Directorate of Operational Research and Analysis
Chief Scientist's Division
Civil Aviation Authority

DORA Report 9023

The use of Leq as an Aircraft Noise Index

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SUMMARY

The results of the public consultation on the proposal to replace the Noise and Number Index by Equivalent Continuous Sound Level are reviewed. Although there were many questions about the way in which Leq might be used, especially with regard to the distinction between day and night, there was general support for its adoption. Means for calculating Leq contours are discussed, as is the comparability of NNI and Leq values.

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GLOSSARY OF TERMS*

ANIS	Aircraft Noise Index Study.
Day	Defined in the ANIS to be 0700-1900 local time.
DORA	Directorate of Operational Research and Analysis of the Civil Aviation Authority.
dB(A)	Units of L_A, decibels.
DTp	Department of Transport.
Evening	Defined in the ANIS to be 1900-2300 local time.
GAS	Guttman Annoyance Scale/Score. A Guttman Scale is a psychological scaling technique used for attitude measurement. One particular scale, to which the abbreviation refers in this report, has been extensively used in aircraft noise work.
L	Average sound level. For this and the following sound level measures, the average is calculated from all sounds above a particular threshold.
L_A	Sound level measured on the A-weighted scale.
L_{Amax}	The maximum value of L_A occurring during an aircraft flyover.
L_{AX}	An approximation to an aircraft noise event SEL calculated from L_{Amax} and the 10dB-down duration (for which the sound level lies within 10dB of (L_{Amax}).
L_{dn}	A "stratified" version of Leq(24hr), widely used in the USA, in which sound energy measured between 2200 and 0700 hours is weighted by a factor of 10.
L_{eq}	Equivalent Continuous Sound Level, measured for present purposes in dB(A). The alternative abbreviation L_{Aeq} has not been used herein because of the general use of L_{eq} in predecessor documents. Denoted in the text as Leq. The measurement period is denoted in brackets, eg Leq(24hr).
L_{PN}	Perceived Noise Level, a special scale used to measure aircraft noise and a component (as an average value) of NNI. Its exact formulation is somewhat complex; it is common DORA practice to equate it to L_{Amax} + 13.

* More rigorous definitions of some of the above terms can be found in DR Report 8402 (Ref 3).

N	Number of events (aircraft sounds) occurring above a certain threshold in a specified time period, eg day, evening or night.
Night	Defined in the ANIS to be 2300-0700 local time.
NNI	Noise and Number Index.
PNdB	Units of L_{PN}, decibels.
SEL	Sound Exposure Level, a measure of aircraft single event noise which takes account of duration as well as intensity ($\overline{SEL}$ denotes an average value).

1. INTRODUCTION

For more than twenty five years the official unit of aircraft noise exposure in the UK has been the Noise and Number Index (NNI) (Ref 1). During that time the CAA's Directorate of Operational Research and Analysis (DORA) has maintained a computer model which generates contours of aircraft noise exposure from input information describing flight routeings and the aircraft traffic upon them. This has been used for many purposes including the preparation of annual noise contours for the London Airports and evidence for most public inquiries into major airport development plans.

While Inspectors and Government Ministers have, on the whole, accepted NNI as a valuable planning tool, it has been subject to numerous criticisms from inquiry participants and others (Ref 2) and the United Kingdom Aircraft Noise Index Study (ANIS) was carried out by DORA for the Department of Transport (DTp) to investigate whether improvements might be possible.

Important conclusions of the ANIS Report (Ref 3) were that a good fit to aircraft noise disturbance responses is given by Leq(24hr) and that continued use of NNI might tend to lead to problems due to its particular combination of noise and number terms. The Department of Transport therefore initiated a public consultation on the advisability of adopting Leq(24hr) as the UK aircraft noise index (see Appendix 1).

Section 2 of this paper summarises and comments upon the submissions made during this consultation, particular attention being given to technical issues. Extensive reference is made to the ANIS Report (Ref 3) which should be considered as essential pre-reading. Section 3 makes specific recommendations for the practical implementation of Leq and briefly describes a computer model developed for the purpose of calculating Leq contours. Appendix 1 includes copies of documents associated with the consultation process and Appendix 2 is a list of the consultees from whom submissions were received by the DTp (submissions were numbered chronologically on receipt).

2. CRITIQUE OF THE TECHNICAL ISSUES RAISED IN THE ANIS CONSULTATION

Sixty-one replies were received by the Department of Transport, though at a later stage some responses were withdrawn. On many points, several consultees had similar views. To avoid tedious repetition, such comments have been considered collectively here although individual contributors are identified by number (from Appendix 2). Several local authorities formed a working group with London Scientific Services. This working group prepared a report referred to here as LSS (Ref 4) which formed part of each of their submissions. Reference 4 was also adopted by the London Boroughs Association. The Local Authorities Aircraft Noise Council (LAANC), whilst generally adopting Reference 4, also provided some views which were not consistent with those expressed in it. In what follows, referenced sections of the ANIS report are designated by square brackets, eg [3.5] refers to paragraph 3.5 of the report.

2.1 Overall View

2.1.1 *Accept Leq*

Of the 61 replies received, only four expressed opposition to the replacement of NNI by Leq (39, 43, 46, 50), two were withdrawn, and five were neutral (25, 35, 44, 45, 51). Of the 50 consultees who accepted a case for Leq (ie more than 80% of those who replied) the majority did so with reservations about the method of application; many of these concerned the 24 hour measurement period. One consultee (27) regarded the acceptance of Leq as predetermined.

2.1.2 *Reformulate NNI*

One consultee (25) considered that a reformulation of the NNI (changing the number coefficient from 15 to 10) would be better, particularly during the period when Leq is being introduced. This idea of introducing a third index, which would be little different from Leq in its implications, seems to be an unnecessary complication.

2.1.3 *Overlap use of NNI, Leq*

About one third of the replies (6, 7, 9, 11, 13, 14, 15, 19, 25, 27, 35, 40, 47, 56, 61, LSS) suggested that any proposed Leq-based index should be used alongside NNI for up to 5 years.

2.1.4 *No prolonged overlap of use of NNI, Leq*

One consultee (49) urged DTp to "fix an early date for the introduction of the use of Leq as a means of measuring aircraft noise and to resist representations suggesting a prolonged introduction period".

2.2 General Criticism

2.2.1 *Leq does not take enough account of number*

Criticisms of Leq for "failing to account for" or "being insensitive to" numbers of aircraft (27, 39) allege that the dependence on numbers, which is implicit in the formulation of Leq, is not strong enough by comparison with the dependence in NNI.

The design of ANIS, and in particular the choice of survey areas, was largely governed by the requirement to separate the effects of L and N in determining noise exposure. Statistical tests were applied to a range of candidate expressions of the "NNI/Leq" type, ie L + k log N, where the value of k was determined by the best fit to the data, both with the present cut-off level (80PNdB) for noise levels and with lower values.

These tests consistently showed that a value of k around 8 or 9 correlated best with reported levels of disturbance. Further statistical tests [Appendix E] demonstrated that it is unlikely that this value of k is simply a sampling effect with a true value in fact being much higher. Furthermore, Leq, which incorporates a number dependency equivalent to 10 log N, when tested in similar multiple regression analyses, correlated just about as highly with annoyance measures as did these particular L + k log N combinations.

The view that, because of its smaller number coefficient, Leq would somehow permit more flights than NNI (44) is incorrect. This is because intervals on the Leq scale have to be interpreted differently; eg a 3dB change of Leq equates to (approximately) a 5-unit change in NNI. Both steps correspond approximately to a twofold change of traffic.

2.2.2 *Study obtains more from the data than is justified*

One consultee (27) commented that the ANIS "attempts to obtain more from the data provided by the social survey than is in fact existing in that data and mere assumptions (which may or may not be correct) have been made in order to fill in that missing data to justify the desired conclusions". Another (29) stated "...conclusions have been drawn which go beyond what can be supported by the data and indeed what the survey were originally intended to determine". However, neither statement was supported by particular instances of error.

2.2.3 *Further work needed*

Several consultees made helpful suggestions for further work. These are considered below under the appropriate subject heading.

2.3 ***Sampling***

2.3.1 *Choice of areas*

The study was criticized for neglecting particular areas (5, 16, 27, 34, 35, 38, 44, 45, 49, 54, LSS). The criticism may be divided into two groups, according to views about the range of noise exposures studied, ie either a lack of respondents within the range or a lack of respondents outside the range

The explicit aim of ANIS [4.15] was **not** to portray the exact geographical pattern of community noise exposure around major airfields. This is because a statistically efficient design (using the smallest number of survey areas to provide a statistically valid estimate of the "trade-off" between noise level and aircraft number) is not compatible with such a portrayal [4.6]. In particular it was crucial to cover adequately areas with both high numbers/low noise and low numbers/high noise combinations which are far fewer in number than areas where noise levels and event numbers are either both high or both low. In fact, there were no claims that the choice of survey areas had failed to meet the statistical requirements as regards combinations of L and N. Rather, some considered that other neighbourhoods of particular interest should have been included.

2.3.2 *"Bias" towards Heathrow*

Of the 23 areas surveyed for the ANIS, 18 were around Heathrow. Some consultees (5, 34, 54) regarded this as an unacceptable "bias". The areas for the social survey and noise measurement were chosen through a statistical design which attempted to ensure that noise level and aircraft number were not correlated throughout the sample. The practical need was thus to find statistically valuable areas ranging from high noise/low number to low noise/high number. In particular only at Heathrow could the highest values of number of aircraft be obtained. In addition, Heathrow is largely surrounded by built-up areas - essential for providing "surveyable" populations. Considerable effort was made to find areas to fit in within the design at other airports, and indeed two areas at Gatwick and one each at Luton, Manchester and Aberdeen were surveyed. It should be noted that when the study was originally planned, using 1979 data, 1.6 million people were estimated to be within the 35NNI contour at Heathrow, compared with 31 thousand at Gatwick - a factor of about 50 more. For 55NNI, the factor was about 70. Any bias, in terms of population exposure, was actually *away* from Heathrow.

Others, indeed felt that *more* areas should have been studied near Heathrow. However, this would have duplicated some noise climates and would not have been statistically efficient: there would have been no benefit unless the responses were likely to be significantly different, eg for demographic reasons. One consultee (38) felt that data from an area near Aberdeen Airport [2.3] should not have been included because it had a very different character to those of the London areas and a slightly different questionnaire had been used.

2.3.3 *Airport dependence*

Others (1, 31, 45, LSS) felt that more areas could have been studied at other airports - not as a direct criticism of the efficiency of the L-N matrix, but because no airport-dependent effects had been studied at high noise exposures.

The NNI value for non-Heathrow sites in fact ranged from 31.7 to 41.0 [4.3], typical of noise exposures around airports smaller than Heathrow. Adequate common noise areas at higher levels could not be found and although airport-dependent effects were sought [8.36], none was statistically strong.

After the ANIS surveys were completed, a further study was carried out around Glasgow Airport (Ref 5) which included areas with higher noise exposure (the highest was 49 NNI). The results of this study are generally consistent with those of ANIS, ie there was no further evidence of a need for an airport-dependent index.

The highest value of NNI in any ANIS survey area was 56.3 (at Colnbrook); the study was criticised for not including areas with NNI values of 60 or more. The reason is that the requirement for all the respondents to have about the same outdoor aircraft noise exposure (within a range of about 3dB) places tight constraints on the choice of common noise areas. In areas close to the airport where NNI values are high, the populations are usually too small for statistically valid samples of people to be drawn.

Predictions of annoyance for 60 NNI or more thus requires extrapolation from the ANIS data. Because of the confidence in the correlation of disturbance with exposure, this extrapolation is not excessive. In any case, since all areas greater than 55 NNI are associated with 'high' annoyance [9.16], the greater plight of those exposed to 60 NNI and more is not understated.

2.3.4 *Variations within survey areas*

One consultee (38) commented that it would have been interesting to know the variation in annoyance responses between individuals within some common noise areas. He expected a large variation, and was disappointed that this point [4.11] was not considered with the "statistical aspects" [Appendix E]. The particular concern here was that the variation might be so large as to require larger samples to be drawn from common noise areas.

Since some of the response measures are binomial on the whole sample of people in the area (eg percentage "very much annoyed"), they do not define variations between individuals. For the remaining measures, the multiple regression analysis used to estimate the trade-offs between noise level and number [Appendix E]. For noise-response relationships for which statistical inferences were made, estimates of the variation are illustrated in the form of error bars on the graphs [Figures 9.2 to 9.10]. Reference 6 includes the raw data from which measures of variations in other measures may be estimated.

2.3.5 *Common noise areas demographically similar*

One consultee (38) said that "it would be important to know that each common noise area studied was representative in sociodemographic terms of other identical common noise areas". Here, 'identical' referred to noise level and number of events, and was taken to apply particularly to those common noise areas in which sampling was replicated. (Note that the replicated areas were the only "identical" areas.)

The sample design adopted gave all the adults aged 18 or over living at addresses within site boundaries an equal probability of selection (Ref 7). For the majority of areas, 120 were selected, but for five (the replicated areas) 240 were selected. The latter samples were divided into two on a random rather than a geographical basis and, within normal sampling fluctuations, these sub-samples were shown to be equivalent in social and demographic terms.

2.3.6 *Apparent changes in annoyance over time due to change in populations rather than change in attitudes*

It was suggested [8.2] that differences in response between the Wilson Committee's study (Ref 8) and ANIS may be partly due to changes in people's annoyance response over two decades. Two possibilities were mentioned [3.2.1], a change in the trade-off constant k between noise level and number and a change in the relationship between GAS and NNI. One consultee (38) felt that such changes would be more likely to arise from changes in the composition of the population caused by people moving into or out of these areas - although changes in "environmental awareness" might also contribute. In fact, although the magnitude of the 20-year shift in annoyance was not considered in ANIS, it was quite small (see section 3.5).

2.3.7 *"Rural"/developing airports*

Two consultees (24, 61) expressed concern that no survey samples had been drawn from the Stansted area. Because of its rural location and its anticipated development, it was suggested that people living near to Stansted Airport could be more sensitive to aircraft noise than residents near Heathrow.

Although it is an airport designated for noise control purposes, Stansted was not included in the study because it was determined that there was little opportunity for reasonable statistical sampling. With regard to the possible effects of low background noise in rural areas, these possibilities were acknowledged at the Stansted Public Inquiry (Ref 9), but subsequent research (Ref 5) has failed to show that background noise has any consistent effect on aircraft noise annoyance, one way or the other. Even if valid Stansted samples could have been drawn, it is unlikely that their inclusion in ANIS would have shed any further light on the question.

The effects of rapid airport growth upon noise disturbance have not been studied in the past; it may be that the situation at Stansted will provide an opportunity for gaining knowledge in the future although any such "longitudinal" study would have to be carried out over a period of several years. In the meantime the only clue on this question obtainable from ANIS comes from the responses at Aberdeen. The study area there had been recently developed for housing, at a time when Aberdeen Airport traffic also had been growing faster than at other

UK airports. Although these factors might have been expected to affect the sensitivity of the population, the annoyance at Aberdeen was consistent with those of the other areas.

2.3.8 *Larger areas needed*

One consultee (44) considered the common noise areas, delineated to restrict the enclosed noise levels to a range of about 3dB, to be too small. He recollected that an earlier publication (believed to be Reference 10) showed that there was only 4dB difference between sites in Osterley and "mid-central Ealing" separated by more than the length of the common noise area actually used at Ealing. The consultee therefore felt the area could have been larger, and added that it should have been much more intensely surveyed.

In fact some common noise areas did encompass a noise level range of 4dB. The preferred range of 3dB was exceeded in cases where a sufficiently large sample could not otherwise be found [B2, B5]. As regards the necessary sample size itself, this was determined during trials work in 1980 [Appendix F].

2.3.9 *Treatment of atypical noise exposure*

Two consultees (27, 44) commented on the exclusion of the survey results from Cranford, the reason for which was that they were obtained immediately after a period of atypical noise exposure caused by exceptionally heavy use of the cross Runway 23 at Heathrow. This made it difficult to estimate exposure at Cranford accurately and also raised the possibility that the response was distorted [7.3]. One of the consultees (27) noted that if exceptional use were to be made of Runway 23 the noise exposure in Cranford would be completely unrepresentative of future conditions. The other finds the explanation "...as specious as the reason given for the destruction of the Ealing area records a mere five and a half years after the completion of a major survey". This is believed to refer to the sleep disturbance study of 1979 (Ref 11). The original questionnaires for that study were in fact destroyed to preserve the anonymity of respondents; this was a condition of their participation. However, the statistical results have not been destroyed - they are recorded in Ref 11 and its supporting references.

2.3.10 *Selection of respondents*

One consultee said that when sampling, a house should be "selected by number from the electoral register and not the occupant by name. We thus eliminate failure to contact at the much lesser risk (in our opinion) of questioning some people who have only recently moved into an area".

In fact the sampling procedure used [5.17] first identifies a particular address; then an eligible resident is selected randomly regardless of whether he or she is on the electoral register. There is thus no failure to contact should the original elector have moved since the compilation of the register. The only people not questioned were those who had been at an address less than three months. The same consultee felt it would have been useful to ascertain why an individual moved into a relatively noisy area. While this might have been of interest, the answer would not really be germane to the specific question of evaluating annoyance indices, where the need is to know the reactions of people to the aircraft noise they receive.

2.4 Annoyance Measures

2.4.1 *Use of Guttman Scales*

A specific Guttman Annoyance Scale (GAS) was one of the main measures of disturbance in the ANIS. Apart from its suitability on statistical grounds, its inclusion ensured comparability with previous work. One consultee (38) was pleased to see that the original scale had been extended to include questions on disturbance of concentration and relaxation, and that GAS correlated well with other measures, particularly "covert" measures (such as "NSEAL2", the percentage at least a little annoyed in general [8.9]). Another (42) says "it is gratifying from a practical point of view that the simplest ways of scoring annoyance (such as degree of acceptability or "percent highly annoyed") are as good as the complex multi-item question and Guttman scales". There is here an implied rejection of the need to use GAS. One consultee (59) goes further and says that an earlier criticism (Ref 12), principally that the averaging of GAS scores (in essence an averaging of opinion) is fallacious, still stands. In fact this criticism was rebutted in Reference 13 where the pre-requisites for GAS construction were discussed [see also Appendix D]. Finally, one consultee (45) was "uneasy" about the use of GAS, "particularly in relation to assessing disturbance and reaction to general aviation and the smaller airfield". But ANIS was required to reflect the nature of disturbance around larger air transport airports such as Heathrow, Gatwick, Luton and Stansted [4.2]; the applicability of annoyance scales to general aviation was the subject of separate research (Ref 14).

2.4.2 *Threshold of annoyance*

It was claimed (LSS,38) that the suggestion in ANIS that 55dB(A) Leq(24h) could be used to indicate the onset of community disturbance is not justified, particularly because some people are significantly annoyed at lower levels.

The question of a "threshold" of annoyance has always been an important practical consideration. Unfortunately there does not appear to be a clear dividing line either between no annoyance and low annoyance or between any other discrete levels of reaction. Researchers have analysed and reanalysed data from many sources (see for example Refs 15, 16); all of these studies indicate that the percentage of people expressing a given level of reaction grows steadily with noise exposure. However a common feature of the data is that below a certain level, typically around 55dB(A) Leq, the fraction annoyed tends to stabilise - at around 5 to 10 percent of the population. It is for this reason that this level has been suggested, for example by the World Health Organisation (Ref 17), as a desirable noise limit for suburban areas.

Evidence from ANIS to support this logic may be seen in Figures 1 to 5. Figure 1 shows the percentage of respondents in each survey area who reported that they were "very much bothered or annoyed by aircraft noise". As is usually found in social surveys, there is considerable variation from area to area and it is therefore helpful to aggregate data into convenient noise bands as shown in Figure 2 (the number of respondents in each band is indicated).

Such measurements of reported annoyance are useful for testing noise indices and for observing the general growth of public reaction with increasing noise level. By themselves, however, they do not really measure the absolute impact of noise; respondents naturally express dissatisfaction with various aspects of their living conditions if invited to do so, and it is important to evaluate their responses with this in mind.

The initial questions of the survey were aimed at ranking noise as an environmental factor and Figures 3 to 5 summarise the responses. The specific questions were:

Figure 3: "What are some of the things you don't like about living around here?"

Figure 4: "If you could change just one thing about living round here, what would you choose?"

Figure 5: "Have you ever felt like moving away from this area? (and if so) Why did you feel like moving?"

Apart from such matters as personal satisfaction with particular homes and convenience to work which were mentioned often, the most frequent responses to these questions may be grouped under five headings:

- Public services (or lack of)
- Amenities (or lack of)
- People (type of neighbours etc)

- Slummy or dirty conditions
- Road traffic

Figures 3 to 5 show the percentages of respondents in each noise band who mentioned these matters by comparison with those who mentioned aircraft noise. All three diagrams strongly suggest that aircraft noise changes from a minor problem below about 55dB(A) Leq(24hr) to a significant one above about 60dB(A).

Figures 2 to 5 provide clear support for recognising a level above about 55dB(A) as a threshold of aircraft noise impact. At levels of 55dB(A) and below aircraft noise is mentioned by survey respondents less often than five other reasons for disliking the area, for wanting to move or as a local living condition they would like to change.

Analysis to support this reasoning may be found in the ANIS report. During multiple linear regression analysis of some of the noise-response relationships, it was found that a response function with a step at around 57dB(A) provided a good fit to the data [8.17] although the data could equally well have been fitted by variants of sigmoid curves (see for example Figure 15 of Reference 18) [8.27, 8.43]. It was conjectured [9.13] that a rapid increase in disturbance over a short Leq range might be the result of aircraft noise becoming noticeable above traffic noise at this level. An alternative explanation was suggested by one consultee - that it may be "only when aircraft noise reaches this level does it first begin to interfere with conversation indoors, one of the major reported disturbances in the Guttman Scale questions".

2.4.3 *Leq for high disturbance*

Although they proposed no alternatives, some consultees (12, 24, 33, 34, 45, LSS) rejected the suggestion that 70dB(A) Leq could be regarded as "high disturbance".

It was noted in the ANIS Report [9.13 et seq] that identification of a particular noise exposure level with a qualitative description is a matter of convention - a reasonable level, but not one reflecting an intrinsic quality. The value of 70dB(A) Leq(24hr) corresponds approximately to 55NNI, conventionally associated with "high" annoyance. However, the response data do not exhibit any features at higher noise exposure analogous to those which allow 57dB(A) to be identified as an annoyance threshold; figures other than 70dB(A) could be chosen as the high annoyance threshold [9.16] although this would be a departure from previous practice.

2.4.4 *Effects on other parts of the body*

One consultee (46), referring to the NNI, stated that "the index is deficient in two important ways:

1. It measures the response of only one human organ - the ear.

2. For convenience of measurement it presents incomplete and transformed data on the pressure fluctuations."

This submission goes on to suggest how sounds of different frequencies affect the cardiovascular system and to imply that physiological measurements on at least 2000 people would be necessary to accomplish the aims of the ANIS. Whilst physiological effects may indeed arise, the research literature suggests that it is likely that these would be induced indirectly via psychological reactions to auditory stimuli (eg Ref 19). Reported disturbance is a widely accepted indicator of the effects of aircraft noise exposure: no logical or philosophical case was made that this is not so in the ANIS.

2.4.5 *Use of double glazing*

One consultee (24) comments that around Stansted "the responses to aircraft noise will only be similar to those in the study if similar percentages of houses with double glazing occurred around Stansted".

In fact the effect of double-glazing (sound proofing) was examined as a "confounding factor" in the multiple regression analyses. In none of the analyses did the incorporation of this variable lead to a significantly higher correlation with the disturbance data - the only confounding factor which did so was airport related employment. The reasons why double glazing had such a little effect are not clear - it may be that respondents with double-glazing are more concerned about noise than the population as a whole, it may be because the social surveys were made in the summer when people both spend more time out of doors and more frequently have their windows open when indoors, or it may be due to a general antipathy to the noise insulation treatments themselves.

2.4.6 *Effect of background noise*

Some consultees (24, 27, 45) believe that background noise has an effect on the disturbance by aircraft noise. This is discussed in sections 2.3.7 and 2.7.5.

2.4.7 *Acceptability*

One consultee (34) regarded the question on acceptability (Q17, 18 or 19 depending on the version of the questionnaire) as unsatisfactory on the grounds that people who do not find the noise acceptable "must logically move away". This criticism does not allow for people who might wish to move away but cannot do so for family, employment or other reasons. Over the whole population sampled some 40% of respondents said they wished to move with 10% giving aircraft noise as the main reason. It is not inconsistent for some of the 27% who find aircraft noise unacceptable to give another reason for wanting to move. Another consultee (38) welcomed inclusion of this question.

2.5 Time of Day/Day of Week Effects

2.5.1 *Weightings for evening, night*

There is a common belief (2, 5, 14, 15, 21, 22, 23, 24, 27, 31, 32, 35, 36, 37, 40, 42, 45, 49, 54, 57, 59, 60, 61, LSS) that noise is more disturbing during the evening and night than during the day. Statistical evidence from ANIS yielded no support for the inclusion of a night weighting in a noise exposure index, and indicated that an appropriate evening weighting would be less than 3dB. These conclusions were generally criticised as being "counterintuitive".

The conclusions were based, in part, on the following distribution of daytime and evening annoyance responses of subjects living in eight survey areas where the difference between day and evening Leq values was small [Table 8.2]:

% ANNOYED:	**DAY**	**EVENING**			**DIFFERENCE**
	(a)	IN during the day (b)	OUT during the day (c)	TOTAL (d)	(d-a)
Very much	19.9	21.1	20.3	20.7	0.8
Moderately	26.8	21.8	31.7	26.4	-0.4
A Little	23.9	27.1	25.6	26.4	2.5
Not at all	29.4	30.1	22.5	26.6	-2.8
Sample size	272	266	227	493	

The fact that the differences between the evening and day percentages (d-a) are not statistically significant was taken in the ANIS analysis as an indication that the aircraft noise index required no evening weighting. But also shown in the above table is a division of the evening data into two groups; (b) from those respondents who were **in** during the day and (c) those who were **out**. LSS suggested that the 10% difference between the "moderately annoyed" percentages for the **in** and **out** groups pointed to the need for an evening weighting perhaps as great as 20dB. However, this is based upon a misinterpretation of the results. As the table shows, the difference between day and (total) evening annoyance is not 10% but 0.4%; the larger figure merely reflects the different incidences of annoyance in the groups who are either **in** or **out** during the day.

It was also implied by LSS that the comparison of day, evening and night responses is somehow invalidated because Aircraft Noise Annoyance Scale (ANAS) questions only were asked for each period, rather than the more extensive Guttman Annoyance Score (GAS) questions. It is possible that some variation would arise from use of the different scales - but as the various measures of disturbance were well correlated with each other, it seems unlikely that the variation would have been large enough to change the conclusion.

Use of a 10dB night weighting in the US (eg in L_{dn}) is adduced as indicating that convincing numerical evidence for it exists. This is not so: Reference 20 traces its history through the adoption of a negative daytime weighting of 5dB (ie the need to reduce the importance of daytime levels in the Index) through modifications (without explanation) to the Composite Noise Rating (CNR) procedure, involving weightings of -5, 0 and + 5dB respectively for day, evening and night periods. Finally, the present form with day and night weightings of 0 and 10dB respectively emerged, and this was retained unchanged in the Noise Exposure Forecast (NEF) procedure. Eventually the retention of the 10dB night weighting in L_{dn} was supported by analysis of the standard deviations of data on 55 community reaction cases. Reference 20 comments that "This is one of the few fragments of numerical support for the 10dB penalty, but it should be noted that according to a standard F-test, the difference between the above two standard deviations is not significant at the 5% level".

Considerable variations in the estimates of evening and night time weightings have been found by Fields (Ref 21) from a detailed multiple regression analysis of the major studies into this topic. Fields explains that these estimates of the weightings from multiple regression are unreliable because day, evening and night noise environments are always highly correlated with each other. It is mainly because of this severe practical difficulty that the issue remains one in which common sense and intuitive feelings have not yet been substantiated as fact.

There is certainly a correlation between day and evening exposures in the ANIS areas. A point made by LSS that the aircraft noise index would need recalibrating if there were a marked change in the diurnal pattern is logically valid: but it is not possible to determine the size of any such effect before such a change.

In the opinion of the authors of the ANIS report, it is probably true that the nature of disturbance in the evening resembles that during the day, while that at night is different. The majority of respondents stated that they were not annoyed at night. They may well have suffered disturbed sleep but this was a subject addressed by the sleep disturbance studies (Refs 11, 22) rather than by the ANIS.

.5.2 *Early morning neglected*

LSS suggested that noise annoyance might increase early in the morning. Since the time classification day, evening, night was exhaustive, it can only be presumed that early morning disturbances were included either with night-time responses (for those still in bed) or with daytime responses (for those who had risen).

.5.3 *Separate sets of contours for day, evening, night*

A reluctance to accept the study finding, that no substantial evening or night weightings could be substantiated, led to several suggestions (5, 10, 21, 22, 23, 31, 37, 54, 57, 59, 60, LSS) that noise exposure contours should be produced separately for day, evening and night, and also (in some cases) early morning - and furthermore that additional research is required. It seems possible that some of those concerned did not appreciate that any index arising from ANIS is not intended to account for the effects of sleep disturbance at night - this was examined separately in other studies (Refs 11, 22). Nevertheless, given the reduced night traffic, Leq(24hr) values are inevitably smaller than daytime ones (eg 12 or 16-hour values) so the suggested use of Leq(24hr) as a "daytime" index, although valid, could cause some confusion.

.5.4 *Negative night weighting*

One consultee (57) commented that if the noise from an aircraft (such as Concorde) is loud enough to disturb sleep, then a positive night-time weighting is required. However, if sleep is not significantly disturbed in the case of aircraft producing lower noise levels, then a negative weighting is appropriate. This would indeed accord with the findings of the ANIS that **annoyance** at night is lower.

.5.5 *No time of day weightings*

Some consultees (3, 11, 17, 18, 20) had no reservations about the proposal to use Leq(24hr) without time-of-day weightings.

.5.6 *Weekday-weekend difference not considered properly*

LSS was critical of the analysis of the difference between weekday and weekend responses. The ANIS report [7.26] was certainly not intended to appear 'dismissive' of the increase in annoyance over the weekend in saying that this was "more a function of people's habits and way of life than of noise exposure" - this comment was made to suggest a reason for the difference. It was reported that in all the areas, except Aberdeen, people were more annoyed at the weekend. In most areas, exposure was very similar on weekdays and weekends, but at Aberdeen Leq(24hr) was 1.5dB less at the weekend. An interesting feature of the responses in general is that they were not polarized into "more" and "less" bothered at the weekend - overall, 50% regarded the two exposures as equally bothersome or didn't know which was more bothersome, although respondents who were at home both on weekdays and weekend days might be expected to reply in this way.

The questions for the aircraft noise annoyance scale were not asked separately for weekdays and weekends. However, a tentative estimate of the shift on this scale can be made as follows. The net percentage of people more annoyed at weekends in all areas is 22.2% although there is considerable variation from area to area. (It is worth noting that overall disturbance as indicated by the proportion "very much annoyed" in general is quite strongly correlated ($r = 0.70$) with the net percentage more bothered at weekends ie the "weekend bother" appears to be expressed in the general disturbance.) The simplest assumptions which can be made are that these increases in disturbance are spread over all the categories of annoyance, and that any individual's shift is by one category except for those "very much annoyed" who remain in the same category. On this basis the increase in the proportion very much annoyed would come from the proportion moderately annoyed, which averages 27.3% over all the areas surveyed (see Ref 6). The increase in the proportion very much annoyed is thus 22.2% of 27.3%, ie 6%. If the change with exposure of the proportion of people generally saying they are "very much annoyed" (as discussed for day-evening differences) can be assumed to apply in this situation, then 6% would correspond to a shift of about 2.5 dB. In other words, a particular weekend exposure annoys to the same extent as a weekday exposure which is some 2.5 dB higher. All the exposure periods examined in ANIS (1 week, 1 month, 3 month) contained weekdays and weekend days in their natural proportions, ie 5:2. If a weekend weighting were adopted, this would require a re-calibration of the response in disturbance with noise exposure.

This simple, rather stylised, calculation should of course be regarded as an illustration only - no attempt has been made to examine the contribution of statistical fluctuations to the large variation from area to area. As an example of this variation, applying the analysis to Aberdeen would produce a net proportion of people more bothered at the weekend of 2.5%, whereas in fact a net 8.9% were less bothered.

2.6 **Policy Implications**

2.6.1 *Public presentation of change*

A number of consultees (11, 18, 22, 34, 55) recognized that the ANIS had involved a great deal of work and thus could only be described in a lengthy report. Nonetheless, they felt that the general public would not fully understand the analysis. Some were concerned that Leq contours might be of a radically different shape to the NNI contours they replaced, thereby causing inconsistencies between past and future planning decisions. Several suggested that simplified presentations and illustrations of the results would be helpful whilst some suggested specific material for inclusion in documents to explain any transition from NNI to Leq. The authors would like to thank these consultees for their proposals.

2.6.2 *Changes to planning circulars*

It was made explicit in the report that it was not the intention that ANIS should prescribe guidelines or recommendations for government policy as regards airport planning, development criteria or possible compensatory schemes [9.1(ii)]. However, it was suggested (28, 36, 47, 50, 61, LSS) that a review of DoE Circular 10/73 "Planning and Noise" (Ref 23) was long overdue (both for aircraft and for other noise sources). Since the Circular was issued, but before the ANIS, new studies of disturbance by aircraft noise, including general aviation and helicopters, had been concluded (Refs 22, 24, 25). ANIS was criticized for failing to make specific recommendations for changes to the circular.

2.6.3 *Comparison with Industrial and EEC standards*

Two consultees (5, 54) said that although some comparisons were made with aircraft noise indices in other countries [3.11], no attempt was made to assess whether standards used by Local Authorities to measure industrial noise could be used. Although again this lay outside DORA's remit for ANIS, two points may be noted:

(i) British Standard BS 4142 (Ref 26) deals with noise external to industrial premises. Although BS 4142 suggested that it might eventually find application to noise other than from "permanent installations", including aircraft, Amendment Slip No 1 (1975) specifically restricted the application to fixed noise sources.

(ii) The Department of Employment "Code of Practice for Reducing the Exposure of Employed Persons to Noise" (Ref 27) defines an upper limit to noise in workplaces as 90dB(A) Leq(8hr) with overriding limits of 135dB(A) for peaks and 150dB(A) for impulses. It is unlikely that any of these levels would be caused by aircraft other than at places actually on an airfield: they are therefore not within the range of noise exposure studied in the ANIS.

2.6.4 *Justification for unlimited night movements*

Since it would be possible to shift aircraft movements from the day to the night without altering Leq(24hr), the proposals were seen as a possible justification for an increase in night time movements (14, 16). A connection was made between this and DORA's night disturbance study (Ref 22) from which it was concluded that an increase of possibly 25% in night movements by quieter aircraft might not increase sleep disturbance. This did not mention the proviso in Ref 22 that any increase in numbers had to be contained in such a way that night-time Leq does not increase. This issue was the subject of a separate consultation in 1987 which led to the present night noise restrictions which came into effect in April 1988: the associated containment of night exposure prevents diurnal patterns from becoming greatly different from those experienced during ANIS.

2.7 **Details Of Noise Calculations**

2.7.1 *Basis of average traffic*

The findings of the ANIS, that community response is more highly correlated with the noise climate immediately prior to the survey ("one week Leq") than with those averaged over the previous month or three months was probably not surprising. Several submissions (35, 43, 45, 47, 60) appeared to conclude that airport noise contours should be produced for weekly intervals. This is not really a practical proposition and the benefits of doing so are not clear. In fact the ANIS report made no recommendation regarding the averaging period for a practical noise exposure index [9.4-footnote]. Some countries use yearly averages; in the UK the summer months (mid-June to mid-September) have been used. These cover not only the period of greatest traffic, but also the period when people are most vulnerable to noise, either out of doors or indoors with the windows open. The social surveys were made during these summer conditions; disturbance reactions during winter are likely to be lower. If winter months were included in the averaging process, higher noise levels might be more appropriate to particular levels of disturbance.

2.7.2 *Noise contour method*

ANIS was not concerned with the technicalities of producing contours (these are described in Ref 28); the noise data in the report were obtained entirely by measurement. The problems of producing contours are not germane to the study of the dependence of disturbance on noise indices.

Several replies (16, 27, 29, 32, 35, 45, 60, LSS) comment that Leq should be directly measurable with an integrating sound level meter. Some note that, as defined in ANIS, Leq relates only to that component of the noise climate which is directly attributable to aircraft noise and that this may differ from a simple, continuous measurement of 'total' Leq.

This distinction is important. There was no intention to complicate the issue; provided aircraft dominate the noise climate, a simple continuous Leq reading will correctly measure the aircraft noise to a high degree of accuracy. If however other sources are significant, ie they make an appreciable contribution to the noise climate, the simple reading would exceed the aircraft noise level. Except at locations where aircraft noise is itself insignificant, correct levels can usually be established by discontinuing the integration (measurement) between aircraft noise events, normally by employing a trigger threshold. The question of mathematical modelling of aircraft noise Leq is considered in section 3.2.

2.7.3 *Noise contour intervals*

It was observed (47) that a doubling of traffic increases Leq contour levels by 3dB, and NNI contours by 4.5 NNI. As the latter is close to the interval of 5 NNI at which contours are generally produced, it was suggested that Leq contours ought to be plotted at 3dB intervals.

2.7.4 *Turning flight*

Some concern (5, 54) was expressed about the effect of aircraft turning in flight. Very few of the study areas were likely to be affected by the noise of aircraft performing turns - most of the common noise areas were deliberately chosen to be close to straight or gently curving flight tracks in order to minimise the noise exposure variation throughout the area. Large heading changes can alter SEL values of individual flights by 2-3dB - an increase inside the turn and a reduction outside. At most locations of interest (close to nominal routes) the effect of turns upon average SELs (and thus on Leq) tends to be reduced because the lateral dispersion of flight tracks means that a range of values (both positive and negative) are experienced. At greater distances from the route, where flight tracks largely pass to one side, average SEL values will be increased inside turns and reduced outside turns.

2.7.5 *Measurement of background noise*

The primary purpose of ANIS was to examine relationships between aircraft noise and disturbance. Some submissions (24, 27, 45) asserted that background noise had an effect on people's responses, and that it required combining with the aircraft noise or that the difference between aircraft noise and background noise should be given. Although ANIS did not investigate background noise effects, these were investigated concurrently (Ref 29), and subsequently at Glasgow Airport (Ref 5); no consistent effect on the disturbance by aircraft noise was found.

2.7.6 *Ground noise*

A related suggestion (39, 16, 24, 27, 40) was that airport ground noise, ie noise generated by aircraft on the ground but not taking-off or landing, should be included in noise assessments. It is quite natural for consultees to raise this question, though in practice there are few locations around airports which are not dominated by noise from airborne aircraft during the day. However, since the ground noise question is discrete from consideration as to whether the contours should be defined in NNI or Leq, ANIS did not include areas affected by ground noise and generated no evidence on this matter.

2.7.7 *No evening measurements*

One submission (27) criticized ANIS for "having no evening and night measurements". But this missed the point [6.8] that this restriction only applied to four areas (Stanwell I - IV), where only "attended" measurements were made. This was considered a reasonable procedure because noise levels of aircraft do not change appreciably with time of day. In the remaining areas, unattended measurements were made throughout the 24 hours.

2.7.8 *Cut-off in noise measurements*

There was some criticism (24, LSS) of the use of a "cut-off" in the measurements. This was necessary because many areas had background noise levels around 55dB(A) so the "10dB down" durations (and hence L_{AX})of events which peaked below about 67dB(A) could not be found. However, omission of the lower values had a very small effect on the estimates of Leq values at the sites studied [6.7 et seq] and thus had minimal effect on the statistical correlations between disturbance and noise exposure.

2.7.9 *Correlation between NNI and Leq*

That the noise climates in ANIS are based on measurements needs to be stressed: the measurements automatically take full account of the effects of flight path geometry upon L_{AX} (those which arise from distance, aircraft speed and turning flight). Even so, some consultees (12, LSS) felt that the correlation between NNI (based on L_{Amax}) and Leq (based on L_{AX}) was so high that such effects might not have been fully represented. For noise measurements gathered over a wide range of positions relative to the flight tracks, the effects of these factors might be expected to result in a lower correlation between L_{AX} and L_{Amax}. However, as explained in paragraph 2.7.4, the study areas were chosen where possible to avoid turns and variable aircraft tracks so that such effects were relatively small.

2.8 **Shortcomings of Leq as an Index**

2.8.1 Failure to account for difference between constant and peaky noises

Some consultees (5, 22, 27, 35, 54) said that Leq either conceals or fails to account for individual events with high peak noise levels which occur from time to time. Of course peak noises generally contribute strongly to Leq values; the consultees presumably meant that there is no explicit criterion involving the highest noise levels heard.

At any location there is a distribution of aircraft noise levels. Over a period of time, this distribution is fairly stable, and it will contain a range of noise levels, some of which are high relative to the average. The logarithmic or energy average peak noise level in each area - which is mainly determined by the highest peak noise levels heard - was specifically included in the multiple regression analysis. Over the range of noise exposures studied no evidence was found that events with high peak levels contributed more to response than is implicit in the construction of Leq.

In noting that NNI includes no allowance for the duration of noise events [9.9(iv)], one consultee said "subjectively, annoyance is more related to maximum level than duration and this effect will be less significant in terms of Leq". This may be taken to mean that, as duration makes at least some contribution to Leq, peak levels may have less influence upon Leq than NNI. Typically, however, the duration components of the SELs which make up Leq do not do not vary nearly as much as the maximum level terms and thus the peak level contribution tends to remain very dominant.

Government policy is that aircraft noise levels on take-off should not exceed 110PNdB by day and 102PNdB by night at the fixed noise monitoring points strategically placed around Heathrow and Gatwick airports. One consultee, though incorrectly referring to these levels as 110dB(A) and 102dB(A) - the limits are actually equivalent to 97 and 89dB(A) - regards them as excruciatingly painful by day and virtually impossible to sleep through by night. The latter might be true for some people (Ref 22), but it is very unlikely that pain (as opposed to considerable disturbance) is experienced in populated areas. The limits of 110PNdB and 102PNdB were established many years ago. It was recommended (paras 645, 646 of Ref 8) that the limits should be progressively lowered. That no action has been taken to do this for 25 years is clearly a source of concern to consultees, even though there is a government commitment to review the limits (Ref 30).

2.8.2 *Noise indices merely measures change*

Two consultees (5, 54) viewed an aircraft noise index in much the same way as the Retail Price Index (RPI). The latter changes with time, generally increasing, so it is supposed that "any index is only designed to indicate differences between one time and another....... the retail price index shows the rise in prices from one year to the next, but says nothing about whether the general level of prices is too high or too low". This analogy is not a particularly appropriate one. It misses the point that an important part of the ANIS was the **calibration** of the noise index against levels of community disturbance. The ANIS also considered the acceptability of aircraft noise (along with many other indications of people's reaction) [eg Figure 7.2]. Not surprisingly, a smaller percentage of respondents find aircraft noise 'not acceptable' at lower exposure than at higher exposure.

3. PRACTICAL IMPLEMENTATION OF AN Leq INDEX

3.1 Summary of Consultation: Requirements

Comment and criticism of the Leq proposals and the ANIS, many of them very detailed, ranged over a wide range of concerns. Unfortunately, though for the most part these concerns are quite understandable and logical, it is sometimes difficult to provide specific responses because these are not readily obtainable from a practical social survey/noise measurement study. Doubtlessly for similar reasons, few consultees offered alternatives to the ANIS methodology. The main goal of the study was to resolve the superficially simple "noise and number" question; this dictated the experimental design. Yet despite its comprehensive scope, the study was only just able, statistically, to provide an answer. Many other detailed questions, such as those concerning time of day effects, background noise, demographic factors, differences between airports etc, are likely to remain open for the forseeable future; the necessary studies would probably be prohibitively complex. The reason is that the effects being sought are "weak", ie they are small by comparison with the strong masking effect of human variability. It is a fact that social survey respondents from any particular study area express a wide range of views even though they all hear more or less the same amount of aircraft noise.

Support for the adoption of Leq is widespread although most consultees expressed reservations about the details of the proposals. The main area of concern is the time-of-day/week/year factor: the use of a 24-hour index with no special consideration of evening and night-time noise weightings is not popular. Suggested alternatives included (i) a 24-hour index with weightings for evening and night and (ii) entirely separate treatment of day, evening and night periods. There were also suggestions that, because ANIS noise-annoyance correlations were higher for 1-week Leq's, the latter should somehow be used in preference to 3-month averages and that consideration should be given to additional weightings for early morning and weekend when noise sensitivities may be heightened.

The difficulty with the time factor is that, despite the "common sense" of such approaches, neither ANIS nor any other study has yielded reliable values for possible weightings. Some consultees indeed felt that more conclusions had already been drawn than the data merited; a decision on temporal weightings would inevitably involve some largely arbitrary choices and this would justify such criticism. Proper weightings should really only be established by extremely extensive parametric studies of aircraft noise annoyance in a range of situations where the day/evening/night mixes of aircraft traffic vary substantially. At present it is unlikely that these would be possible, even with unlimited resources (Ref 31). The ANIS itself provides a clear illustration of the difficulty of unravelling the effects of just two variables - noise and number - and this problem is rather more straightforward than that of the time factor.

ANIS did not prove that the 24-hour index is optimal; rather it demonstrated that none of the time-weighted indices examined provides a statistically better predictor of general aircraft noise annoyance. However, in view of the concerns expressed about different effects of aircraft noise by day and by night, it seems prudent to distinguish between the two periods in the application of noise indices. Assessments of the relative impacts denoted by day and night noise contours could then readily be adjusted as and when new research information becomes available. The two DORA studies of the effects of aircraft noise upon sleep (Refs 11, 22) have shown that Leq for the period 2300 - 0700 hrs local time is a relevant measure for night noise and as it is already used for night noise policy assessment it is logical to complement this with one for a 16-hour 0700-2300 "day".

As to the effects of background noise and noise level cut-off, two factors are important. The first is that no consistent effect of background noise upon aircraft noise annoyance has been found. This is probably because in most of the studies undertaken, in situations where statistically valid conclusions can be drawn, aircraft noise tends to exceed the background by a margin which makes the background noise relatively insignificant. This is true at Heathrow as well as Stansted. That background noise becomes relevant when it starts to mask the aircraft noise cannot be disputed; however in such a case the aircraft noise is probably of minor concern to those affected anyway. The second is that a cut-off has to be introduced into Leq, both measured and "forecast", for the practical reason that background noise in most areas prevents accurate definition of the lower event levels from which aircraft Leq is composed. However this cut-off need not be fixed; lower values could be used in situations where non-aircraft noise is genuinely low. This question is discussed further in section 3.3.

The "averaging period" for any noise index is largely a matter of choice and is governed more by the uses to which the index is to be put than the measured noise-response correlations. ANIS showed measured annoyance to be most highly correlated with "previous week" Leq. But annoyance itself will vary from week to week; it would be impractical to follow this in any assessment method. The original reasons for adopting the summer season for averaging NNI still remain valid and there seems no good reason to change established DTp practice. At the same time an attractive feature of Leq is its inherent flexibility and there seem to be no reasons why this should preclude the use of different averaging periods for special applications.

The remainder of this section examines the practical questions surrounding the application of Leq as an aircraft noise index, particularly with regard to mathematical modelling, which DORA has been developing since the consultation at the DTp's request.

3.2 The Leq Model

The Noise and Number Index is conventionally defined as:

$$NNI = L_{PN} + 15 \log_{10} N - 80$$

where N is the number of events with maximum levels greater than or exceeding 80PNdB between 0700 and 1900 hours local time on an average summer day (between mid-June and mid-September) and L_{PN} is the (energy) average maximum perceived noise level of these N events.

DORA's computer model calculates NNI at any point on the ground by summing contributions from all relevant aircraft traffic on nearby flight paths, making the necessary allowance for the scatter of actual tracks about the mean arrival and departure routes. The maximum noise level generated by any particular aircraft flying along any particular route is determined by its minimum slant distance using simple sound attenuation rules based on experimental data available at the time the model was first developed.

One of the main applications of the NNI model has been the preparation of annual noise contours for the London Airports. A major foundation of the official NNI methodology, which distinguishes it from procedures used elsewhere, is that such computations are always based on actual measurements: the model has a firm empirical base. Each summer, hundreds of noise levels and flight tracks are recorded in the vicinity of the airports and added to the model's database.

A practical requirement for switching from NNI to Leq for aircraft noise exposure rating purposes is a suitable computer model to calculate Leq contours. Questions which arise include the following:

- A major difference being that Leq involves the duration of each aircraft noise event whereas NNI does not, how can the fact that duration depends upon the entire flight path, and not just the shortest distance between the aircraft and the listener, best be taken into account?

- A perceived advantage of Leq is that, unlike NNI, it can count quieter sounds which may be considered important in areas of low background noise. But computational practicalities require some threshold or "cut-off". What should this be?

- As its name indicates, NNI is viewed as an index of noise impact rather than a physical measure of noise energy like Leq (although Leq is also acceptable as an index). As such, it incorporates some nominal - and conservative - calculation procedures which have tended to be retained in unchanged form in order to maximise the comparability of noise contours from one year to the next. Methods for computing Leq can be expected to improve progressively from year to year and, in the interests of accuracy, it will be desirable to upgrade those used in the model.

At the outset, three computer modelling options were considered:

- Develop an entirely new model tailored to specific UK needs.

- Adopt a "standardised" procedure recommended by one of the international organisations (Refs 32-34).

- Modify the existing NNI software.

Of these, the first was considered too expensive in terms of both time and costs so that the choice was between the second and third. The second had obvious attractions, especially since the CAA had made substantial contributions to the deliberations behind the international recommendations. However, such an approach would require comprehensive tabulations of aircraft noise and performance data, including standardised aircraft flight profiles and noise-distance curves for different engine power settings - data which could not be obtained from NNI-type field measurements (they would have to be acquired from the aircraft and engine manufacturers). Such a change was considered a high risk departure from past UK modelling practice in that it would take too long to introduce and substantiate. Furthermore, since the purpose of the model is to estimate actual community noise exposures as accurately as possible, there is a preference for field measured data. In the event of an index change it was expected that the Department of Transport would wish to publish NNI contours alongside Leq ones during some suitable overlap period. This strengthened a general view that in order not only to minimise effort and risk, but also to ensure maximum comparability, the Leq model should retain the same basic structure and the same database as the NNI model, at least during its early life. Thus the third option was chosen.

Aircraft noise Leq can be described by the approximation

$$Leq = \overline{SEL} + 10 \log_{10} N - \text{constant}$$

where N is the total number of aircraft noise events, the constant depends upon the length of the measurement period and $\overline{SEL}$ is the log-average sound exposure level of the N events.

In the computer model SEL could be specified directly as a suitable function of minimum slant distance. But because SEL is also affected by changes of aircraft heading and engine power along the flight path, the result would have to be adjusted in some way when these occur. These difficulties have been avoided altogether by obtaining SEL from an effective time integration of L_A at the receiver point. This has been done by retaining the flight path structure of the NNI model, which approximates their actual geometry (including the dispersed tracks) by series of straight line segments, and summing the contributions from **all** significant segments of each path to obtain the SEL for each aircraft on that path.

Although this alternative approach requires rather more computer time, it has the important advantage that the segment SEL contributions are calculated via L_A values computed from the existing NNI database. The only additional input information required is the speed of the aircraft on each segment.

Further changes from the NNI model include the replacement of the simple ground attenuation function by the more elaborate "lateral attenuation" algorithm developed by the SAE (Ref 35) and the use of SAE recommended improvements to the way in which "start-of-roll" noise is modelled (behind aircraft at brake-release). These had been under consideration for some time as a potential improvement to the NNI model, being held back because of the comparability argument noted above; eventually it became logical to defer their introduction to the new Leq model.

3.3 Sound Level Thresholds

A practical requirement is a fixed sound level threshold or **cut-off** below which minor aircraft noise energy contributions can be neglected. Without one, the number of events "heard" is calculated to be everywhere equal to the number of all aircraft movements, clearly an unrealistic proposition.

By definition, the peak noise levels averaged in the NNI formula exclude values below 67dB(A) (equivalent to 80PNdB). A common criticism of NNI made by environmental groups is that the 67 dB(A) cut-off is too high, resulting in the exclusion of quieter, but still audible aircraft events. This concern has increased as aircraft have tended to become quieter generally. Since reasonably accurate estimation of SEL requires integration over at least the highest 10 dB of the event time-history, **full** retention of the event SELs for the sounds included in NNI requires the Leq cut-off to be below 57 dB(A). But this automatically adds in sound energy associated with those events, not included in NNI, which peak between 57 and 67dB(A). (The time-histories of these events are truncated less than 10dB below their peaks; the corresponding SELs thus underestimate the "full" values.) However, this is quite consistent with the concept of an audibility threshold. Still lower cut-offs cause N to increase further but the practical aim must be to match numbers actually heard as closely as possible. It is expected that for the majority of major airport applications a threshold of 55dB(A) will provide valid estimates of Leq, SEL and N. But any threshold can be specified in the Leq model and for special applications, for example in the case of lightly used aerodromes in areas of low background noise, the use of lower values could be considered.

3.4 Time Periods

The ANIS revealed no "better" predictor of annoyance than Leq(24hr). But the adoption of a 24-hour index would be rather a radical change from the present 12-hour one and in any event it would not recognise the somewhat different considerations applying to the evaluation of noise by day and by night. The two DORA studies of the effects of aircraft noise upon sleep (Refs 11, 22) have shown that Leq for the period 2300 - 0700 hrs (local) is a relevant measure of night noise and it is logical to complement this with a 16-hour day value. The great majority of all aircraft movements occur between the hours of 0700 and 2300 and, furthermore, as a predictor of annoyance, Leq(16hr) is statistically indistinguishable from Leq(24hr). The 8-hour night broadly covers the typical hours of sleep and encompasses that part of the night during which night restrictions on aircraft operations are imposed at the London airports. Contours of Leq(8hr) have already been used for evaluating the effectiveness of these restrictions. With regard to longer term averaging, for the present there appears to be no reason to change the NNI practice of computing noise exposures for the average summer day (taken at present as between mid-June and mid-September) for daytime and night-time values.

3.5 Comparable Points on the NNI and Leq Scales

As has already been made clear, the principal scientific support for the change of index comes from the ANIS report. This indicated a marked increase in some reported disturbance measures at around 57dB(A) Leq(24hr) (equivalent to about 58.5dB(A) Leq(16hr)). It did not reveal any other divisions between different bands of annoyance which might have provided definitive Leq boundaries, ie it did not suggest a new basis for aircraft noise contours.

In view of this, it seems desirable that the NNI-Leq conversion should, as far as possible, meet the following requirements:

- Published daytime contours should indicate the same degrees of noise impact, ie average annoyance levels, as the long-established 35, 45 and 55 NNI contours (irrespective of any intermediate values which might be included).
- The contours should have numerical values which are convenient and systematic, eg they should be integers at equal intervals which are related to key properties of the decimal and/or decibel scales. Steps of 3, 5, 6 or 10 dB would best meet this requirement (see also section 2.7.3).
- The number and spacing of Leq contours should not differ markedly from customary NNI practice and the "standard set" should include values used as special boundaries for noise abatement purposes, eg for land-use zoning or noise insulation grant schemes.
- The transition from NNI to Leq should be "smooth", ie at the moment of change, "equivalent" Leq and NNI contours should be reasonably matched in size and shape.

There is no unique relationship between Leq and NNI. Some typical relationships can be defined; perhaps the most familiar of these are those derived from the regression equations given in the ANIS report and tabulated below. These illustrate average physical relationships between NNI and Leq which were measured in 1982.

NNI	**Leq, dB(A)**	
	24hr	16hr
35	56	57.5
45	63	64.7
55	70	71.8

These relationships were derived by comparing different indices of noise exposure only; they take no account of the corresponding levels of public annoyance. This could be done in various ways, one of which is to make use of the "Guttman Annoyance Scale (GAS)" used in the 1961, 1967 and 1982 noise surveys. (Close agreement of the NNI-GAS relationships supported the finding that the 1961 conclusions were still valid in 1967.)

The history of NNI is described in Reference 1 which records that it was derived by the Wilson Committee from the 1961 Heathrow survey results. It goes on to note that "...the Government Social Survey suggested that in deriving the general level of community annoyance, the expression "very much" related to 60NNI, "moderate" related to 45NNI, "little" related to 32NNI..." and that "...it has since become general usage to describe 55, 45 and 35NNI respectively as denoting "high", "moderate" and "low" community annoyance". Levels of annoyance appropriate to particular NNI values may be quantified in terms of average GAS scores:

NNI	AVERAGE GAS	
	1961/7	1982
35	2.22	1.93
45	3.04	2.90
55	3.86	3.88

If it can be assumed that in all three studies (a) the Guttman scaling procedure rated annoyance consistently, (b) the noise variables were estimated accurately and (c) the survey samples were representative of the populations surrounding the airport(s), it may be concluded that by 1982 people had become slightly less susceptible to aircraft noise annoyance, at least at lower noise exposures. However, this apparent shift may be attributable to non-representative sampling or simply to the failings of NNI; it may not have arisen if the noise exposure had been measured on the Leq scale. Also, it is by no means certain that the above assumptions are wholly valid.

The 1982 ANIS relationships may be used to determine what NNI or Leq values correspond to (ie would "predict") the earlier GAS scores:

GAS	NNI(1982)	Leq(16hr), dB(A)
2.22	37.9	59.6
3.04	46.4	65.6
3.86	54.8	71.4

To achieve a "smooth" changeover from NNI to Leq, the Leq contours must be reasonably well matched to the 35, 45 and 55NNI contours at the time of transition. The 1988 equivalences at Heathrow and Gatwick which would best achieve this aim are, approximately:

NNI	Leq(16hr), dB(A)
35	57.0
45	63.5
55	70.0

Summarising, three transformation options are:

NNI	Leq(16hr), dB(A)		
	1- Best fit: 1982	2- "Traditional" Annoyance: 1982	3- Best fit: 1988
35	57.5	59.6	57
45	64.7	65.5	63.5
55	71.8	71.4	70

Option 1: This would be appropriate were the aim to illustrate the same degrees of noise impact as the 1982 NNI contours.

Option 2: This would adjust the contour areas to indicate the (different) degrees of annoyance appropriate to 35, 45 and 55 NNI in 1961/67.

Option 3: This would ensure continuity; ie the Leq contours would match existing NNI ones as closely as possible and thus represent the same degrees of annoyance, on average, as the 1988 NNI contours.

It must be stressed that this kind of analysis has to be largely a matter of judgement; there are statistical and methodological uncertainties and the numbers are indicative rather than definitive.

Obviously, none of these options meets all the requirements set out above. The Leq intervals for the three options are, approximately, 7, 6 and 6.5 dB and there must therefore be a preference for practical spacings of 6dB within the range 57 to 72 dB(A), ie 57/63/69 to 60/66/72. A set towards the upper end of this range would return aircraft noise impact assessment to its 1960s position but the contours would be substantially smaller than the present NNI ones. (The latter may have grown excessively due to the prolonged adherence to NNI.) A set at the bottom end of the range would ensure that the maximum number of people were enclosed by the contours. Currently at Heathrow and Gatwick the 57/63/69 set match at 35 NNI; 58/64/70 match at 55 NNI. This may be seen in Figures 6 and 7 which show 1988 Leq(16hr) contours at 6dB intervals for Heathrow, Gatwick and Stansted by comparison with the 35, 45 and 55 NNI contours. Figure 6 shows 57, 63 and 69 dB(A); Figure 7 shows 58, 64 and 70 dB(A). (These contours are approximate; the official "historical" ones differ in some small respects.)

Annual NNI contours for the designated airports have always been drawn at 5 NNI intervals from 35 to 60NNI. The corresponding Leq(16-hr) maps would be, for example, from 57 to 72dB(A) in steps of 3 dB(A).

4. CONCLUSIONS

A detailed analysis of the replies to the Department's consultation revealed no substantive technical or statistical arguments against the adoption of the conclusions of the ANIS Report. Indeed, over 80% of the replies expressed support for a change to Leq as the UK Aircraft Noise Index - a major conclusion of the ANIS. However, many of the replies expressed various reservations about particular aspects of the actual use of Leq: these points have been considered in the approach to implementing the Leq Index.

A particular concern was about the use of noise exposure averaged over 24 hours as an index of annoyance. In fact, Leq (16hr) for the 0700-2300 local time was subsequently examined and found to provide a statistically acceptable index.

An important feature of Leq is that it incorporates the effect of the duration of aircraft sounds. This feature has been incorporated in a computer model for generating Leq contours; the model relies heavily on the database used to generate NNI contours.

Many respondents had views about the particular Leq values indicated by the ANIS as suitable to describe the onset of annoyance and corresponding to high annoyance, bearing in mind the long established NNI values of 35 and 55. This report therefore examines a number of options for dealing with these comparable annoyance values.

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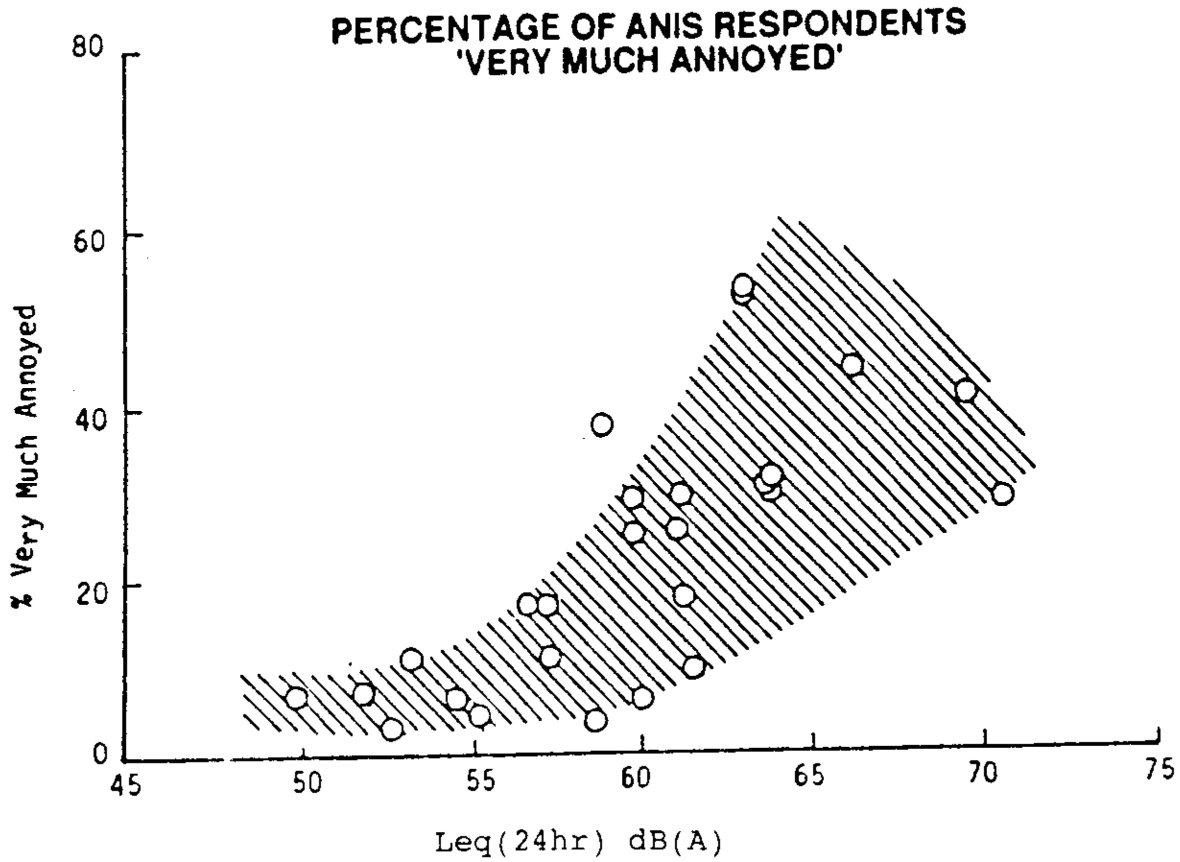


Figure 1

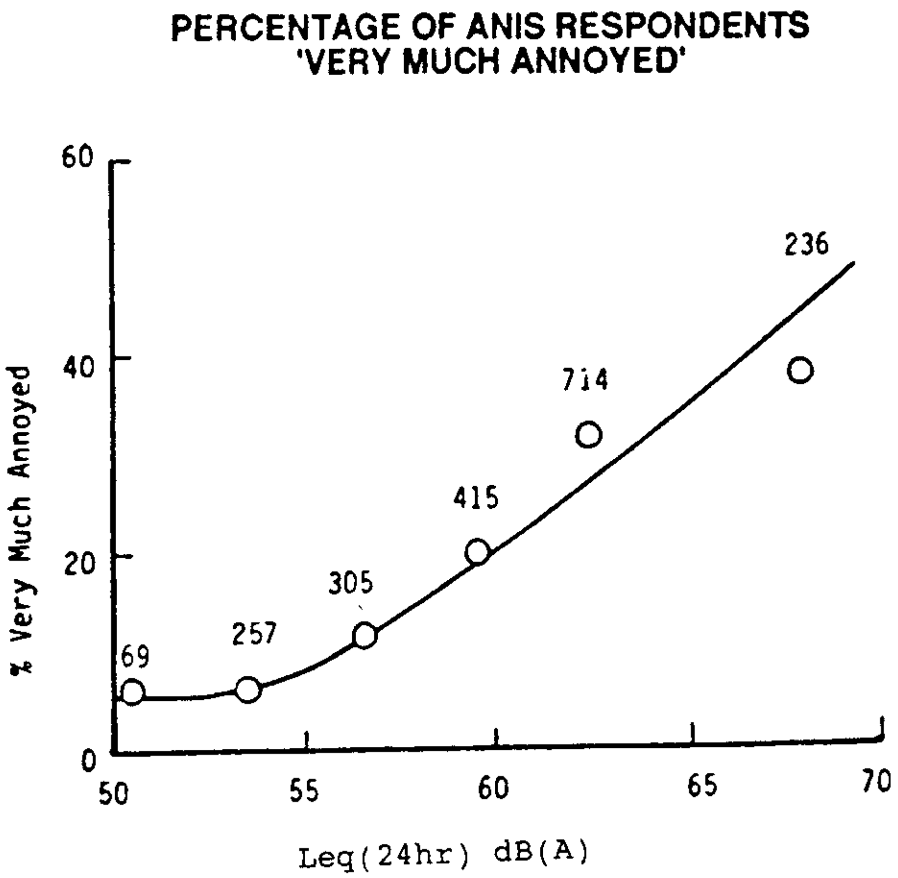


Figure 2

DISLIKES SPONTANEOUSLY MENTIONED BY ANIS RESPONDENTS

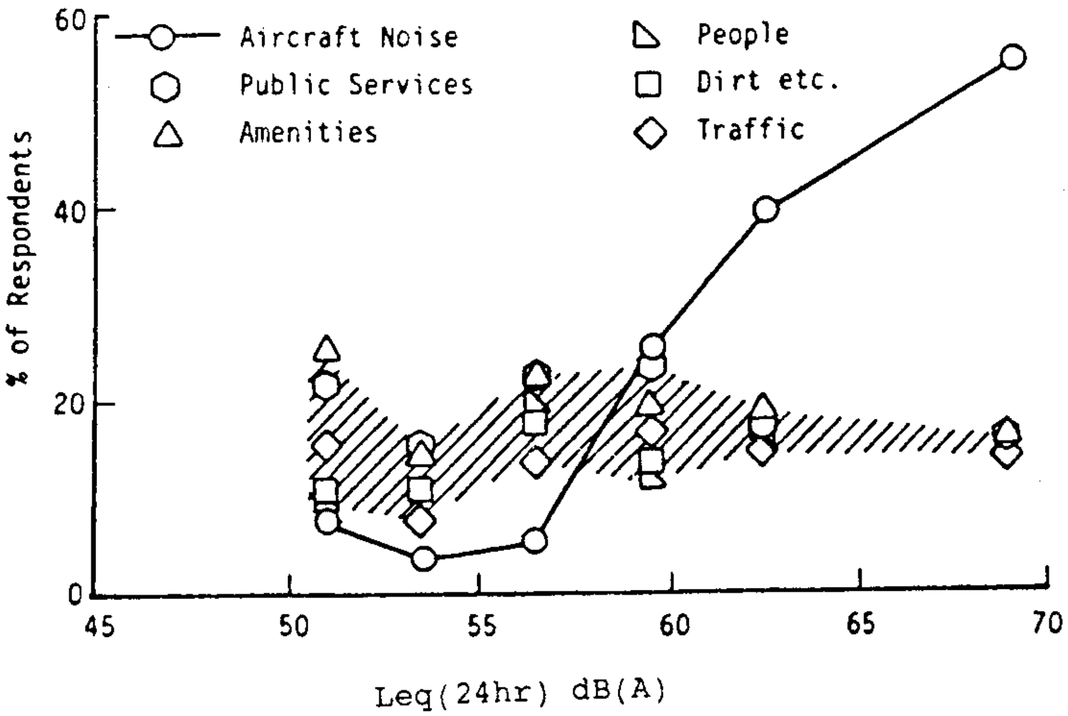


Figure 3

ONE THING ANIS RESPONDENTS WOULD LIKE TO CHANGE

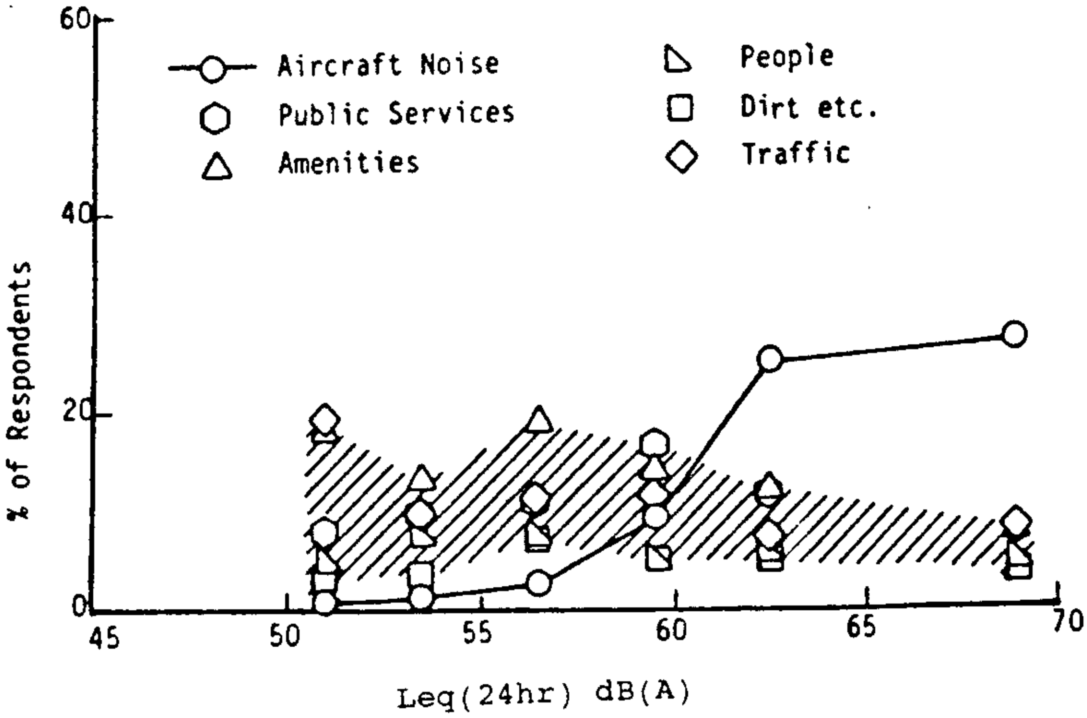


Figure 4

REASON FOR ANIS RESPONDENTS WANTING TO MOVE

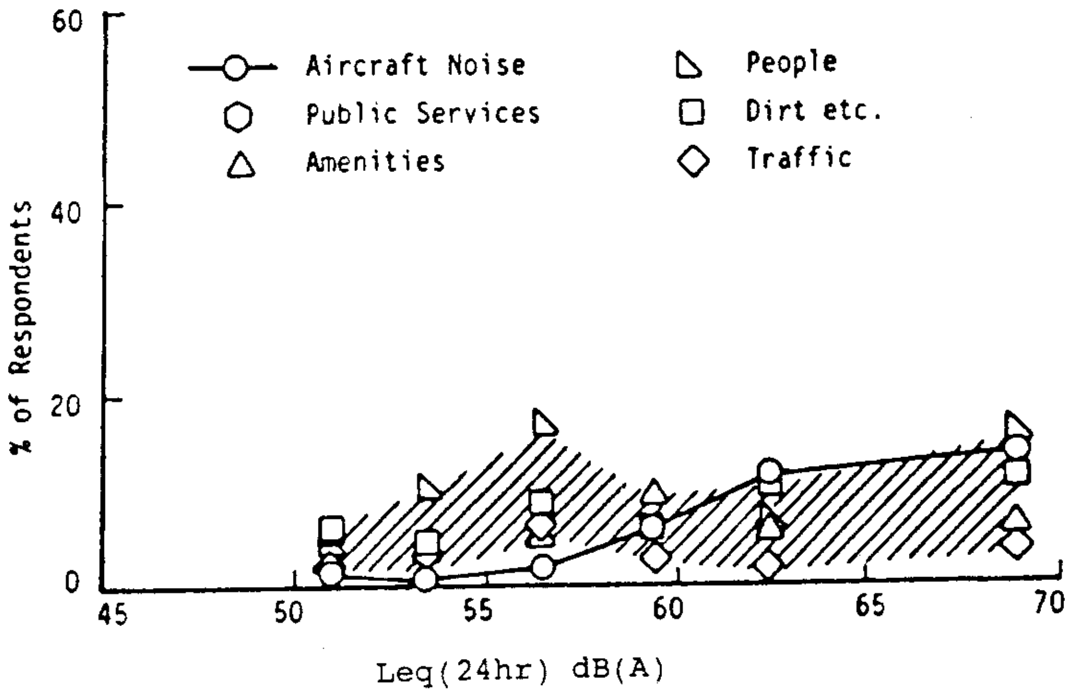
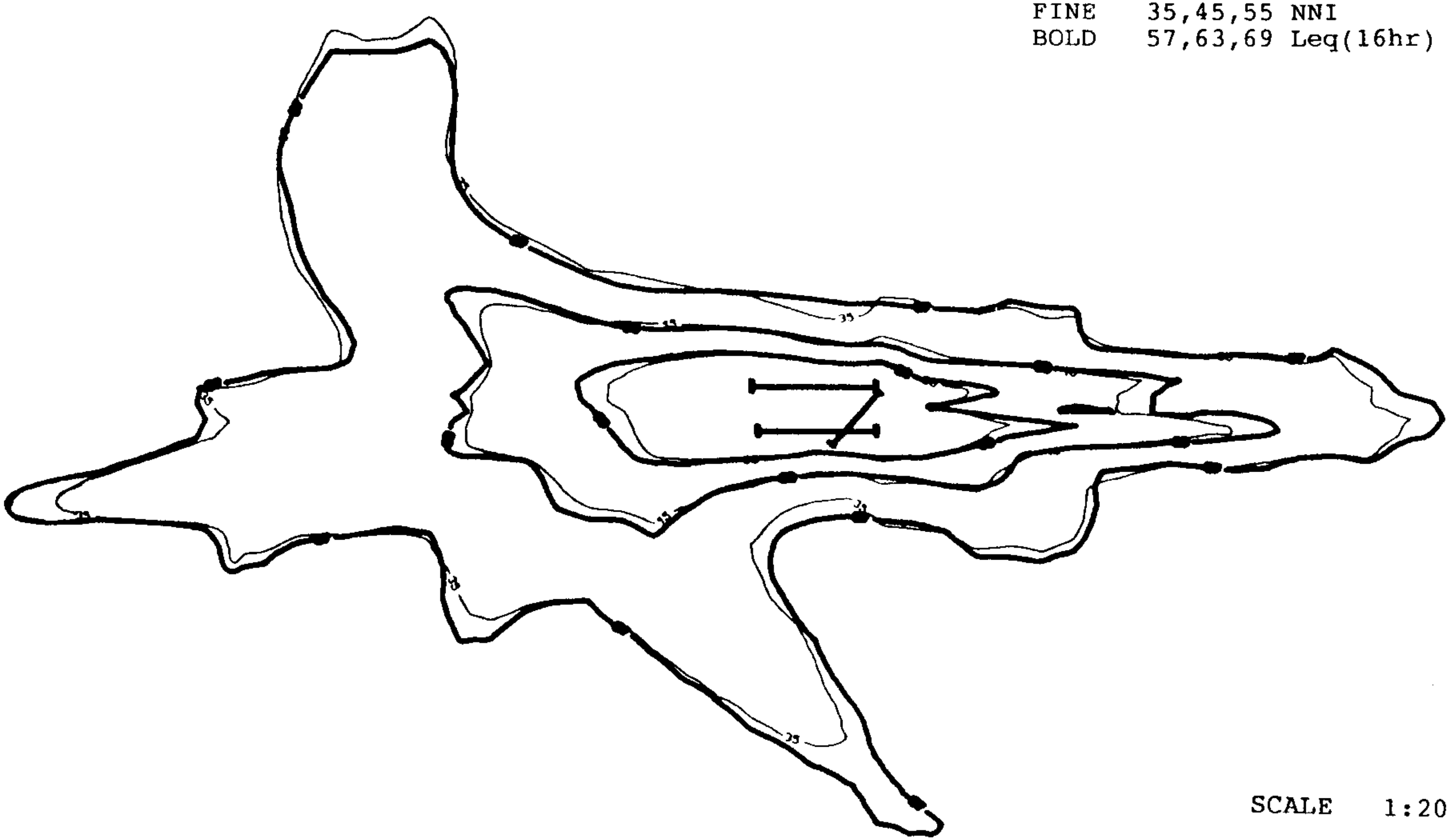


Figure 5

FIGURE 6(a) 1988 AIRCRAFT NOISE CONTOURS
HEATHROW

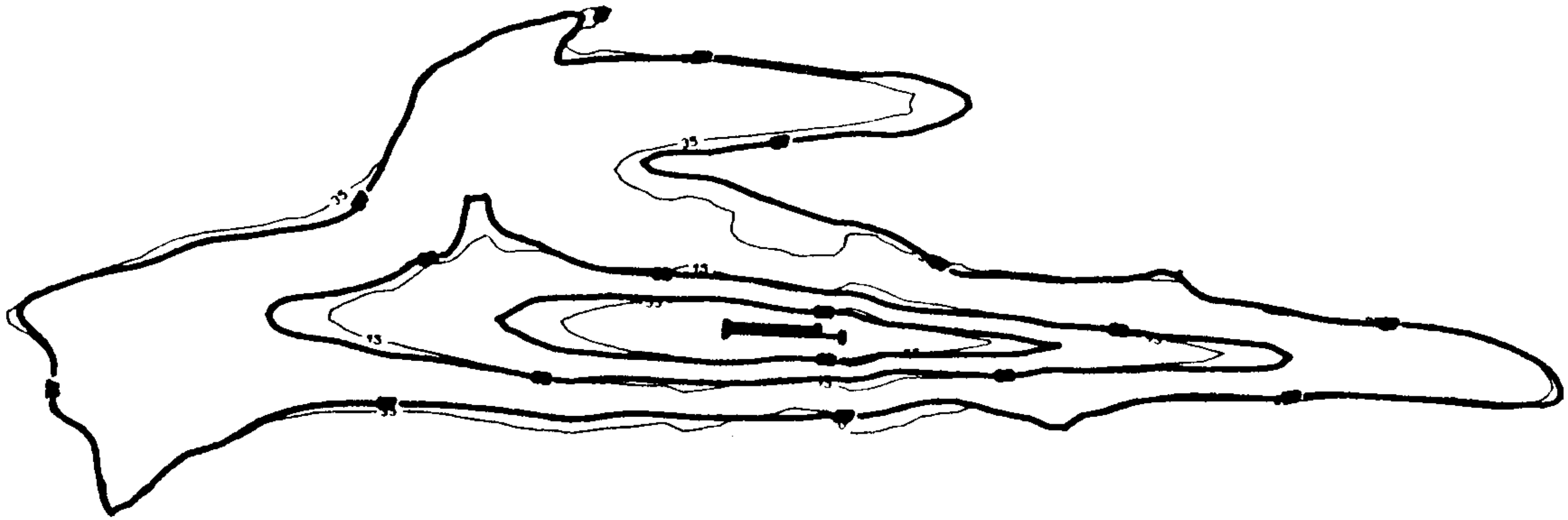
FINE 35,45,55 NNI
BOLD 57,63,69 Leq(16hr) dB(A)



SCALE 1:200000

FIGURE 6(b) 1988 AIRCRAFT NOISE CONTOURS
GATWICK

FINE 35,45,55 NNI
BOLD 57,63,69 Leq(16hr) dB(A)



SCALE 1:200000

FIGURE 6(c) 1988 AIRCRAFT NOISE CONTOURS
STANSTED

FINE 35,45,55 NNI
BOLD 57,63,69 Leq(16hr) dB(A)

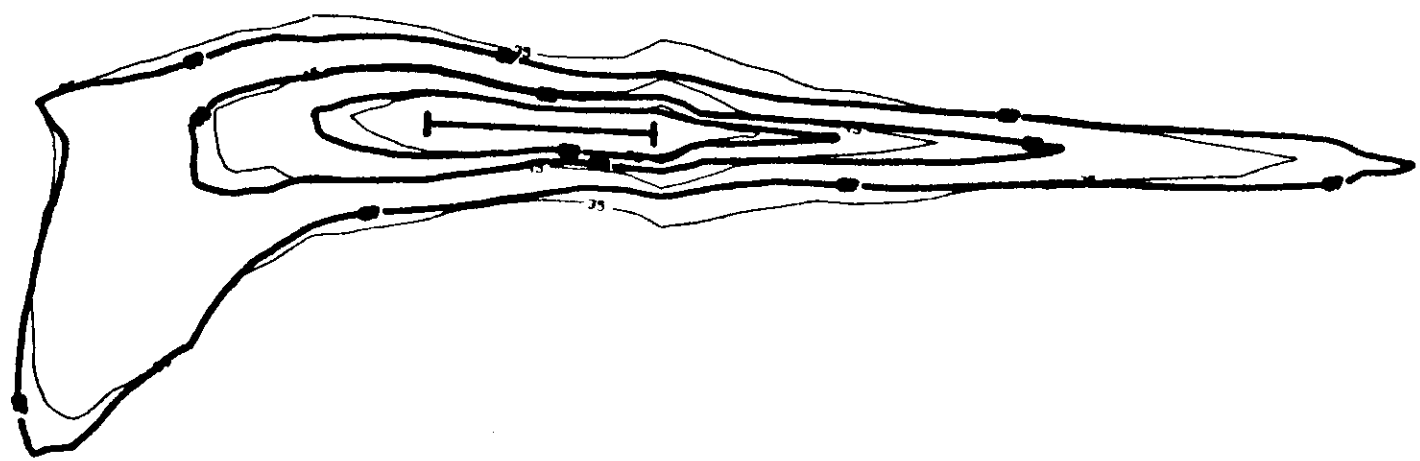


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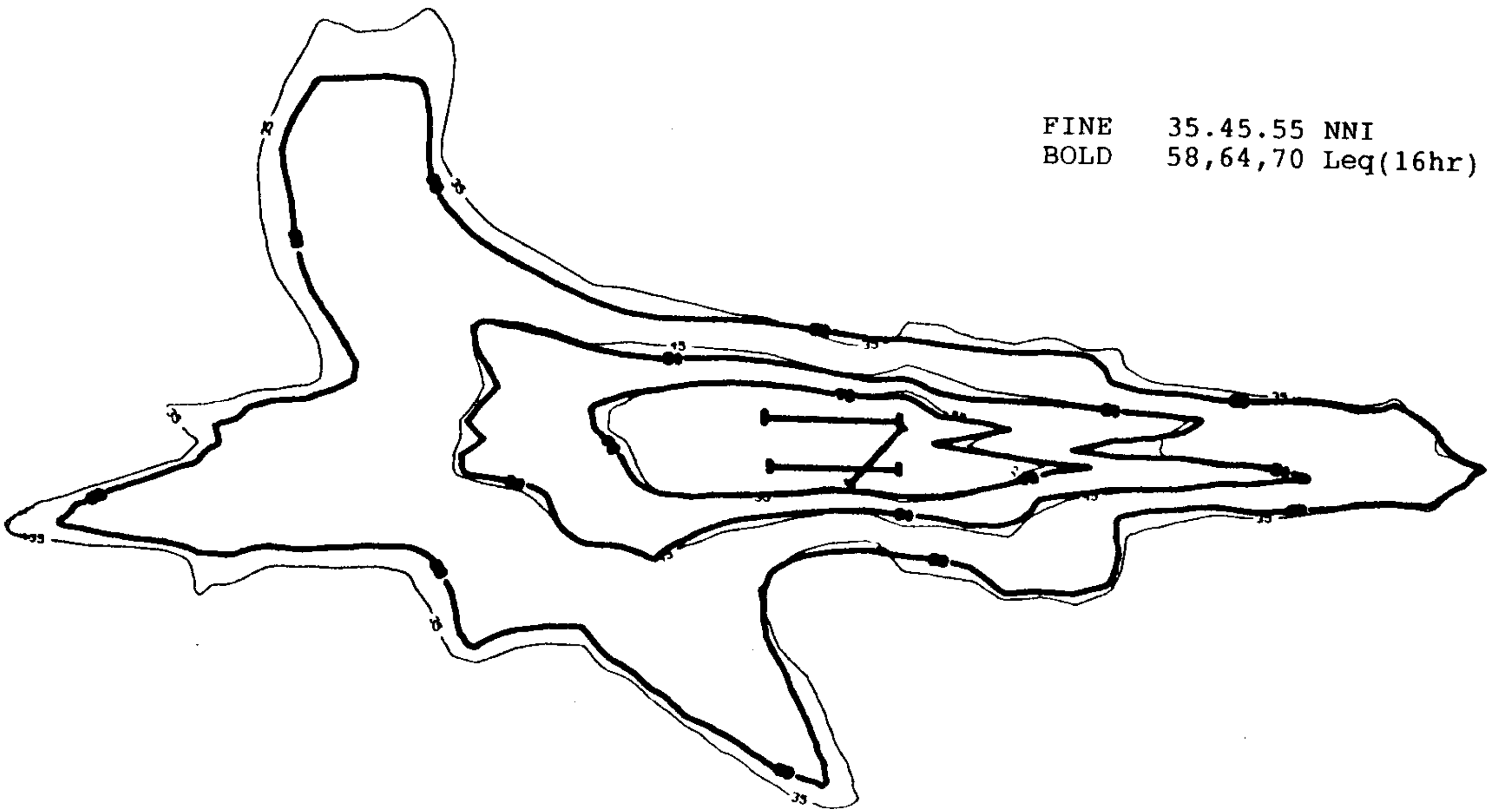
FIGURE 7(a) 1988 AIRCRAFT NOISE CONTOURS
HEATHROW

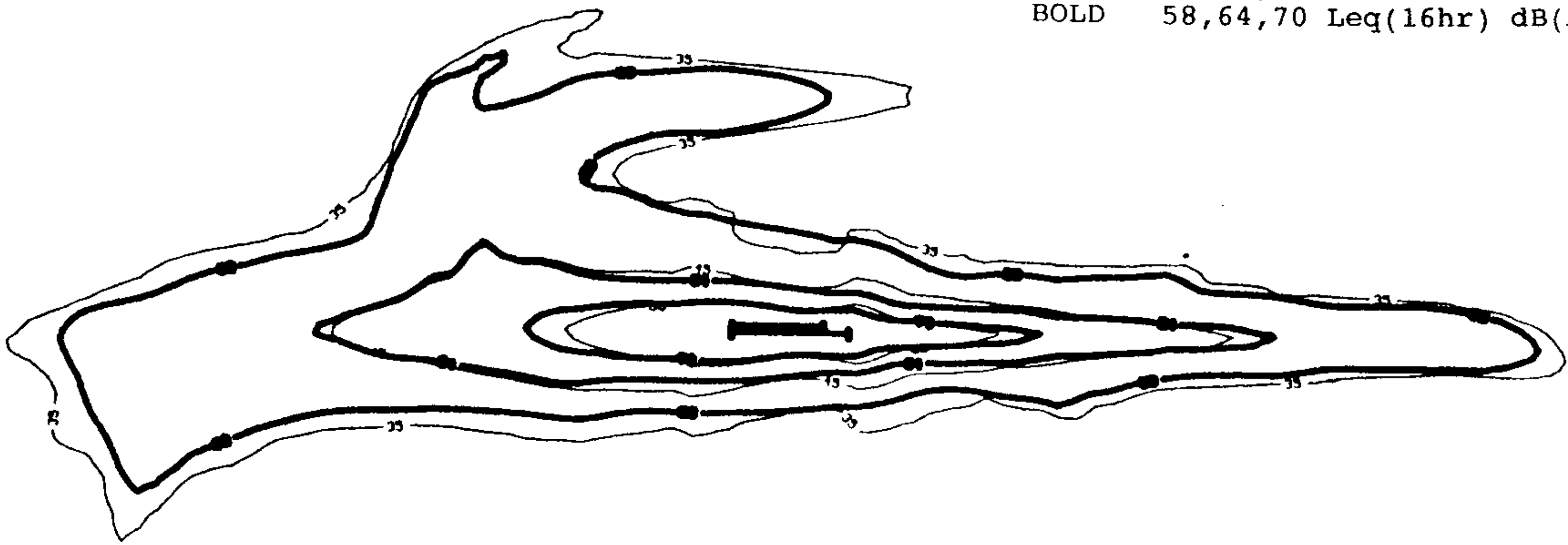


FINE 35.45.55 NNI
BOLD 58,64,70 Leq(16hr) dB(A)

SCALE 1:200000

FIGURE 7(b) 1988 AIRCRAFT NOISE CONTOURS
GATWICK

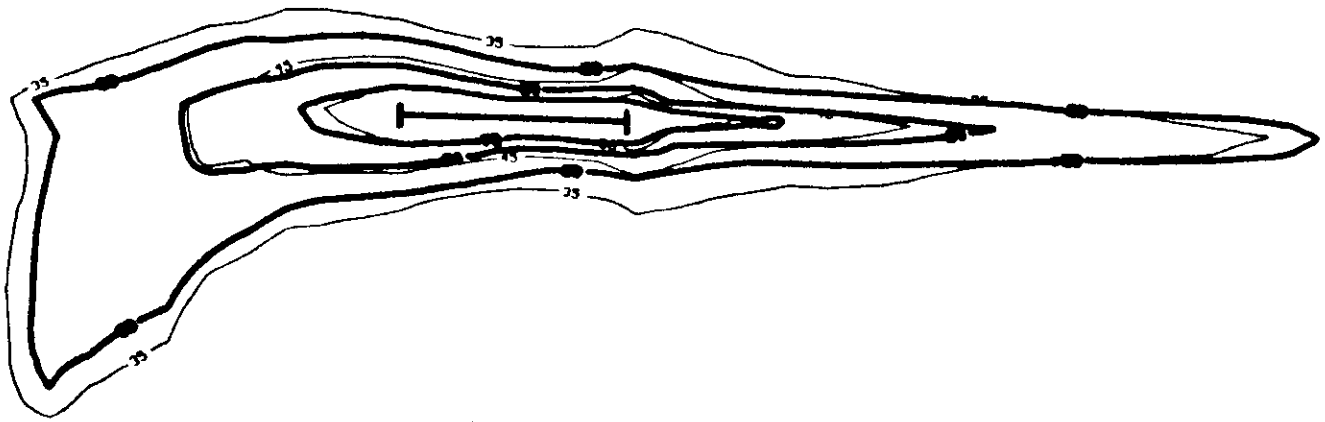
FINE 35,45,55 NNI
BOLD 58,64,70 Leq(16hr) dB(A)



SCALE 1:200000

FIGURE 7(c) 1988 AIRCRAFT NOISE CONTOURS
STANSTED

FINE 35,45,55 NNI
BOLD 58,64,70 Leq(16hr) dB(A)



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APPENDIX 1

CONSULTATION DOCUMENTS

PARLIAMENTARY UNDER SECRETARY OF STATE

DEPARTMENT OF TRANSPORT
2 MARSHAM STREET LONDON SW1P 3EB
01-212 3434

My ref:

Your ref:

MINISTER FOR AVIATION

Michael Ancram Esq MP
Parliamentary Under-Secretary
of State for Scotland
Dover House
Whitehall
London SW1A 2AU

February 1986

Dear Michael

AIRCRAFT NOISE INDEX STUDY

As you may know, the Noise and Number Index (NNI) has hitherto been generally accepted in the UK as a reasonable guide to disturbance from aircraft noise. However, as stated in our White Paper on Airports Policy (Cmnd 9542), a then recently completed research project, commissioned by my Department, has concluded that the NNI system of measurement might be replaced by one based on the Leq (Equivalent Continuous Sound Level) scale. The White Paper, therefore, also indicated our intention to consult all interested parties on the case for a change in the system of measurement, and the appropriate time for any change.

I thought that you should know that I have now initiated this consultation process and enclose a copy of my Department's Press Notice of today. I enclose copies of the report of the research project - DR Report 8402: United Kingdom Aircraft Noise Index Study: main report - a short background note which I hope you will find useful as a guide to this complex subject, and the full list of those being consulted.

As you will see from the consultation list, I have sought the views of those likely to have a real interest in the study, including local authorities who, of course, make use of the NNI for planning purpose around airports.

I would welcome the views of your Department by the end of August.

MICHAEL SPICER

CIVIL AVIATION POLICY DIRECTORATE DIVISION 5

Department of Transport

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2 Marsham Street London SW1P 3EB

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Chief Executive
Bucks County Council
County Hale
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HD20 1UA

February 1986

AIRCRAFT NOISE INDEX STUDY

The Noise and Number Index (NNI) is presently used as a reasonable guide to disturbance from aircraft noise. However, the White Paper on Airports Policy (Cmnd 9542) stated that a then recently completed research project, commissioned by the Department of Transport, concluded that the NNI system of measurement might by replaced by one based on the Leq (Equivalent Continuous Sound Level) scale. The White Paper, therefore, also indicated the Government's intention to consult interested parties on the case for a change in the system of measurement and the appropriate time for any change.

I thought that you should know that this consultation process was initiated today and I enclose a copy of the Department's Press Notice. I invite you to play a part in this process, and enclose copies of the report of the research project - DR Report 8402: United Kingdom Aircraft Noise Index Study: main report - a short background note which I hope you will find useful as a guide to this complex subject, and the full list of those being consulted.

We are allowing six months for the consultation phase of the exercise, so I would welcome any comments on the report by the end of August.

PETER COWLING

Transport

Press Notice No: 89

26 February 1986

MINISTER SEEKS COMMENTS ON THE UNITED KINGDOM AIRCRAFT NOISE INDEX STUDY

Michael Spicer, Minister for Aviation, today asked for comments on a report of an aircraft noise index study.

In reply to a Parliamentary Question from Toby Jessel MP (Twickenham), Mr Spicer said:

"I have today initiated this consultation process.

"Following criticism of the Noise and Number Index (NNI), which has been used since 1963 as an index of aircraft noise disturbance, a full study was commissioned by the Department of Trade, which then had responsibility for Civil Aviation matters. The main aim of the study was either to substantiate the NNI or if necessary devise some better index.

"The main conclusion reached by the authors of the study report, the Directorate of Research of the Civil Aviation Authority, is that there appears to be a case for replacing the NNI system of measurement by one based on the 24 hour Leq (Equivalent Continuous Sound Level) scale.

"As indicated in the White Paper on Airports Policy (Cmnd. 9542), the Government is concerned that aircraft noise disturbance is monitored as accurately as possible, and by methods that fairly represent the level of annoyance experienced, and so command public confidence. I would, therefore, like those whom I am formally consulting, and others who may wish to play a part, to let me have their comments by the end of August. These comments will be carefully examined and will be taken into account in the development of future policy. A Synopsis of the comments will be made generally available.

"I have placed a copy of the study report in the Library of the House."

NOTES FOR EDITORS

1. The study report describes the results of a nationwide programme of social surveys and noise measurement in areas affected by aircraft noise.

2. To ensure that the results of the study were nationally representative, twenty three areas around five major civil airports - Heathrow, Gatwick, Luton, Manchester and Aberdeen - were selected. Fieldwork consisted of aircraft noise measurements and a programme of social surveys. About eighty randomly-chosen residents were interviewed in each of the chosen areas; in total over two thousand people were interviewed. A pilot survey was carried out in the summer of 1980 with the main survey following in the summer of 1982.

3. The Noise and Number Index (NNI) was devised some twenty years ago to take account of noise levels of individual aircraft and the number of aircraft heard. Its purpose is to represent the community reaction to the local level of aircraft noise exposure so as to guide planning, development and noise control. Each year the Department of Transport provides NNI contours for Heathrow, Gatwick and Stansted Airports.

4. Equivalent Continuous Sound Level (Leq) is defined as the level of that hypothetical steady sound which, over the measurement period, contains the same sound energy, weighted according to the response of the human ear, as the actual variable sound. Leq is commonly used as a measure of noise exposure. As well as forming the basis of the majority of indices of aircraft noise exposure in use throughout the world, it is used to quantify noise exposure from other sources such as road traffic, railways and industrial premises.

5. Copies of the report - DR Report 8402: United Kingdom Aircraft Noise Index Study: main report (price £12.50) are available (to callers only) from the CAA Library, CAA House, 45-59 Kingsway, London WC2B 6TE, tel 01 379 7311 or by post from Civil Aviation Authority, Greville House, 37 Gratton Road, Cheltenham, Glos. CL50 2BN, tel 0242 35151.

6. Press copies of the report are available from the Department of Transport Press Office, 01 212 0431.

2F

UNITED KINGDOM AIRCRAFT NOISE INDEX STUDY: MAIN REPORT

1. The purpose of this note is to indicate the background to the study report, and to introduce the reader to some of the conclusions reached by the study.

2. In January 1985, the Directorate of Research (DR) of the Civil Aviation Authority (CAA) published DR Report 8402: United Kingdom Aircraft Noise Index Study: main report. The study had been commissioned by the Department of Trade when responsibility for civil aviation policy rested with that Department: the responsibility now continues with the Department of Transport (DTp). The main objective of the research was "either to substantiate the Noise and Number Index (NNI) or if necessary to devise some better index of aircraft noise".

3. The study followed the general pattern of the two major studies of aircraft noise disturbance at Heathrow carried out in 1961 and 1967 in that the fieldwork consisted of aircraft noise measurement and a social survey. Twenty-three areas around five major civil airports were selected to ensure that the results of the study were nationally representative. They were:-

Heathrow	18 areas
Gatwick	2 areas
Luton	1 area
Manchester	1 area
Aberdeen	1 area

The areas chosen were about 1 sq km in extent and over an individual area the aircraft noise exposure was, within a small range, the same for all residents. Noise measurements made at one central site could therefore be taken to characterise the noise climate of the whole area.

4. Some of the areas were sampled twice, but with different respondents, because they contributed more than other areas to the design of the study; this effectively raised the number of areas to 26. About 80 randomly-chosen residents were interviewed in each area and in total 2097 people were interviewed.

5. The study considered several measures of annoyance reaction but the long-established Guttman Annoyance Scale (GAS) was found to be a good measure of annoyance/disturbance and correlated well with other scales which were tested. It was found that 24 hour Leq* (the value of the Equivalent Continuous Sound Level referred to the whole 24 hour day) averaged over the three summer months gave a slightly better correlation than did NNI with community annoyance.

6. Since many countries use Leq-based exposure indices weighted for time-of-day, the study considered the need for such weightings.

----

* 24 hour Leq refers to the value as a result of aircraft noise: it does not include other noise sources.

It was concluded that the rejection of any weighting at all was consistent with the study data.

7. The conclusions of the study are broadly that there is a case for the replacement of NNI by 24 hour Leq for the following reasons:-

(i) Use of 24 hour Leq as an index shows a statistical improvement over NNI in terms of correlation with community annoyance reaction.

(ii) Since the NNI formula includes a cut-off at 80 PNdB it means that in future, with the progressive introduction of quieter aircraft, it will take proportionally fewer aircraft into account in its calculation. This could lead to an under-estimation of public reaction.

(iii) 24 hour Leq takes account of all aircraft movements over the full 24 hours; it also takes account of the duration of the noise of each aircraft which NNI does not.

(iv) The use of an Leq-based index would lead to a greater consistency with other aspects of annoyance at aircraft noise where Leq is already used, eg helicopters, general aviation and sleep disturbance.

(v) The use of an Leq-based index would be more generally consistent with practice worldwide where the majority of indices have the form of Leq (in addition Leq is more amenable to 'on site' spot checks than is NNI).

8. The values of NNI taken by the Wilson Committee to indicate low, moderate and high annoyance, ie 35, 45 and 55 NNI, are 'reasonable' but essentially arbitrary in view of the linear nature of annoyance response against NNI which they found. The study analysis also found a smoothly increasing, nearly linear, variation of response against Leq but with the important exception of a 'step' in reaction (indicating a rapid increase in disturbance over a short range of Leq) at 57 Leq. This indicates a 'natural' value for the onset of annoyance.

9. On the basis of the conclusions of the study there appears to be a case for changing the national exposure index from NNI to 24 hour Leq.

MINISTER FOR AVIATION

DEPARTMENT OF TRANSPORT
2 MARSHAM STREET LONDON SW1P 3EB
01-212 3434

My ref:

Your ref:

Dr J G Walker
Institute of Sand and Vi bration Research
The University
Southampton
SO9 5NH

3 OCT 1986

Dear Dr Walker,

AIRCRAFT NOISE INDEX STUDY

Mr Spicer has asked me to thank you for your contribution to the consultation process on the case for a change in the system for the measurement of disturbance caused by aircraft noise. He has asked me to assure you that your contribution, and all others, will receive the most careful consideration.

It is difficult to indicate how long the analysis of the various points made, many of which are complex and technical, will take. However, I would like to assure you that you will be kept informed.

Yours sincerely,

ANDREW CAMPBELL
Private Secretary to Michael Spicer MP

APPENDIX 2

LIST OF CONSULTEES FROM WHOM SUBMISSIONS WERE RECEIVED

Contributions received from:

1. Joint Airports Committee of Local Authorities (JACOLA)
2. Patrick Ground MP
3. Alfred Morris MP
4. Welsh Office
5. Gatwick Area Conservation Campaign (GACC)
6. Hertfordshire County Council
7. Buckinghamshire County Council
8. Horsham District Council
9. International Air Transport Association (IATA)
10. Bracknell District Council
11. Dan Air
12. Heathrow Association for the Control of Aircraft Noise (HACAN)
13. Heathrow Airport Consultative Committee
14. Gatwick Airport Consultative Committee
15. West Sussex County Council
16.* Mole Valley District Council
17. Manchester Airport plc
18. Gatwick Resident Airline Operators Association
19. Stansted Airport Consultative Committee
20. Aerodrome Owners Association
21. Surrey Heath Borough Council
22. Reigate and Bansted Borough Council
23. Association of District Councils
24. Uttlesford District Council
25. British Airways
26.* Royal Borough of Windsor and Maidenhead
27. Local Authorities Aircraft Noise Council
28. Scottish Office
29.* Hounslow London Borough
30. Short Brothers plc
31. Little Hallingbury Parish Council
32. Graham Parry (Acoustic Consultant)
33. Ministry of Defence
34. Loughborough University of Technology
35. Tandridge District Council
36. Department of Environment
37. Waverley Borough Council
38. Dr Stansfeld Inst Psychiatry
39.* Spelthorne Borough Council
40. South Bucks District Council
41. Withdrawn
42. Institute of Sound & Vibration Research University of Southampton
43.* London Borough of Richmond Upon Thames
44. Ealing Aircraft Noise Action Group (EANPG)
45. Airfields Environment Federation
46. Shepperton Residents Association
47.* London Borough of Hillingdon
48.* London Boroughs Association
49. Elmbridge Borough Council
50.* Surrey County Council

51. DoE For N. Ireland
52. Withdrawn
53. Alan Haselhurst
54. Geoffrey Howe
55. British Airports Authority plc
56. Heathrow Scheduling Committee
57. Dr A J Pretlove, Reading University
58.* London Borough of Ealing
59. Travers Morgan Planning
60. Association of Noise Consultants
61. Renfrew District Council

* These consultees comprised the Local Authorities Working Group which submitted a joint report prepared by London Scientific Services.