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PUBLIC REACTION TO AIRCRAFT NOISE: RECENT UK STUDIES

Peter Brooker

Chief Scientist's Division, Civil Aviation Authority, CAA House 43-59 Kingsway, London WC2B 6TE, England.

INTRODUCTION

The Noise and Number Index (NNI) is used in the UK in the assessment of the noise nuisance resulting from aircraft flights from major civil airports. It was originally devised from a 1961 social survey/noise measurement programme for a wide sample of people in the vicinity of Heathrow Airport [1]. There have been further research studies ([2] summarises and gives references) but the original concept has been retained for the last two decades. In 1981, following research trials, the UK Department of Trade decided that a fresh major study should be carried out. This paper discusses the factors which led to this decision, the objectives of the study, and the methodology used in the research programme.

BACKGROUND

The NNI is defined by:

$$NNI = \bar{L} + 15 \log_{10} N - 80 \quad (1)$$

where $\bar{L}$ is the average peak noise level heard (in PNdB) and N the number of aircraft heard during the day (0600-1800 GMT, averaged over the summer period). In practice $\bar{L}$ is estimated in dBA and 13 is added - the ICAO Annex 16 recommendation: 'heard' is taken to mean a peak noise level in excess of 80 PNdB. The form of NNI was chosen as a combination of measured physical variables which correlated well with annoyance as determined from social survey responses. Annoyance was assessed in the 1961 study by the use of an attitude rating method - the "Guttman Annoyance Scale" (GAS -[2]). Each individual surveyed produced a GAS score from 0 to 6 (highest disturbance) in unit steps. The GAS score is computed from a set of questions on disturbance from aircraft noise exposure, including:-

: The Aircraft Noise Annoyance Scale (ANAS) - was the respondent 'Very Much', 'Moderately', 'A Little' or 'Not at All' bothered or annoyed by the aircraft noise;

: Interference and Annoyance with specific activities or states - conversation, listening to radio/television (now includes 'Hi-Fi'), house vibration, waking up, startle;

: Interference and Annoyance with any other activity or in any other way the respondent can specify.

The NNI expression was chosen so that over the exposure range of interest the NNI was proportional to the GAS score. In the UK 35 NNI is taken for official purposes as the onset of significant community disturbance : 55 NNI is taken to represent high community disturbance (50 NNI is used for noise insulation grants).

CRITICISMS OF THE NNI

Some of the criticisms which have been made of the NNI are relevant to the new study: some criticisms are less relevant because of misunderstanding of the role of the index; for example NNI is not expected to predict accurately an individual's annoyance, but instead to indicate the broad reaction of groups of people to different noise exposures. The major criticisms are [3]:-

The NNI expression is 'out of date': This covers general shifts in attitudes to disturbance and changes in the frequencies of the activities used in constructing the GAS score. Of concern are the changes in the aircraft noise environment. As an illustration consider the (approximate) movement figures at Heathrow (this assessment was made in 1980).

	1961	1967	1979
Movements	147,000	236,000	281,000
Jet Movements	38,000	146,000	253,000
Jet Movements as %	26%	62%	90%
Wide Body as % total	-	-	19%

The differences in peak noise levels and noise spectra between non-jets, jets and Wide Body jets are known to be marked.

NNI is 'out of line' with other countries' indices: There is a tendency for some states (particularly the USA) to use Leq-based indices, ie based on the total noise energy received - 'time integrated' rather than 'peak level'. Leq-based indices weight the importance of the number of aircraft heard rather less than NNI (in the 'trade-off' between L and Log N, the factor '15' in the expression essentially being replaced by '10').

Movements in the evening and night periods should be accounted for in the index: Unlike many other indices the NNI does not take these

movements into account; daytime movements serving as a 'surrogate' for total activity. Night movements, resulting in sleep disturbance have been seen in the UK to be a separate matter from annoyance [4].
The 'Cut-off' of 80 PNdB is too high: It is argued that it is wrong not to take account of the, possibly many, movements just below 80 PNdB. This is of particular relevance given the number of quieter wide-body jets which will operate in future.
Further Criticisms The effects of modal split, diurnal/weekly/ seasonal variation, backgound noise.

THE AIMS AND METHODOLOGY OF THE STUDY

The UK Department of Trade (DoT) agreed three objectives: (a) The Index should enable policy decisions to be made on as equitable a basis as possible; (b) It should be possible to defend the use of the Index against criticism; (c) The Index has the prime need that it should reflect the nature of the disturbance around Heathrow, Gatwick and Stansted (the responsibility of the DoT). While the 'London' airports have been emphasized here, the survey results need to be applicable to other UK airports. In particular for those airports with a relatively small number of movements but at high noise levels, the 'London' airports are not a sufficient representation - it was thus necessary to include some of the former for a generally applicable index.

Note that the extent of disturbance at Heathrow is of a different order from that at other UK airports. This can be illustrated by the populations within NNI contours: using the 1979 figures, the numbers within NNI contours are (with Gatwick the next major UK airport for comparison):-

	Heathrow	Gatwick	
55 NNI	73,000	1,000	) rounded
45 NNI	311,000	3,000	) to nearest
55 NNI	1,610,000	31,000	) 1000

A cluster sample methodology is used in the study (previously used in other noise work by the CAA research team [4]). Social Survey Sampling of 70-80 people takes place at a number of sites, typically about 1 sq km in area. An individual aircraft type noise level at any point within each site does not vary by more than a few dB - the value being pre-determined. At each site noise measurements are taken at a central location on a number of days for each airport mode of operation. Because of the dominance of Heathrow in aircraft noise exposure the major part of any UK study needs to take place in its environs: the low density of population around Gatwick militates against the choice of sites there. Stansted, with present movements, offers little opportunity for reasonable population sampling with the cluster methodology. An examination of the major airports in the UK indicated that at Luton a site could be found which does not have a counterpart at Heathrow (it has comparatively small number of movements and high noise levels over populated areas); there are also good general sites at around 35 NNI at Manchester and Aberdeen.

During the feasibility work for the 1982 study the design centred on a matrix of noise level L and aircraft number N which covered a wide range of aircraft noise exposures. Figure 1 presents an approximate $\bar{L}$ - N matrix of sites for Heathrow.

L / N	83 PNdB	89 PNdB	95 PNdB	101 PNdB
32	4+	3+	2++	1+
56	8+	7	6+	5
100	12	11	10+	9++
178	16++	15+	14+	13+
316	20++	19+	18+	17+

FIGURE 1 : Approximate $\bar{L}$ - N Matrix for Heathrow Sites
KEY + - Site for survey, ++ - double survey (see final paragraph)

Having such a cluster-site matrix plan is not enough; the following questions need to be answered before a survey can be designed:-

: How many people should be sampled?
: Should all cells be sampled? Should some cells be sampled more than once? (Replicated sampling)
: What sorts of questions should be asked - should they be the same as for the previous surveys?

To answer these questions it is necessary to focus on the purposes of the work. Probably the crucial aim is to distinguish between the relative merits of NNI and Leq. The study had to be of a design and scale as to provide some answer to this question which is defendable on a statistical basis. It is necessary to retain the Guttman Annoyance Scale for comparisons with past work: the problem then arises that the GAS responses may have shifted over the years, as mentioned earlier. The need to have knowledge on the variation in GAS scores before the survey sample size can be properly estimated was an inducement for a set of trials to be carried out. These took place in 1980 at 5 sites within the matrix parameters - the results will nearly all be suitable for incorporation in the full study results. Several ancillary points about the design are worth noting:-

Background Noise: It was decided that very limited background noise measurement should be carried out - merely as a guard against taking results from a very noisy/quiet site as representative. (Background

noise effects are the concern of complementary UK research).
Demographic Factors: It was decided not to select sites with regard to demographic factors, eg socio-economic, house construction differences.
Average vs Worst Mode: Survey design has been on the basis of the usual 'average mode' NNI (with an assumed 70:30 split in favour of westerly operations) but the data collected allows disturbance related to runway mode effects to be examined.
Evening/Night Movements: In view of the fact that some other indices include an allowance for evening/night movements it was decided that noise and attitude data on these should be collected.
Cut-off: It was decided to carry out analysis of noise data with cut-offs of 70 and 75 PNdB in addition to the usual 80 PNdB.
Annoyance Scales: The GAS score is used as a measure of annoyance but variants of GAS and other disturbance scales are also included in the Social Survey questionnaire. This was based on earlier versions, but with some significant improvements.

The main conclusion arising out of the trials work and the statistical simulation of responses and noise measures for possible selections of sites was that a survey of every cell in the $\bar{L}$ - N matrix was not efficient. If the main concern was, as in earlier work, to 'paint a picture' of disturbance around airports then such a 'random' design is quite adequate. However, the degree of correlation between $\bar{L}$ and N means that some of the combinations of $\bar{L}$/N cells in the matrix provide more information on the $\bar{L}$ - N trade-off than others. As the major aim is to discover the best relationship between disturbance and the important components of noise exposure, then the type of index to consider would seem to be of the form:-

$$I = \bar{L} + k\log N + \text{constant} \qquad (2)$$

Here $\bar{L}$ is some average noise level and N some average number of aircraft. The focus of the study is the discrimination between the cases k = 10 (Leq-type) and k = 15 (NNI-type). The index is to match with an annoyance score, which could be GAS, ANAS or some other attitude scale. Annoyance scores are not cardinal numbers (like distances or heights) in that they are only guaranteed to rate disturbance on what is inherently an ranking scale. This causes problems for less noisy sites, eg perhaps less than about 30 NNI, where many scores are zero, and the supposition of cardinality implicit in much of the statistical analysis becomes particularly tenuous - implying the need for rank correlation methods in the analysis.

Given data on annoyance scores and on the corresponding $\bar{L}$ and N, the value of k best suited to the data set can be estimated (the simplest method is by 'multiple regression analysis'). The important thing is how accurate is the estimate of k as compared with the value of k which gives the best fit to all the possible data, ie including everyone who could be said to be exposed to aircraft noise. The precision of an estimate of k depends on a number of factors: if noise level and number could be estimated accurately for every individual and all individuals responded in the same way to aircraft noise, then the sample size necessary to determine k would be very small. However, the aircraft noise parameters are not perfectly estimated and there is a considerable variation in response between individuals. To determine the constant k a sufficient sample of the population is therefore required: to reiterate, it need not be representative in a geographic sense of the population in the environs of an airport - rather it must cover the range of factors such as noise level and number of aircraft. An effective sampling plan is one which provides the most accurate and precise estimate of k for a given number of people sampled. A sampling design may be effective in the above sense but still be more costly than necessary. One way in which costs can be reduced is for survey samples in some cases to be increased in size or (the method chosen) replicated, ie two surveys of different sets of individuals could take place in the same site. This reduces the amount of noise measurement required because one set of noise data then serves to characterise two sets of survey responses.

The end result of the analysis is shown by the symbols in Figure 1. Cells 5, 7, 11 and 12 are eliminated from the design because they are near the average NNI and N values and are therefore less 'statistically efficient', while sites 2, 9, 16 and 20 are sampled twice because they are nearer the extremes of NNI and N. Not shown on this Figure is a Luton (double) site with (approximately) L=100+ and N=50, and sites at Gatwick (two), Manchester and Aberdeen at around 35 NNI. At each site about 70-80 people were interviewed, twice that number at the replication sites. This work took place in 1980 (trials) and 1982 : in total some 2100 people have been interviewed. All the social survey and noise measurement data has been collected. Processing and analysis are in progress - the study is planned for completion in early 1984.

REFERENCES

[1] Committee on the Problem of Noise, 'Noise Final Report' HMSO Cmnd 2056 (1963). [2] DORA Comm 7907, 'The Noise and Number Index', Civil Aviation Authority (CAA), (Second Edition 1981). [3] P Brooker, DORA Comm 8106, 'Criticisms of the Noise and Number Index', CAA, (1981). [4] DORA Report 8008, 'Aircraft Noise and Sleep Disturbance, CAA (1980).