

Phase 1 Pilot Findings

1.2.3 The individual Phase 1 pilot studies and conclusions drawn from each were as follows.

- a qualitative exercise established that the “discriminable factors” that influence community annoyance were: aircraft type, number, and time of day or night; and identified the discriminable differences in levels for each dimension;
- further qualitative studies of reported annoyance to aircraft noise at night suggested a link between the proportion of night-time aircraft activity and reported aircraft annoyance, though the pilot was not sufficiently extensive to separate out confounding factors such as different types of aircraft (e.g. cargo planes);
- an investigation of different monitoring methods for identifying specific aircraft noise events concluded that there was no justification for widespread aircraft sound level measurement using either fixed indoor monitors or personal dosimeters in the Phase 2 main study. On the other hand, some outdoor monitoring was judged to be necessary as a basis against which to provide empirical validation of calculated outdoor sound levels for some lower noise sites included in the Phase 2 main study;
- a quantitative assessment of reported annoyance in very low aircraft noise areas (areas overflown at heights ranging from 4000 to 12000 feet) found that there may be some additional factors associated with stacks *per se* that are a source of annoyance independently of sound levels but, generally, there was little evidence of reported annoyance in these areas. It was also concluded that sound level measurements could not be expected to provide any useful insights, given the low aircraft event sound levels experienced. In turn, this would preclude the use of SP techniques in these areas for the purpose of valuing annoyance arising from aircraft noise;
- two quantitative pilot surveys were carried out to explore the workability of an SP exercise with each option described in terms of varying levels of: aircraft type, number and money (in the form of council tax). The estimated SP models bore out the rationality of responses and respondents’ systematic choice behaviour in trading between the aircraft types, and showed high correlation with the noisiness of different aircraft types. Crucially, there was no indication that fundamental changes in the SP design were needed, though some modifications were seen to be desirable, notably that the number of movements for each type of aircraft should be more in keeping with the actual numbers of movements in each period. It was also agreed that a common length of period should also be adopted;
- an exercise was conducted to explore the cognition of a number of alternative ways of presenting aircraft noise options within a SP trade-off environment. Cognitive investigation affirmed a high level of understanding by respondents of the essence of the choices they were being invited to make, namely trade-offs between alternatives made up of different mixes of sound levels and/or money amounts.
- the same exercise also revealed that, for some people, there were connotations relating to how the rebates could effectively be negated by local council action. An alternative vehicle in the form of an annual (or monthly) grant seemed to accrue no negative connotations, and was adopted in place of the Council Tax rebates;
- another exercise focusing on SP presentation issues tested a range of alternative approaches, and found them to be unsatisfactory because they could not be fully grasped or were even disliked by a relatively high proportion of respondents. These approaches were: showcards with pictograms to represent the number of aircraft

movements; expressing different aircraft noise alternatives in terms of decibels; expressing options as different distributions of aircraft movements spread over 24 hours presented in histogram form; and associating different aircraft noise alternatives with “event characteristics” (such as vibration);

- the above “presentation pilots” also concluded that each respondent should also be exposed to customised presentation material in both aural and visual forms. Customisation would be achieved by recording and photographing examples of the relevant aircraft types close to respondents’ homes. At interview, before embarking on the formal SP exercises, respondents would be played and shown this material and asked to confirm that it did reasonably represent what they would hear and see outdoors at their homes. When this was tested, most respondents had a clear opinion of whether the sound levels played to them corresponded to the aircraft being shown to them, and there was strong evidence that the more customised the aural and visual material was to their home localities, the more likely respondents were to feel that it represented their experience;
- subsequent tests found that almost all respondents were content to accept the customised playbacks as good representations of the aircraft sound levels they experienced at home;
- in parallel with the “presentation pilots”, a cognitive exploration of the intended reported annoyance questions (the current ISO standard) was carried out to test if attitudes to aircraft noise changed depending upon whether the questions were asked at the very beginning of an interview, or at the end after it had become obvious that the whole interview was about aircraft noise. The conclusion was that the ISO questions do indeed provide a robust measure of reported annoyance. For a subsequent main study, there thus appeared to be no reason not to employ the ISO standard annoyance questions; and
- the research team designed and carried out a major SP pilot specifically to test whether the willingness-to-pay valuation of annoyance estimated from SP responses might be influenced by the SP scenarios, rather than (as should ideally be the case) be independent of them: an effect referred to as “numbers-gaming” in the main report. This might arise if respondents were having difficulty in carrying out the SP tasks and were resorting to some simplifying rule to provide a “choice”, though this might not be their “genuine” preference if they could be faced with the options in real life. The findings provided evidence to reject the numbers-gaming hypothesis while remaining consistent with the conventional hypothesis, and that there was no further need to consider the form of SP model, which could therefore be taken forward as the primary SP form for a main Phase 2 study.

1.2.4 The key strategic outcomes of Phase 1 were as follows.

- SP could be employed to inform on the objectives of the study, namely to:
 - establish the relative weights of “noise (ie sound level)” and “number” in their contribution to annoyance,
 - examine variation in annoyance by time of day, and
 - estimate money (willingness-to-pay) valuations of annoyance in these dimensions;
- a CVM test would be included in interviews; and

- the ISO reported annoyance questions would elicit robust qualitative indications of respondents' levels of annoyance and provide some backwards compatibility with the corresponding question in the last national aircraft noise/annoyance study – the ANIS research.

Phase 2 Main Survey

- 1.2.5 The Phase 2 survey methodology began by identifying aircraft noise exposed areas within England which were suitable for the study, both in terms of identifying the airports themselves and then defining the spatial envelope surrounding them, outside of which it can be assumed that aircraft noise is only faintly audible. Within these aircraft noise exposed areas, a means of stratifying the population according to the characteristics of the aircraft noise to which it is exposed was developed. Areas were selected to populate a 'matrix' dimensioned by average event sound level (L) and number of movements (N). The sampling methodology ensured that, within each stratum, all residents of every candidate area had the same probability of selection. [Note that the objective of the procedure used to draw a sample of sites was to obtain a fully representative selection of areas with differing aircraft noise environments. We were not interested in selecting sites from individual airports per se: it was the characteristics of the aircraft noise environment that was of interest].
- 1.2.6 Two types of interview were conducted. A "full" interview included the SP exercises and was undertaken by the majority of the Phase 2 sample. A "restricted" interview excluded the SP exercises and was undertaken by respondents in areas of low or irregular aircraft noise.
- 1.2.7 Interviews were undertaken at 2,733 households in 76 different sites. A total of 2,132 Full Survey interviews were undertaken (around 60 in each of 36 randomly selected sites), and 601 Restricted Survey interviews were undertaken (around 15 interviews in each of 40 randomly selected sites). The maximum variation in LAeq within each site was limited to 3.5dB, so as to ensure that respondents within each site were responding to a narrow range of aircraft sound levels (denoted Common Noise Area or CNA in the report).
- 1.2.8 The full survey was undertaken during the period August 2005 to January 2006, whilst the restricted survey was undertaken between November 2005 and February 2006.
- 1.2.9 Prior to analysis the social survey data was weighted to correct for response bias (e.g. older residents being more or less likely to participate) and correction for household size.
- 1.2.10 A sound level measuring and modelling exercise was carried out in parallel with the social survey and SP data collection, to derive aircraft sound level estimates for each respondent. The particular metrics required for the study were estimates of: L_{Amax}, the maximum sound level received during a single aircraft noise event, L_{Aeq}, average numbers of aircraft events above an L_{Amax} of 65dB (denoted N_{av} in the report), and average sound level of aircraft events above an L_{Amax} of 65dB (denoted L_{av} in the report). In reality, it was only possible to estimate L_{Aeq} values for the population-weighted centroid of each CNA. L_{Amax} was adopted as a proxy for measuring aircraft sound levels in areas where aircraft events were so irregular as to make it impossible or meaningless to derive a value of L_{Aeq} with any degree of precision.
- 1.2.11 Key inputs to the noise modelling process were Air Traffic Control (ATC) data from each airport where the social survey was carried out; and new, monitoring data collected as part of the ANASE study to calibrate the modelled results. The model used to calculate sound levels at every site was the Integrated Noise Model (INM) v6.2.

1.2.12 At each stage of the Phase 1 and Phase 2 work, the findings were scrutinised by independent review bodies. Four distinct advisory project committees were established during the course of the study: *a Steering Group* (to oversee the development of the study); *an international Peer Review Group* (international experts from whom the DfT obtained advice); *an SP sub-group* (subset of SG members with SP expertise, and invited SP experts from the transport and environment fields); and *a Non-SP sub-group* (technical experts who reviewed the non-SP analytical and modelling results).

1.3 Main Research Findings

Reported Annoyance

1.3.1 Figure 1 shows the percentage of respondents (in each of 56 sites) who were at least very annoyed with aircraft noise by LAeq (the existing measure used as a basis for estimating community annoyance).

- on this chart, for areas with LAeq less than around 43, the proportion of respondents who are at least very annoyed is less than 12%;
- the proportion of respondents at least very annoyed generally increases with LAeq for values of LAeq over 43, although there is a relatively large spread in percentages for most LAeq values; and
- for all except one of the areas with LAeq greater than 57, more than 60% of respondents were at least very annoyed.

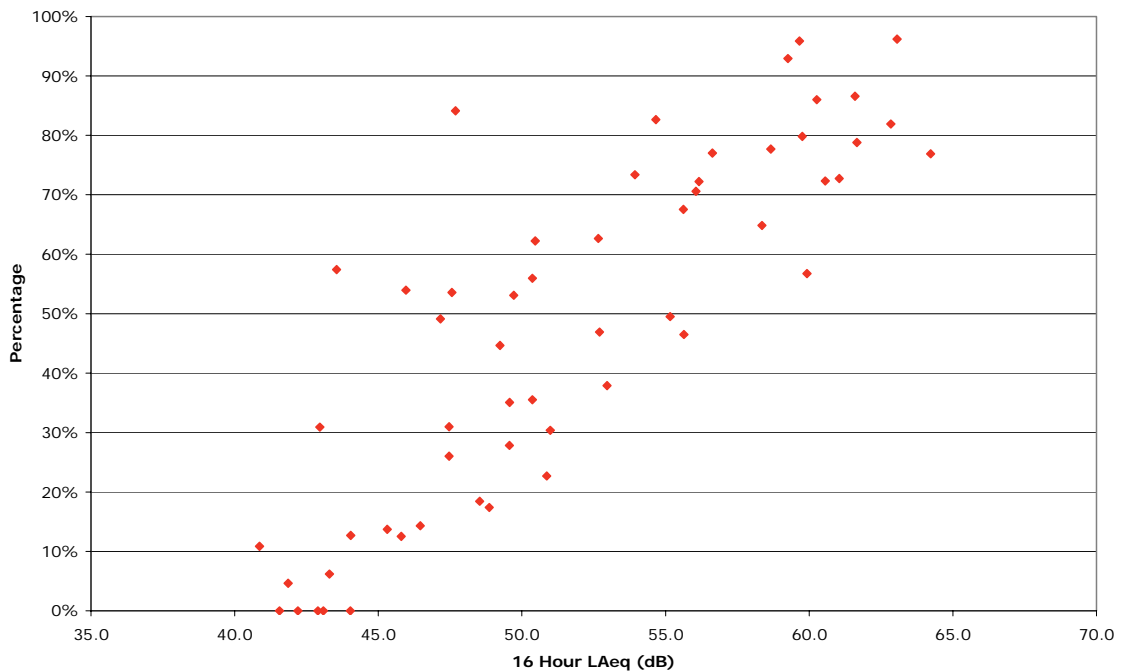


Figure 1 Percentage of Respondents at Least Very Annoyed with Aircraft Noise

1.3.2 As explained above, for sites with low sound levels or irregular aircraft events, we are limited to LA_{max} values only for each site.

1.3.3 Figure 2 shows the mean level of reported annoyance (10=‘Not at all annoyed’ ... 90=‘extremely annoyed’) at all 76 sites by LA_{max}. There is no indication from these findings that irregular aircraft events leads to greater reported annoyance than regular aircraft events, at any given level of LA_{max}. The figure also shows that there is a relationship of increasing annoyance as LA_{max} increases, but this is not as strong as the relationship between reported annoyance and LA_{eq}.

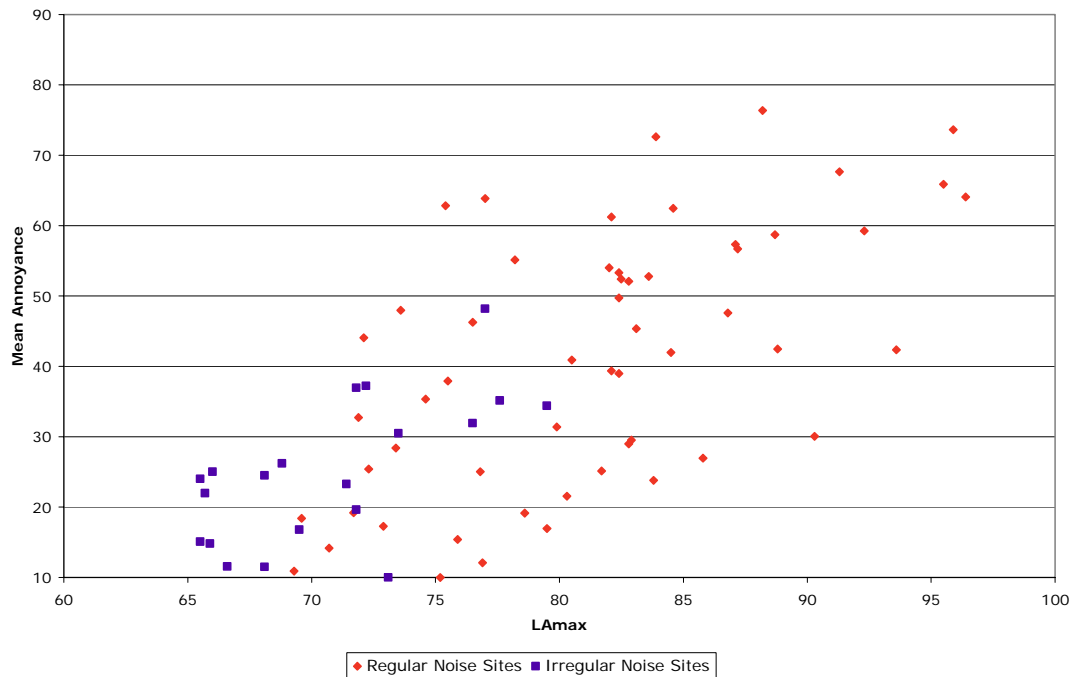


Figure 2 Mean Reported Annoyance with Aircraft Noise by LA_{max}

1.3.4 A range of different regression models were developed in order to further explore the relationship between reported annoyance and sound levels at site level. These included basic linear models, logistic models, piecewise models, step models and other non-linear models.

1.3.5 All of the linear model formulations accounted for a similar variation in reported annoyance, although none improved on the adjusted R² (0.739) of the basic linear model.

Basic Linear Model:

$$\text{Mean Annoyance} = -80.0 + 2.3 \times \text{LA}_{eq}$$

1.3.6 The basic linear model, therefore, accounted for around three-quarters of the variation in reported annoyance between sites, with a coefficient on LA_{eq} of 2.3 (ie an increase in LA_{eq} of 1 accounts for a 2.3 scale point increase in the mean annoyance score, with the mean annoyance score ranging between 10 and 90).

Logistic Model:

- 1.3.7 A logistic model fitted the data equally well (in terms of adjusted R^2), and is a more appropriate model form as it is constrained to the bounds of annoyance in the data.

$$\text{Mean Annoyance} = 10 + 80 / (1 + \exp(7.32 - 0.13 \times \text{LAeq}))$$

- 1.3.8 The linear and logistic models are presented in Figure 3. The two regression lines are similar across the central range of LAeq values.

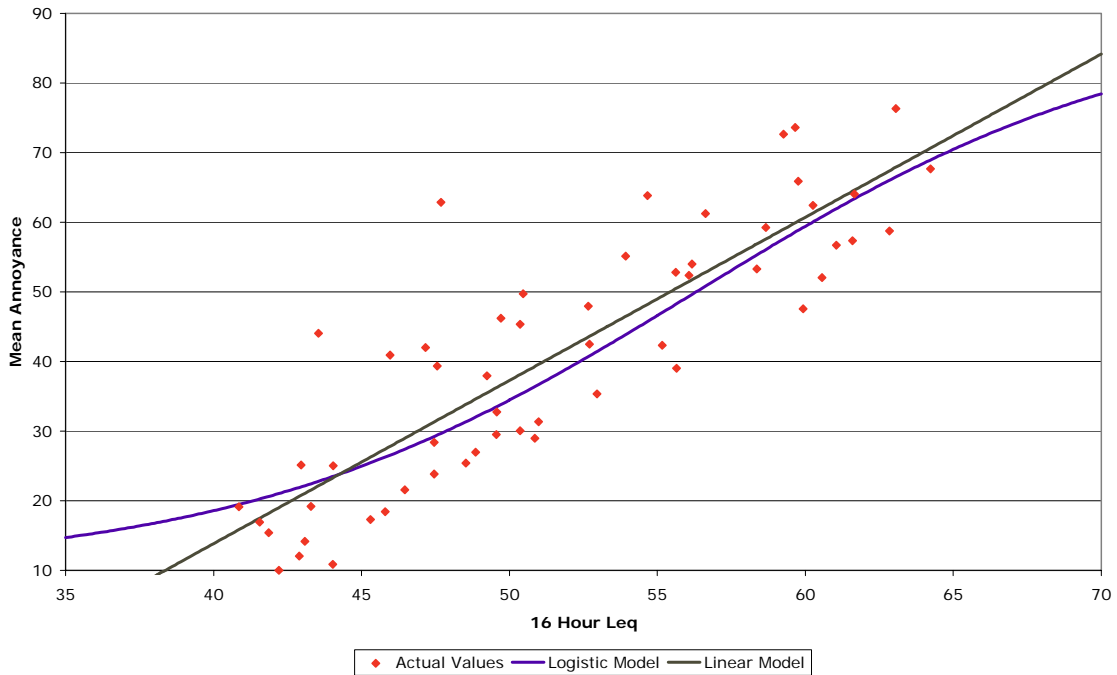


Figure 3 Models for Linear and Logistic Regressions on LAeq

- 1.3.9 The piecewise models revealed features of interest, notably:

- at the lower end of the range of aircraft sound levels measured in LAeq, there is a region up to around 42 LAeq where there is no apparent increase in reported annoyance as LAeq increases; and
- for a given change in LAeq, the increase in annoyance is greater for values of LAeq less than around 59 than for values of LAeq greater than around 59.

- 1.3.10 No threshold, or discontinuity, in the relationship between mean annoyance and LAeq was identified.

- 1.3.11 A wide range of explanatory variables was tested separately on the intercept and the slope of the regression model. In all cases, the coefficient of LAeq remained significant, but only three socio-demographic variables had significant coefficients:
- working from home (those who work from home generally have a greater level of annoyance);
 - income (those who have a higher household income are generally more annoyed – measured either as average household income or those with an income more than £40,000); and
 - SEG (those in a higher SEG category are generally more annoyed – measured as either in SEG A or B, or in SEG A, B or C1).
- 1.3.12 Using the variables identified above, a stepwise regression estimation was carried out, to identify the most significant combination of variables.

Stepwise (LAeq+other Factors) Model:

$$\text{Mean Annoyance} = -76.4 + 2.1 \times \text{LAeq} + 43.8 \times \% \text{ Respondents who work from home} + 0.2 \times \% \text{ Income greater than } \pounds 40,000 \times \text{LAeq}$$

- 1.3.13 This model form explained more than 80% of the variation in reported annoyance.
- 1.3.14 When a single outlier is removed, which has a higher than average percentage of respondents who work from home, the best-fitting model contains just an income term, and explains 79% of the variation in the data.

Stepwise (LAeq+other Factors) Model excluding outlier:

$$\text{Mean Annoyance} = -79.4 + (2.14 + 6.61 \times 10^{-6} \times \text{mean income}) \times \text{LAeq}$$

Attitudes over Time

- 1.3.15 To explore changes in attitudes to aircraft noise over time, we compared the results from ANIS (1982 survey) and ANASE (2005 survey). It should be noted though that there were differences in the designs of the two surveys (in terms of sample coverage and representativeness and annoyance questions asked). Comparable annoyance scales were devised, and the results of the comparison are provided in Figure 4.

- 1.3.16 So that the models can be considered on a comparable basis (since only ANASE obtained annoyance responses below 50dB LAeq), the basic linear model for ANASE has been calculated for sites which have a LAeq value greater than 50 only. The dotted line in Figure 4 shows the ANASE model estimated from all sites, and it can be seen the inclusion of lower noise sites produces a virtually identical line.
- 1.3.17 For the ANASE sites in areas with a LAeq greater than 50, half of the variation in mean annoyance can be explained by LAeq alone – almost identical to the ANIS level of explanation.

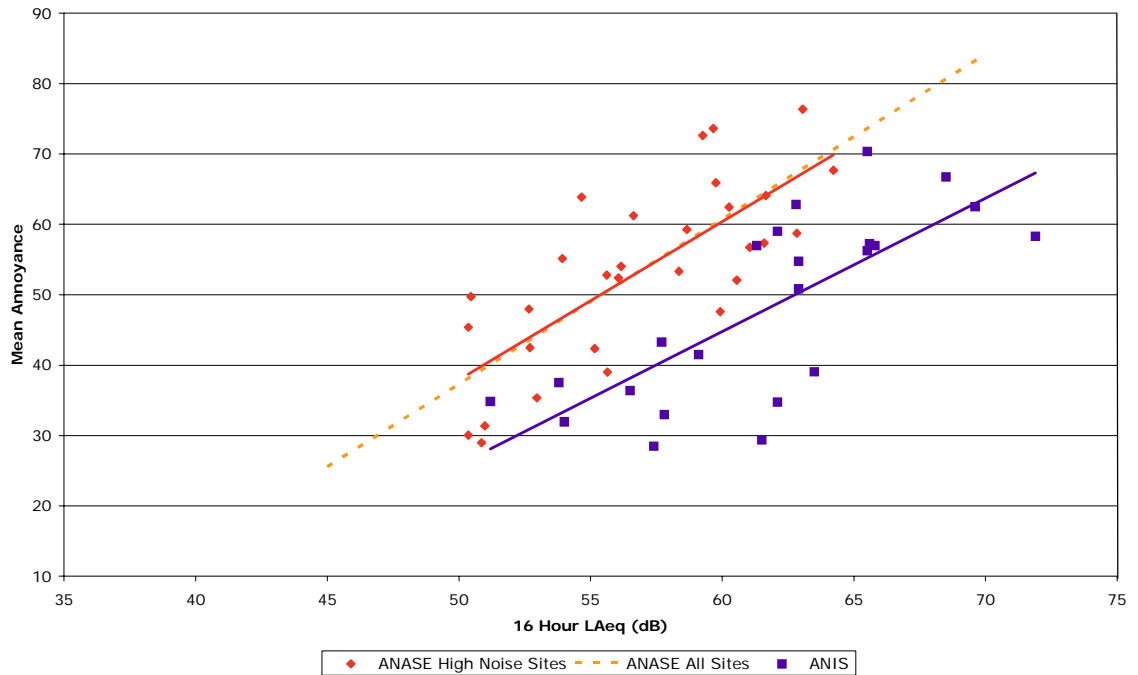


Figure 4 Mean Annoyance against LAeq for ANIS and ANASE for Higher Noise Sites

- 1.3.18 The ANASE and ANIS regression model lines are reasonably parallel, suggesting that when considering this higher range, there is a similar relationship of increasing annoyance as sound level increases, but the level of annoyance is consistently greater in ANASE than it was 23 years ago. For a given mean annoyance score, the 16-hour LAeq value in the ANASE survey is higher by between 3dB (for a mean annoyance score of 10 or not at all annoyed) and 11dB (for a mean annoyance score of 90 or extremely annoyed). A modelled mean annoyance of 50 is at 63dB in ANIS and at 55dB in ANASE, a different of 8dB.
- 1.3.19 For a LAeq of 57 (identified in the DORA report as the onset of significant annoyance), the modelled value of annoyance for ANIS is 39 (slightly higher than "a little annoyed" on the ANIS scale), whereas for ANASE it is 53 (somewhat higher than "moderately annoyed" on the ANASE scale) – a difference of 14 points on the annoyance scale.
- 1.3.20 There is uncertainty associated with the measurement of LAeq and Mean Annoyance. To test the robustness of the difference in the ANIS and ANASE outcomes we conducted a series of sensitivity tests. These tests showed a range of difference from 7 to 21 in the ANIS and ANASE scores at 57 LAeq. The difference produced from the comparison of the central ANASE model and ANIS – at 14 - is very close to the mid-point of the range.

- 1.3.21 The results from the sensitivity tests confirm the conclusion that, measured in LAeq, people are more annoyed in 2005 than they were in 1982.
- 1.3.22 Some of this difference can be associated with income effects (as we have already noted that annoyance increases with income for a given LAeq). In the absence of any stronger evidence we took the ANASE cross-sectional estimate to examine the possible effect of income over time. This resulted in a drop in estimated reported annoyance.
- 1.3.23 In addition to income changes, there will have been other changes over time which are closely correlated with income. Taste effects – such as society’s level of tolerance to environmental intrusion and its expectation of acceptable living conditions - have changed over time; as has people’s willingness to be more openly critical of officialdom and government policy. While such changes are difficult to quantify, it seems reasonable to conjecture that the differences between the ANIS and ANASE results could be reconciled with a combination of the effect of increasing income and a “taste effect”, whereby people have become less tolerant of intrusive noise over time.
- 1.3.24 An alternative hypothesis is that LAeq is not the appropriate measure, and that annoyance in both studies would correlate better with another metric. For the ANIS study, there were generally fewer aircraft, but the average sound levels were higher. In the more recent ANASE study, there is a greater number of aircraft, but average sound levels were lower giving rise to the possibility that changes in annoyance levels are due, in part, to differences in noise composition.
- 1.3.25 Comparisons of the relationships between reported annoyance and Lav and, separately, Nav revealed that there has been a shift in the relative importance of the two components of overall noise: the sound level of the aircraft and the number of aircraft on reported annoyance. To investigate this change in importance, regression analysis was conducted between mean annoyance scores from ANASE and ANIS and combined metrics based on Lav and log Nav, rather than LAeq.
- 1.3.26 Whereas the best fit ratio of the coefficients on log Nav and Lav was 6 in ANIS, it is over 20, in ANASE, indicating that the relative importance of the number of aircraft has increased over time. By taking a compromise value of 15, similar to the Noise and Number Index (NNI) used prior to the 1982 study, it is possible to obtain a close match between the points from the two datasets.

- 1.3.27 Figure 5 plots mean annoyance against $L_{av} + 15 \log N_{av}$ for ANIS and ANASE and shows that the relationship for both ANIS and ANASE is very similar. The overlap between the 1982 ANIS and the 2005 ANASE data suggests that under present day conditions, an NNI type metric could provide a better fit than L_{Aeq} to the combined data set. However it should be noted that whereas L_{Aeq} is a meaningful physical quantity, $L_{av} + 15 \log N_{av}$ does not reflect actual sound energy in the same way.

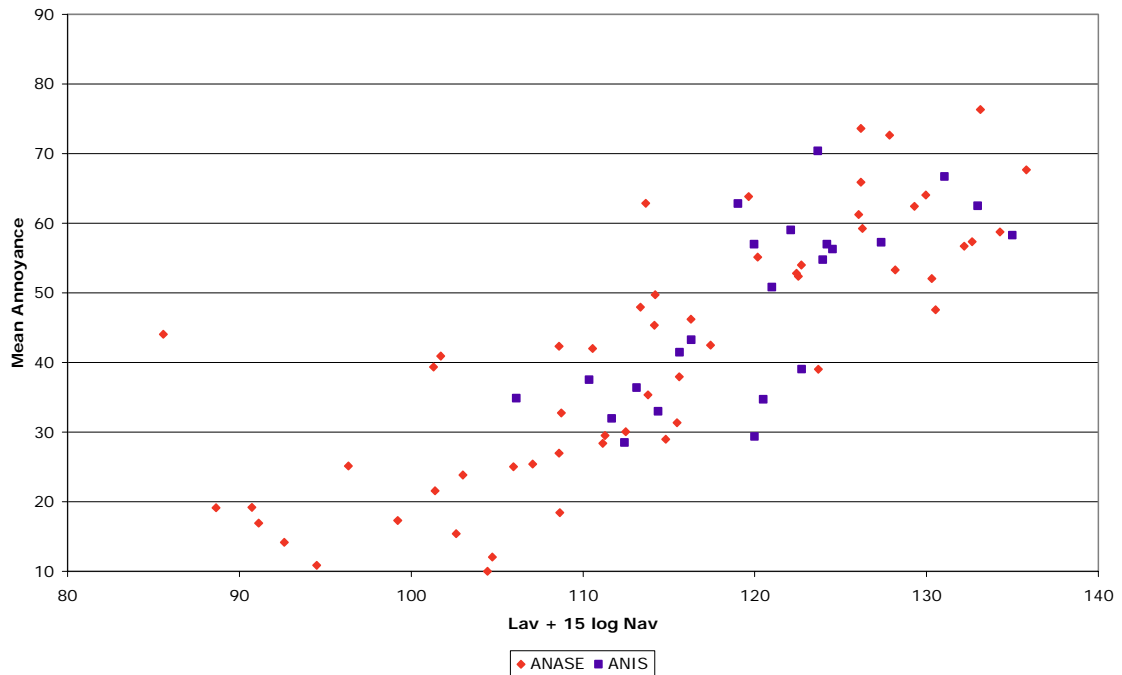


Figure 5 Mean Annoyance against $L_{av} + 15 \log N_{av}$

- 1.3.28 The above analysis was carried out using the cut-off of 65 L_{Amax} for the ANASE data, and further investigation showed that this overlap between ANASE and ANIS was not sensitive to cut-off value.

SP Analysis

- 1.3.29 The SP questions were of the form:

"Please think about what it would be like for you and the other member(s) of your household if there were different numbers of certain aircraft flying over YOUR HOME. I also want you to imagine that households near the airport qualify for an annual grant. This household grant can be spent on anything your household wants. So, you could spend it on improvements in insulation or double-glazing, or put it towards something like a new car or a holiday.










The Next questions are about the time of day between and

On a typical day there was this number of each type of aircraft flying over your area [on their way to land at/taking off from] the airport between and

I now want you to think about three different situations. [PRESENT COLOURCARD] Have a look at the situations described in each of the three boxes A, B and C, and tell me which you think would be the best situation for you and your household.

Please assume that there are no other differences in the numbers of the other types of aircraft, and no changes in the numbers of aircraft outside the hours and We want you to only think about the effect of the differences shown on this card. Everything else remains the same.

Which do you think would be the best situation for you and your household?.

BOX Athe following planes fly overhead:	BOX Bthe following planes fly overhead:	BOX Cthe following planes fly overhead:
0 Jumbo 	1 Jumbo 	1 Jumbo 
7 Under-wing 	3 Under-wing 	7 Under-wing 
0 Tail-jet 	0 Tail-jet 	6 Tail-jet 
<hr/> 7 Total aircraft	<hr/> 4 Total aircraft	<hr/> 14 Total aircraft
No grant	No grant	£200 grant every year

And which would be worst for you and your household?.

- 1.3.30 Different discriminable aircraft types were included in the SP exercise depending upon which types were the most common aircraft to fly over each site.
- 1.3.31 The 'Basic' SP models produced a relative coefficient (β_{ij}) for each aircraft type in each time period, and a relative coefficient for money (β_m) for each of the 36 sites. Each Basic SP Model, therefore, derived 13 or 19 relative coefficients, depending upon whether the site-specific SP exercise comprised 2 or 3 aircrafts with varying levels. With only 60 respondents contributing to the estimation of each Basic SP model, the fact that the vast majority of derived coefficients were statistically significant was a reassuring finding.
- 1.3.32 Aggregating by time period and (separately) aircraft type resulted in considerable loss of explanatory power at site level. This finding indicated that both the time of day and type of aircraft contributed significantly to respondents' relative valuations. The final SP model was a pooled National SP Model covering all 36 sites, with a single set of time period coefficients, and a single money coefficient. The model provided the basis for deriving a relative weight (utility) for a unit reduction of aircraft by aircraft type at each site. Inspection of the within-site aircraft valuations within the National Model showed the vast majority to be consistent with relative SEL values - i.e. aircraft with a higher SEL has a higher relative value than aircraft at the same site with a lower SEL. On average, a single jumbo had the same disutility as approximately 3 underwings or turboprops, or 4 tailjets.

Implications for LAeq

- 1.3.33 Transforming the sound levels of each SP option into an implied sound energy form enabled us to investigate the suitability of LAeq as a means of gauging changes in annoyance in response to changes in aircraft sound levels (namely the number of movements and the Sound Exposure Level (SEL)).
- 1.3.34 The result suggested a non-linear variation in valuation per dB (of a particular aircraft event) with the following shape:

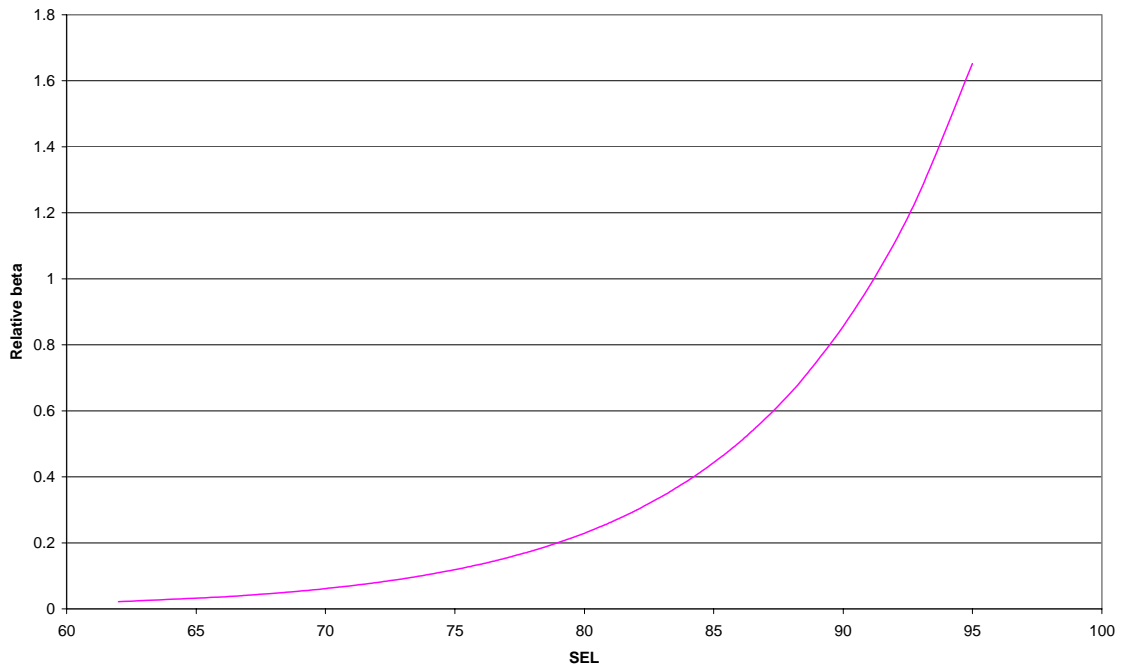


Figure 7 Relationship Between SP Coefficients and SEL

- 1.3.35 The graph is shown over the range of SEL presented in the SP survey. The implied valuation rises by about 14% for each additional dB, so that for an additional 10 dB the valuation is 3.7 times as much. However, although this looks steep, it is in fact only about half the rate per dB which would be implied by the LAeq formula, where the implied valuation increases by 10 times for an additional 10 dB. LAeq implies that, for example, 100 events with SEL 80 is equivalent to 10 events with SEL 90, over the same defined period. The results here imply that the equivalence is nearer to 32 events with SEL 90, in other words that the role of number should be upgraded relative to SEL. Approximately, the implied relationship can be considered to be:

$$\text{LAeqx} = \text{SEL} + 20 \log_{10} N - 10 \log_{10} T$$

- 1.3.36 Therefore, for predicting changes in community disutility in response to changes in aircraft sound levels, a ('k') weighting of 20 on the number variable would be better than the weighting of 10 that currently exists in the LAeq formula. This supports the finding reported from the non-SP analysis that NNI, which has a weighting of 15, may be a better proxy than LAeq for predicting changes in community annoyance over time.

Time of Day Sensitivities

- 1.3.37 The results of the National SP model indicates that, relative to the **daytime**, and with some rounding, the sensitivity to the same aircraft noise at other periods are:
- 2300-0300: **80%** more annoying;
 - 0300-0700: **35%** more annoying;
 - 1900-2300: **15%** more annoying; and
 - 1500-1900: **10%** more annoying.
- 1.3.38 The above relativities reflect society's sensitivity overall, and implicit in these weightings are the proportion of people at home exposed to the noise. However, further investigation revealed that people are differentially annoyed at different times of day regardless of whether they are at home or not. This may be because they know aircraft noise annoys others in the home at this time, or because the respondent, though not at home, is exposed to aircraft noise elsewhere, or some other external factor that is correlated with presence in the home and annoyance with aircraft noise.

Willingness to Pay

- 1.3.39 The willingness to pay per month per household for one less aircraft per day for different sound levels during the middle of the day (1100-1500), implied by the National Model, is indicated below. The implied willingness to pay values are given by aircraft type, and across LAeq bands, in high noise areas (LAeq >60dB).
- Jumbo: £5 - £9 per aircraft (min SEL = 84dB, max SEL = 95dB)
 - Underwing: £2 - £6 per aircraft (min SEL = 82dB, max SEL = 89dB)
 - Turboprop: £2 - £3 per aircraft (min SEL = 77dB, max SEL = 84dB)
 - Tailjet: £2 - £5 per aircraft (min SEL = 67dB, max SEL = 84dB)
- 1.3.40 At low aircraft sound levels (below 50 LAeq), the typical SEL of aircraft is around 10dB lower and the ANASE results suggested willingness to pay values of around £2 lower.
- 1.3.41 In comparison with the limited contemporary research available, these willingness to pay values seem high. The ANASE SP values are very high when one considers the number of aircraft – even Jumbos – that would need to stop flying overhead in order to reduce the overall LAeq by 1dB at the site.
- 1.3.42 We have not been able to explain the cause of this considerable disparity between the ANASE SP-based valuation and other research valuations based on hedonic pricing and contingent valuation. In the authors' view, there is no reason to think that SP will inherently produce vastly over-estimated monetary valuations of goods and services. The SP technique has been used for more than twenty years and has been validated (through the use of observed data) on many occasions.
- 1.3.43 We are also of the view that the SP design, data collection and analysis accurately captures the views and preferences of respondents. This is based on anecdotal information gained throughout the study (i.e. cognitive assessment of respondents' decision processes when considering the SP trade-offs), and we are confident that respondents considered the SP

options that they were presented with to be realistic, and that they stated their 'true' preference from each choice-set.

- 1.3.44 We believe the area of greatest uncertainty is the link between respondents' willingness to pay for a reduction in aircraft (e.g. around £5 a month for one less jumbo every day during a certain 4-hour period) and their assumed improvement in their quality of life (through reduced annoyance by aircraft noise). The ANASE study has revealed that a change in the number of aircraft is perceived to have the greatest effect on reducing aircraft noise annoyance. However, more research is needed to explore how accurately people associate a reduction in aircraft numbers with a change in overall sound levels. It may be that respondents perceive that a reduction of a few jumbos during a particular period of the day would have considerable impact on their overall sound levels yet in reality might not even notice the reduction in practice.
- 1.3.45 A further possibility allowed for in ANASE was to adopt an overall willingness to pay value for reduced aircraft noise, derived from the CVM data. The best individual-level model (in terms of statistical goodness-of-fit) was with LAeq and mean income. This suggests a willingness to pay to eradicate aircraft noise of £270 per household per annum for households at 57 LAeq with an income of £20,000; and a marginal change is valued at £3.84 per household per annum per dB LAeq for these households. Similarly, for households with an income of £60,000 at 57 LAeq, there is a suggested willingness to pay of £700 per household per annum, and a marginal change is valued at £11.50 per household per annum per dB LAeq.
- 1.3.46 Overall, the results of the ANASE CVM research suggest a statistically valid relationship between willingness to pay to eradicate aircraft noise, and the level of current aircraft sound levels in the form of LAeq (for the LAeq range 40-65dB covered in the research). The implied willingness to pay of £3.80 – 11.50 per dB LAeq reduction per annum for respondents, depending upon household income level, is within the range of values derived in other CVM and Hedonic Pricing studies.

1.4 Conclusions

Re-assessing Attitudes to Aircraft Noise in England

- 1.4.1 Analysis of the ANASE survey data has shown that as the sound level indicator LAeq increases, the annoyance levels of respondents also increase, and that a large proportion of measured variation in annoyance can be accounted for by LAeq. However for a given LAeq, there is a range of reported annoyance indicating that annoyance is not determined solely by the amount of aircraft sound as measured by LAeq.
- 1.4.2 Our analysis showed that respondent's household income and SEG were the most important influences on the level of annoyance. Once these factors are accounted for there are no further significant location effects (ie those affected by aircraft at Heathrow, for a given LAeq and income, are no more annoyed than those living close to other airports covered in the study).
- 1.4.3 For both this study (ANASE survey work carried out in 2005), and the ANIS survey (undertaken in 1982), LAeq is effective at explaining much of the variation in respondents' reported annoyance. However, this comparison has also shown that for the same amount of aircraft noise, measured in LAeq, people are more annoyed in 2005 than they were in 1982. For an LAeq of 57 (identified in the DORA report as the onset of significant annoyance), the

modelled value of annoyance for ANIS is 39 (slightly higher than "a little annoyed" on the ANIS scale), whereas for ANASE it is 53 (somewhat higher than "moderately annoyed" on the ANASE scale).

- 1.4.4 If LAeq **is** an appropriate proxy measure of annoyance, one possible explanation of the increase in reported annoyance for a given LAeq, between 1982 and 2005, may be a combination of changes in income/standard of living (which were significant cross-sectional factors in ANASE) and changes in attitudes within society. This view is supported by social trend data. While both income and taste effects are likely to be important, it is not possible to identify their relative strength from our research: they are, of course, closely correlated.
- 1.4.5 An alternative hypothesis is that LAeq **is not** the appropriate measure, and that annoyance in both studies would correlate better with another sound level indicator (as discussed below).
- 1.4.6 The SP results have shown people to be much more sensitive to aircraft noise at night (particularly around midnight and the early hours thereafter). In contrast, people are least sensitive to aircraft noise in the morning and early afternoon. Ideally, therefore, a metric that reflects attitudes to aircraft noise should reflect these time of day sensitivities better than the existing LAeq - which does not weight by time of day.

Re-assessing their Correlation with LAeq

- 1.4.7 Models were estimated which predicted mean annoyance values using LAeq. These showed that the best fitting model, with around three-quarters of the variation explained, is a linear relationship between annoyance and LAeq. However a logistic model, which produces an almost identical fit to the basic linear model, has the added advantage that it is bounded to the mean annoyance scores.
- 1.4.8 The modelling work also showed that respondents were less sensitive to changes in sound level below 42 LAeq and above 59 LAeq, adding support to a logistic form. There was no threshold, or discontinuity, in the relationship between mean annoyance and LAeq.
- 1.4.9 The ANIS and ANASE surveys allowed us to compare the correlation of reported annoyance with LAeq at two points in time. Over the period between the two surveys, there has been a substantial change in the make-up of aircraft, with many more aircraft in 2005 but with a lower (average) sound level than in 1982.
- 1.4.10 We found that the relationship between annoyance and sound level was strong for ANIS, but there was little relationship between annoyance and aircraft numbers. The converse was the case for ANASE. Therefore, the changes in reported annoyance for a given LAeq between 1982 and 2005 may reflect the changes in the composition of number and sound level that people are exposed to, suggesting a **different** formulation to that implied by LAeq.
- 1.4.11 An NNI-type measure gives a larger weight to the number of aircraft relative to the sound level than LAeq, and comparisons of the ANIS and ANASE mean annoyance against the NNI-type metric showed that the two datasets were much more closely aligned with the NNI-type measure than LAeq.
- 1.4.12 However, the relationship between reported annoyance, sound level and the number of aircraft has not been stable over time. The weight on aircraft numbers (relative to sound level) has risen from 6 in ANIS to over 20 in ANASE, so the contribution of aircraft numbers to annoyance has increased quite markedly. Because of its instability over time, use of the

LAeq measure to predict future levels of annoyance may be misleading. Although the NNI-type index is also not stable over time, with the later ANASE result giving greater weight to aircraft numbers, the ANASE result is relatively insensitive to a weight greater than 20, so an NNI type measure may provide a better tool for predicting annoyance from aircraft noise.

- 1.4.13 **Overall**, we consider that while LAeq continues to be a good proxy for measuring community annoyance at a point in time, the relationship between LAeq and annoyance is not stable over time. An NNI – type measure appears to offer a stronger basis than LAeq for estimating future levels of annoyance in response to changing numbers and types of aircraft.

Time of Day and Willingness to Pay to Reduce Aircraft Noise

- 1.4.14 The results of the SP survey have shown strong internal consistency and statistical validity, with a clear indication that aircraft SEL, aircraft type, time of day and personal characteristics (in particular household income) influence annoyance and willingness to pay to reduce it.
- 1.4.15 As a proxy for predicting changes in community annoyance in relation to a change from the current noise environment, our SP research supports the view that the role of **number** of events needs to be higher than that implied in the LAeq index.
- 1.4.16 The SP results have shown people to be more sensitive to aircraft noise at night (particularly around midnight and the early hours thereafter). In contrast, people are least sensitive to aircraft noise in the morning and early afternoon. These time-of-day sensitivities seem intuitively plausible and are also comparable with other research.
- 1.4.17 Unfortunately, despite the internal consistency, the implied valuations from the SP are much higher than may be considered plausible, when translated into a “per dB” value.
- 1.4.18 Valuations were also obtained from the CVM analysis. The implied willingness to pay to remove all aircraft noise was £3.80 - £11.50 per annum per dB reduction in LAeq for respondents, depending upon household income level. However, although this value is in the same ball-park as recent valuations based upon Hedonic Pricing, we have some reservations about the data, both because of the large proportion of respondents professing zero willingness to pay, and the apparent influence of the initial starting point in the “bidding” process.
- 1.4.19 Overall, therefore, we do not think that the valuations from either method are safe, and it will probably be necessary to rely on sources based on Hedonic Pricing. Nonetheless, the relative valuations – particularly those relating to time of day variation – can be used.

Further Research

- 1.4.20 The ANASE study has produced a range of interesting results from the survey data collected, and could form the basis for future research to address a number of issues raised. Some of the issues can be investigated with more detailed analysis of the current data, whilst others will require supplementary data collection.

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