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Aircraft noise assessment – alternative approaches

Ian Flindell, University of Southampton,

Paul Le Masurier, MVA Consultancy,

Dirk Schreckenberg, Zeus GmbH

[1] Congress Innsbruck

Rennweg 3, 6020 Innsbruck, Austria

ABSTRACT

Government policy makers need to balance the needs and rights of residents in close proximity to airports against the need to meet the ever-increasing demand for air travel. The UK Government has based their understanding of community annoyance on primary research conducted in the UK more than thirty years ago. In this paper, we compare more recent quantitative data against the historic data, and suggest that, using traditional models of aircraft noise annoyance, some adjustments to current noise metrics would seem to be justified in order to better deal with current conditions as they exist today. On the other hand, we have also been investigating alternative qualitative and trading methods of data collection which in many cases have found substantially different results to the current assumed status-quo. The results suggest that standard questionnaires (such as the ISO standard 'annoyance' scales) do not always reflect respondent's underlying attitudes particularly well. In most cases, reported annoyance is not so much determined by the amount of aircraft noise measured using traditional acoustic metrics such as LAeq and Lden, as by a whole range of beliefs and attitudes about the way that the airport operates and engages in meaningful mitigation and compensation programmes.

Keywords: Aircraft Noise, LAeq, Alternative Methods

HISTORICAL BACKGROUND

According to the Wilson Report on 'The Problem of Noise', published in 1963[1], aircraft noise did not start to become a significant problem for residents around the larger UK airports until turbo-jet powered civil transports were introduced from around 1958. Legal actions against nuisance caused by civil aircraft in flight or on aerodromes were prohibited by the Air Navigation Act in 1920, and subsequent Civil Aviation Acts have imposed duties on the Secretary of State to provide alternative safeguards. Legal immunities were provided to the industry to prevent individuals from being able to restrict growth in civil aviation against the interests of the population as a whole. It therefore became a matter for Government to impose whatever steps were considered necessary to minimise nuisance while at the same time not unduly compromising the economic and social benefits provided by the industry.

In 1961, soon after jet aircraft noise had started to become significant, the Wilson Committee

[1] http://discovery.nationalarchives.gov.uk/SearchUI/Details?uri=C11243865

decided to measure the extent of the problem by commissioning a pioneering survey of aircraft noise disturbance and annoyance around Heathrow Airport. The survey was also intended to establish the physical correlates in terms of sound levels and numbers of events. Based on the results of this research, the Wilson Committee recommended the adoption of the Noise and Number Index (NNI) to show the extent of noise nuisance around major airports. Subject to limitations which are clearly set out in their report, the Wilson Committee considered that the data showed that a fourfold increase in the number of aircraft heard (outdoors) was 'very approximately' equivalent to a 9dB increase in average maximum sound levels during each event. Successive UK governments have continued to follow this general approach by commissioning aircraft noise contours around major airports to be able to demonstrate the benefits of aircraft noise reduction at source in offsetting the considerable increases in traffic which have taken place since that time.

The limitations of the first studies of aircraft noise and annoyance were recognised at the time and increasing numbers of similar studies were carried out at different locations around the world. This eventually led to a confusing proliferation of different noise scales and indicators, all purporting to measure much the same thing but with many subtle, and sometimes significant, differences. By the late 1970s, people had begun to doubt that the NNI was still the most appropriate indicator of aircraft noise for use around the UK and so the Civil Aviation Authority commissioned a new 'Aircraft Noise Index Study' which was carried out in 1980 and 1982 (REF DORA 9023[2]). Based on this new data, and after further consultation and research, in 1990, the UK Government changed from using the NNI to a 16 hour day 3 month summer average LAeq for showing the extent of noise nuisance around major airports. The benchmark for the 'onset of annoyance' (somewhat later this became the 'onset of significant annoyance') was 57 LAeq. Around this time, older noisier aircraft types were increasingly being replaced by newer quieter aircraft types leading to continuing reductions in average maximum sound levels over time while overall traffic was continuing to increase. The practical effect of changing over from NNI to LAeq when plotting aircraft noise contours around major airports was that the reductions in average maximum sound levels had a proportionately greater effect on the areas enclosed within defined LAeq contour values, than the increases in traffic. Over the next few years from 1990 onwards, the areas enclosed within defined LAeq contour values continued to shrink, providing a clear demonstration of the benefits achieved from noise control at source. However, the problem of aircraft noise, judging from the increasing areas around major airports from which noise complaints were being received, did not appear to have been reduced in proportion.

By the late 1990s, there were in general two main approaches to official and regulatory aircraft noise assessment. In the USA, and mainly based on research carried out in the USA, the Federal Aviation Administration (FAA) had decreed that a noise contour level of 65 Ldn defined the difference between 'significantly aircraft noise affected' and 'not significantly aircraft noise affected' areas. With, in general, plenty of land space available, this allowed the continued development of large airports at sufficient distances from areas with high population densities to avoid incurring excessive costs for noise insulation or other noise mitigation measures whilst not unduly compromising surface access and also ensuring a level playing field in terms of commercial competition. In Europe, often with more tightly constrained airports, each member state tended towards their own noise scales and indicators with a proliferation of different regulations and benchmarks for different kinds of noise control action. While this multiplicity may have been reasonably successful in terms of accommodating observed differences in attitudes and opinions and individual circumstances, it offended against the principle of European harmonisation and was not therefore looked on very favourably by the European Commission. In addition, in many cases, there was no convincing scientific justification for the detailed differences between the different scales and indicators used. Researchers in the Netherlands (Miedema et al[3]) followed the approach pioneered by Schultz in the USA (Schultz 1978[4]) to produce harmonised dose-response curves based on meta-analysis of all available and comparable survey data collected in many different separate research studies carried out in Europe and America. The Miedema curves were then adopted by the European Commission in

[2] http://www.caa.co.uk/docs/33/ERCD9023.PDF
[3] http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240282/pdf/ehp0109-000409.pdf
[4] http://www.ncbi.nlm.nih.gov/pubmed/361792

their 2002 Environmental Noise Directive (END 2002[5]) which required noise mapping using the harmonised LAeq based noise indicator Lden and noise action plans to be published for the information of the public. To carry out the meta-analyses, it was necessary to apply a wide range of normalising and averaging assumptions. The different data sets acquired using questionnaires administered in different languages and aircraft noise measurements and calculations using different noise scales and indicators were not otherwise compatible. It should be noted that the normalising and averaging assumptions may have concealed real and potentially important differences between the different data sets. However, for application in 2013 and the future, it may be even more important to note that the data sets included in Miedema et al's meta-analysis only covers the period from 1965 to 1992 and much has changed since then.

Figure 1 below shows the results of more recent aircraft noise annoyance studies carried out around major airports in Europe plotted out against the standard EU curve (Miedema et al 1998, 1999 and 2002[6]). For clarity, Figure 2 below shows just the regressions for the same data sets without the individual data points shown on Figure 1. Also shown is the data for the 1980/82 UK Aircraft Noise Index Study (Brooker 1985[7]) for comparison purposes. It should be noted that the same caveats mentioned above in relation to applying normalising and averaging assumptions to the different data sets also apply to this analysis. However, the problem has become less important for the most recent data sets because of increasing standardisation of measurement.

Figures 1 and 2 show that the ANIS data is reasonably well represented by the EU curve at the lower aircraft noise sound levels (55 Ldn or 24 hr LAeq and below). At higher sound levels (65 to 70 Ldn or 24 hr LAeq), the EU curve underestimates the percentage highly annoyed in the ANIS data by the equivalent of around 2-3 dB. What is much more striking however is the general degree of consistency between the more recent studies (ANASE, Paris, Amsterdam, Frankfurt) and the clear difference, equivalent to around 5-6 dB, between the average trend of all of these more recent studies and the much older ANIS data. This implies that using the data of older studies such as ANIS, and the contemporaneous and even earlier data represented by the EU curve, is likely to significantly under-estimate the extent of reported annoyance around any of the major European airports represented in the figures under present day, or at least more recent, conditions.

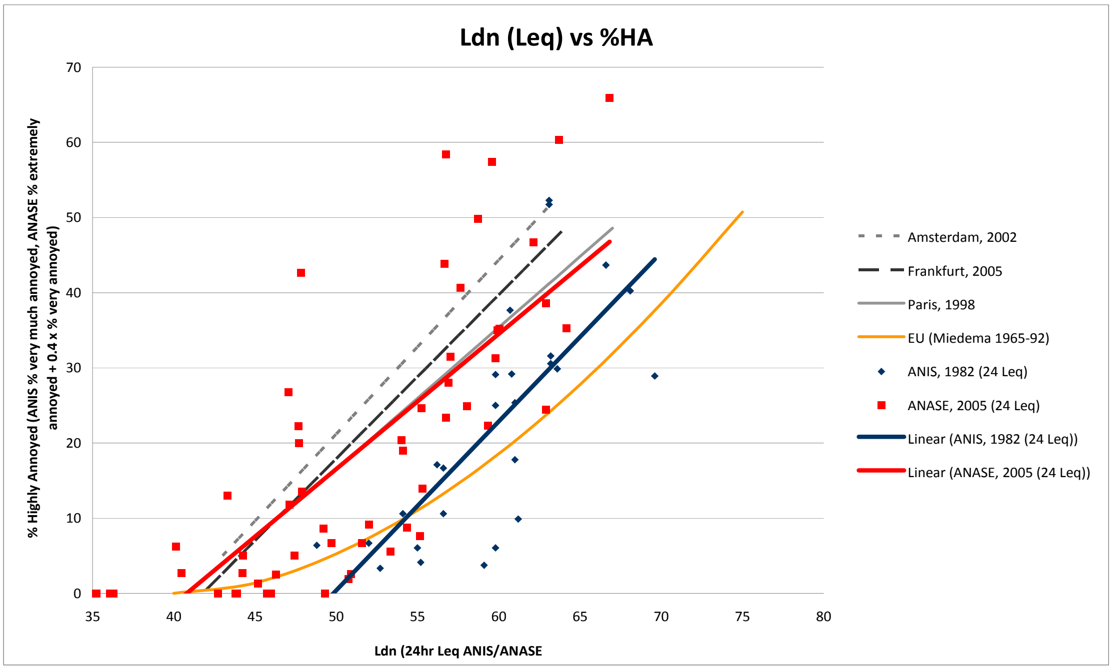

Figure 1 – Recent aircraft noise annoyance study findings (with ANASE/ANIS data points)

5 http://ec.europa.eu/environment/noise/directive.htm
6 http://ec.europa.eu/environment/noise/pdf/noise_expert_network.pdf
7 http://www.caa.co.uk/docs/33/ERCD%208402.PDF

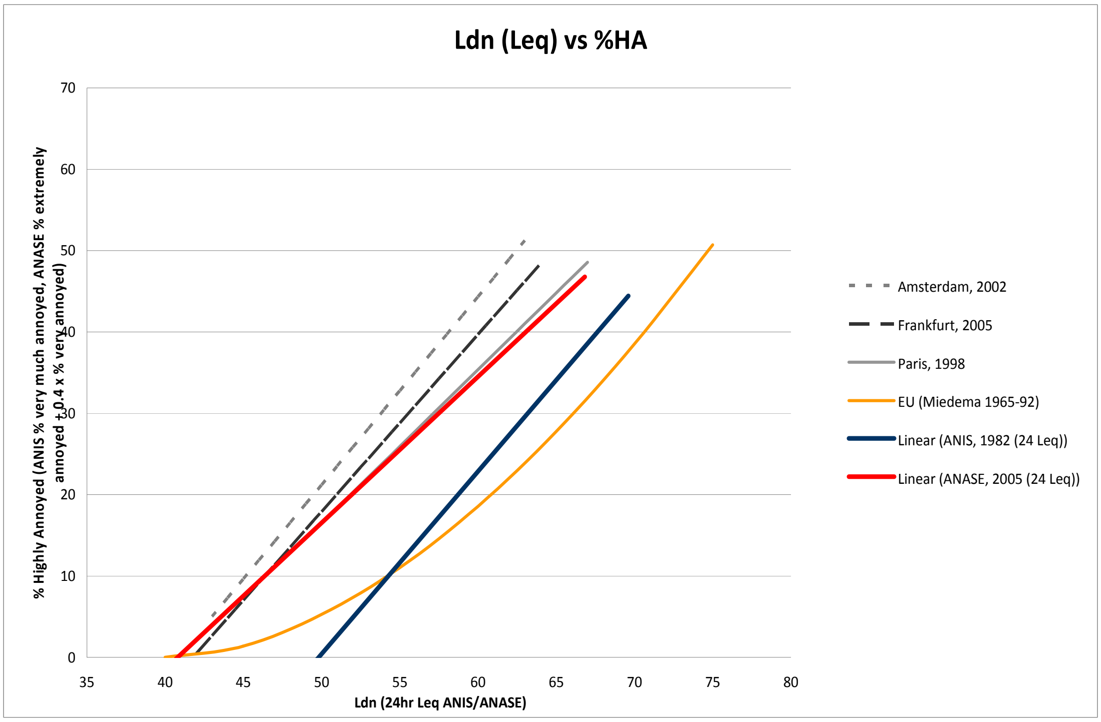

Figure 2 – Recent aircraft noise annoyance study findings (Regression lines only)

The conclusions that adopting the EU curve, or similar, for forming conclusions on community annoyance levels is confirmed by recent comparisons of exposure-response relationships (e.g. Guski, van Kempen and Kamp; and Janssen et al[8]).

DISCUSSION

There are two key questions arising from these comparisons;

a) what is the explanation for the observed differences shown on the figures;

b) what are the implications for policy?

There are, in general, two alternative scientific hypotheses which can be invoked to explain the differences [question a) above]. If we hypothesise that there IS a fundamental underlying relationship between the amount of aircraft noise measured outdoors using some form of long time A-weighted energy average (LAeq, Ldn, or Lden, etc.) and the resulting degree of disturbance and annoyance, then any differences in observed dose-response relationships arise from, or are caused by, uncertainties in measurement along either the horizontal axis representing the noise 'dose' or input variable and/or the vertical axis representing the reported annoyance or outcome variable. Improved consistency of measurement achieved by using standardised questionnaire scales for reported annoyance (ISO TS 15666[9]), and standardised methods for measuring and calculating aircraft noise sound levels (REF ECAC CEAC Doc 29[10]) will have improved comparability in recent years, but there are still large differences in response at different receiver sites even where averaging across all receiver sites included within particular studies has reduced apparent differences between different studies. The scatter of individual receiver site data points shown on Figure 1 should make this point clear. Note that the receiver site data points shown on Figure 1 have already averaged across

[8] Guski, Noise Health (2004); van Kempen and Kamp, RIVM (2005); Janssen and Vos, TNO (2009)
[9] http://www.iso.org/iso/catalogue_detail.htm?csnumber=28630
[10] http://www.boeing.com/commercial/noise/ECACDOC29e.pdf

individual responses which always show further variance above and below receiver site averages. It should also be noted that minor uncertainties regarding the comparability of annoyance questions asked in different languages or different ways of adding up day, evening and night-time noise included in different versions of LAeq based metrics could all be responsible for small differences, but none of these uncertainties seem to be big enough, on their own, to explain all the observed differences between the recent studies and the older studies represented by the EU curve.

The alternative scientific hypothesis [to explain question a) above] is that there is no unique underlying relationship between the amount of aircraft noise measured outdoors using some form of long time A-weighted energy average (LAeq, Ldn, or Lden, etc.) and the resulting degree of reported disturbance and annoyance. Differences in observed dose-response relationships represent genuine differences in response caused by differences in sensitivity to different features of aircraft noise in different environments, or even to different socio-economic and attitudinal factors. There is increasing interest in these so-called non-acoustic factors (e.g. Vos 2010, Griefahn et al. 2013, Schreckenberg et al. 2010, Broer 2007[11]) which can more easily be revealed by newer methods of qualitative research. The general consensus, if there is one, seems to lie somewhere between these two extremes.

As a UK specific example of these kinds of problems, Figures 1 and 2 show significant differences between the observed dose-response relationships between the 1982 ANIS study and the 2005 ANASE study, both carried out in the UK. If we ignore measurement uncertainties along the horizontal and vertical axes then we must conclude either that UK residents have become more sensitive to aircraft noise over the 23 years between the two studies, or that their fundamental dose-response relationship has not in fact changed, but instead either that the noise measurement scale (in this case different variants of LAeq) has not captured or reflected any differences in the aircraft noise environment properly, or that the reported annoyance scales used in the two studies were not at all comparable. The more recent 2005 ANASE study was carried out in full compliance with current scientific best practice using the same standardised questionnaires and aircraft noise measurement and calculation procedures as for the other recent European studies. The earlier 1982 ANIS study was not compliant with current scientific best practice which had not been standardised at that time, but since it is not possible to go back in time to repeat measurements using standardised procedures, there is no way to determine what the effects of non-compliance might have been.

A comprehensive statistical analysis of the differences between the 2005 ANASE study and 1982 ANIS data sets was published in 2007 (ANASE 2007[12]). This analysis demonstrated that by taking greater account of the number variable when measuring the aircraft noise input sound level, the apparent difference in dose-response relationships between 1982 and 2005 disappeared. The best fit to both data sets was obtained by using a number factor equivalent to the original Noise and Number Index dating back to 1963. However, it is not possible to distinguish this conclusion from the alternative hypothesis based on an assumption that the noise scale based on LAeq is definitive and that the differences in response arise either from differences in sensitivity to aircraft noise or even from different interpretations of the reported annoyance scales used. At the time that these analyses were being reported, the CAA (who carried out the 1982 ANIS study) suggested that the apparent increase in reported annoyance at the same LAeq from 1982 to 2005 could have represented some kind of protest against then current aviation policy and did not necessarily represent underlying or actual annoyance at all (CAA peer review 2007[13]). Interestingly, detailed study of the non-standard annoyance questionnaires used in the 1982 ANIS study shows that the way in which respondents were gradually led from questions about their satisfaction with the general area in which they live onto more specific questions about noise disturbance and annoyance was clearly biased against the number variable. It

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[11] Vos (InterNoise 2010); Schreckenberg and Schuemer (InterNoise 2010); Griefahn et al (InterNoise 2013); and Broer (2007)

[12] http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/aviation/environmentalissues/Anase/

[13] http://www.obsa.org/Lists/Documentacion/Attachments/235/Attitudes_noise_aviation_sources_England_EN.pdf

could be argued therefore that the apparent relative insensitivity to the number variable observed in the 1982 ANIS data was, to some extent, a foregone conclusion. Unfortunately, none of the other recent European studies were designed to permit the relative effects of the number and average sound level variables to be compared in the same way that they could be compared in the 1982 ANIS and 2005 ANASE databases (and in the original 1961 Heathrow study database).

The second key question is 'what are the implications for policy'? Firstly, if policy makers wish to fully understand the effects in terms of standardised reported annoyance of civil aviation across Europe, then the current standard EU dose-response curve is out-of-date. A further implication is that not only are the historic studies represented by the EU curve out-of-date, but even the more recent studies, which generally show higher reported annoyance than predicted according to the EU curve, are themselves likely to become increasingly out-of-date as we move into the future.

Secondly, since it appears that standardised aircraft noise annoyance dose-response curves are subject to considerable uncertainty and always likely to be more or less out-of-date as circumstances change over time, then perhaps a less harmonised approach is justified. Recent qualitative research (not yet formally published, but nevertheless increasingly well-known) has clearly demonstrated a wide range of individual sensitivities and concerns to different features of the overall aircraft noise environment in different situations, which no standardised dose-response curve based on long time averaged noise metrics such as 16 hour LAeq, Ldn, or Lden can possibly represent. A simple example of this problem is runway alternation at Heathrow Airport which provides scheduled respite for people living under alternative approach tracks to the airport. Scheduled runway alternation at Heathrow has no effect on LAeq or Lden contours yet is a measure which has long been held to provide benefits for many residents. Recent qualitative research is suggesting that the perceived benefits can be significantly affected by the extent to which residents are even aware of the policy. While residents are likely to be aware to at least some extent of time periods during which they are overflown, they are generally much less aware of time periods when they are not overflown. There are many similar examples where what might in fact be relatively minor changes to aircraft fleets, flight tracks, or operating procedures can have apparently disproportionately greater effects in terms of community response. None of these possibly unexpected changes in community response should be dismissed by policy makers simply because they are above or below the harmonised EU curve. Instead they should be taken, or accepted, as clear demonstrations of an absolute requirement for individual airports to fully engage with their surrounding communities to explain and justify where noise is unavoidable and to make their economic and social contributions to general welfare much more explicit. There is increasing research evidence that residents consider it OK if they are annoyed from time to time if they also understand what has been done to reduce the problem and why the remaining annoying circumstance is unavoidable. Many residents can then still find the presence of an airport nearby to be, on balance, entirely acceptable.

CONCLUSIONS

In 1963, when discussing their proposal for the Noise and Number Index to measure aircraft noise, the Wilson Committee also set out three clear limitations as follows;

a) the inevitable approximations in the basic data of noise levels;

b) the coincidence of high noise levels and large numbers of aircraft, so that there was no-one in the sample of people questioned who heard only a few very noisy aircraft or a large number of aircraft only faintly;

c) the scatter of results, i.e. by no means all the people who were very annoyed lived in the noisiest areas.

These limitations still apply today.

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