DORA Communication 7907
(Second Edition September 1981)

The Noise and Number Index

Prepared by the Civil Aviation Authority London
on behalf of the Department of Trade, September 1981 Price £1·50

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

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SUMMARY

This paper presents a short review of the Noise and Number Index (NNI), covering its origin and applications, its basis and limitations, the research which has been done upon it and a comparison with other indices. The opportunity is taken to explain in the course of the discussion those points which have been the most frequent sources of difficulty. It is hoped that this will contribute to a wider understanding of the nature of the Index and of its relevance and validity in the many different circumstances in which it may be used.

[This second edition incorporates the corrigenda and addendum published subsequent to the first edition. In Annex 1 there are also textual changes relating to the changed situation since the publication of the first edition.]

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Printed by Civil Aviation Authority, Greville House, 37 Gratton Road, Cheltenham, England
Distributed by Department of Trade

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ORIGIN OF THE NNI

1 In April 1960 a Committee was appointed by the Lord President of the Council and Minister for Science under the Chairmanship of Sir Alan Wilson FRS 'to examine the nature, sources and effects of the problem of noise and to advise what further measures can be taken to mitigate it.' This Committee examined all aspects of noise at work and in the environment, in town and country, and also the law relating to noise. The Committee also commissioned a survey of the noise exposure and corresponding public annoyance from aircraft around Heathrow Airport. Aircraft noise measurements were made at 85 typical locations spread over the area within a 10 mile radius of Heathrow Airport, and public annoyance was assessed by the Government Social Survey from the responses to a questionnaire of 42 questions asked in interviews with 1731 people living around Heathrow.

2 The Committee concluded that 'the survey provides a tentative basis for establishing a combined noise and number index, defining the total noise exposure which causes annoyance.....' and ' ..... that the data showed that in causing annoyance a four-fold increase in the number of aircraft heard is very approximately equivalent to a rise in average peak noise level of 9 PNdB.' The basis for this relationship is given in Figure 1 (reproduced from Appendix XI of the Committee's final report, Ref 1). This shows annoyance to be proportional to noise level L and to the logarithm of the number N, and leads to

$$NNI = L + 15 \log N - 80$$

as the mathematical expression of the Wilson index. It cannot be emphasized too often that the NNI is an <u>empirical</u> formula, ie one which fits the observed data. The analysis by the Government Social Survey suggested that in describing the general level of community annoyance the expression 'very much' related to 60 NNI, 'moderate' related to 45 NNI, 'little' related to 32 NNI, and 'not at all' to about 3 NNI. It has since become general usage to describe 55, 45 and 35 NNI respectively as denoting 'high' 'moderate' and 'low' community annoyance.

3 The Committee were tentative in their conclusions because they had not been able to carry out research on all the aspects of aircraft noise which might be relevant. For instance they had not made an adequate survey of night noise, they did not have a proven noise exposure model (ie a computer program for estimating the noise at any location) and they did not consider in detail the effect of the different directions (modes) of runway operation at Heathrow Airport. The Government therefore commissioned a second survey in 1967 'to re-examine and extend the findings of the 1961 Survey'. The report on the second survey (Ref 2) again failed to achieve a convincing night noise index but in general it confirmed the findings of the Wilson Report and the relevance of the NNI. However it pointed out (as did the earlier report of the Government Social Survey commissioned by the Wilson Committee/ Ref 3) that the coefficient '15' in the NNI, although adequate for general annoyance assessment, could not be said to indicate with any certainty the exchange rate between noisiness and number in causing annoyance. This threw some doubt on the predictive capability of the NNI for

circumstances markedly different from those of Heathrow in the '60s.

4 After the Second Survey Report the Government initiated a programme of research under Ollerhead at Loughborough University to investigate indices used in other countries and to evaluate the NNI further, particularly at provincial airports (Refs 4 - 7). More recently the Department of Trade, following a period of public consultation, decided to phase out the noisier night flights (Ref 8) and commissioned the CAA (DORA) to make a major survey of sleep disturbance around Heathrow and Gatwick Airports (Ref 9) in the belief that night flying noise could not be regulated without more adequate knowledge of how sleep was being disturbed. The results of this survey will be available in 1980.

DEFINITION OF THE NNI

5 The Wilson Committee's Report did not fully specify the Noise and Number Index. A definition effectively arose from common usage after 1963 and was embodied in the second survey. The NNI at any point on the ground is calculated from the formula of paragraph 2 in which L is the logarithmic mean of the peak noisiness for a number N of flights which make a peak noise level exceeding 80 PNdB at that point. (Ref 10 gives a detailed explanation of the method by which NNI contours are calculated). In practice in both major surveys, and subsequently, official measurements have been produced as dBA + 13, which is closely equivalent to PNdB (Ref 1, Appendix X). The effect of the logarithmic mean noise level, rather than the better known arithmetic average, is to give more weight to the louder flights than their number would contribute to the arithmetic average. In official usage the flights which determine L and N are those which take place in the 12 hour period, 0600 to 1800 GMT, which is averaged for the 3 summer months mid-June to mid-September following the 1961 and 1967 survey procedure. For the evaluation each flight is assigned the 'noise signature' of its type, a route and a navigational error, and from the total 12 hours traffic the values of L and N are calculated at the desired points on the ground. This is done separately for each runway direction, and then either the average values of L and N are used to compute the official 'average mode' NNI (which is close to Wilson's concept) at each location or, if one is computing the 'worst mode' NNI, then its highest value is selected at each point, since naturally no one runway gives the worst noise at all places. (A discussion of the merits of using 'worst mode' NNI is given in Ref 11: there are indications that 'worst mode' results have a slightly better correlation with annoyance than 'average mode' - but the conclusion was that there was insufficient evidence to justify the adoption of the 'worst mode'.)

APPLICATIONS OF THE NNI

6 Each year the Department of Trade provides the NNI contours for Heathrow, Gatwick and Stansted Airports together with a count of the population resident within each contour as a monitor of the year to year changes in the noise environment. The Index is similarly used by the British Airports Authority (BAA) to assess the effect of developing existing

airports. For instance, NNI contours and population counts were submitted to the Inquiry into BAA's application to build a fourth terminal at Heathrow Airport. Similarly, NNI contours and population counts have been published in Government consultation documents concerning national airport policy and planning and specifically in the selection of a site for a third London airport (Refs 12, 13, 14). The boundaries of noise insulation grant schemes at British airports are normally based wholly or largely on selected NNI contours.

7 The Noise Advisory Council (Ref 11) has judged that there is a wide acceptance of the Noise and Number Index in the United Kingdom for guidance in land use and development. The Department of the Environment's circular 10/73 'Planning and Noise' gives guidance in terms of NNI values to Local Authorities on the granting of planning permission in areas subjected to aircraft noise. (Ref 15 gives a comprehensive description of recommended environmental practices for airport planning and development.)

VALIDITY OF THE NNI

8 The purpose of the NNI is to represent community reaction to the local level of aircraft noise so as to guide planning, development and noise control. It does not, indeed could not, represent any one person's susceptibility because people respond differently to the same values of L and N. Some research (Ref 16) has suggested that individual representation could be achieved by an index containing terms classifying the individual (e.g. age, socio-economic group, etc) as well as L and N which describe only his noise environment - but this would have little relevance to our stated purposes. Traffic, the runway in use and the weather conditions vary from day to day; an overflight at just the wrong moment or when one is distressed is more annoying than at other times, and the measure of community impact must aggregate all such variations between individuals and circumstances and seek to represent a general level of reaction from all people who over a period experience comparable noise exposure. We refer to this as 'community annoyance'.

9 The question of validity falls naturally into two parts: first whether the terms in the Index adequately represent the noise exposure for present and future environmental assessments (paras 10 to 13), and secondly whether community annoyance (representing the environmental impact) has been properly assessed in calibrations of the Index (paras 14 to 19).

The NNI and Noise Exposure

10 The Wilson Committee considered it reasonable to describe the local aircraft noise environment in terms of how noisy the flights were in that neighbourhood and how many were heard. It is relevant that these two factors L and N are also convenient for forecasting and for regulation, in that noisiness is a matter of technology, size and operational procedure whilst number relates to traffic. The choice of two distinct factors immediately exposes to question the relative contributions from each (which Wilson derived from Figure 1 and are represented by the logarithmic form of N and its coefficient '15'). The question might

not have arisen if the index 'Equivalent Sound Level' (Leq) had been chosen, because L and N do not appear explicitly; but Leq can also be calculated from noisiness and number data and is comparable with a two-part index L + 10 log N. The 'balance' between the contributions from noisiness and number is invariably present in any environmental noise index, either explicitly as with NNI or implicitly as with Leq and this balance must be right if the Index is to forecast annoyance correctly, especially in today's circumstances which are characterised by increasing numbers of less noisy aircraft. The doubts about this aspect have not been resolved for any index, but the NNI is rather more sensitive to number than most which means that it is less likely to underestimate future annoyance from a greater number of less noisy aircraft.

11 Should factors other than L and N be included in the noise exposure formula? - for example some indices used in other countries (Annex 1) include the duration of the noise and/or its quality through the use of EPNdB as a noise measure or by the use of an Leq base for the index. The inclusion of a factor for the duration of the aircraft noise was investigated in the analysis of the 1967 survey (Ref 2, Chapter 6). A marginal improvement in predictive power was achieved, but it was apparent that the effect of aircraft duration on annoyance was rather complex. As regard noise quality, this may differ markedly between propellers, jets and helicopters, and it may affect their propensity to annoy; but when used for general purpose airports the Index must aggregate over a variety of operations so that only a drastic change in the mix of traffic would need specific attention. It has not been the usual practice to include helicopters in calculating the NNI because it has been felt that they may be more annoying than fixed-wing aircraft at the same loudness (although the National Physical Laboratory, App X of Ref 1, found no evidence for this). In addition, recent trials in the USA (Ref 17) show little additional annoyance specific to the helicopter and because they do not add much to the general level of environmental noise (Ref 18) it would seem unnecessary to continue to distinguish them from fixed-wing aircraft. It would be premature to say that the effects of duration, noise quality etc, on annoyance are understood, but it would seem that their inclusion in an NNI type expression is unlikely to improve predictive power substantially.

12 One factor which may have some impact is the general level of 'background' noise, on the basis that the higher it is then the less obtrusive will be the aircraft. This is far from proven at present, but seems more likely to be relevant where many relatively quiet aircraft overfly quiet areas; and correspondingly of little relevance where aircraft are very noisy. It is therefore a subject which may merit further investigation, particularly for a future environmental situation at any airport in a rural area. It can also be argued that the NNI is not known to be sufficiently accurate at the lower levels (below 35NNI) and that the cut-off at 80 PNdB, below which aircraft are not counted is not appropriate to quiet areas. However, it should not be supposed that an allowance for a 'background' noise term is the solution without also adjusting the cut-off level, nor that the net result of whatever amendment future research may show to be suitable will necessarily affect the final value very much.

13 An aspect which has caused some concern has been the restriction of the traffic count to the 12-hour period rather than counting for the whole day, and also to using only the 3 busiest summer months rather than the whole year. In some instances this objection has arisen from a mistaken impression that including traffic outside the 12-hour total would, by increasing 'N', indicate a higher level of NNI and so a greater annoyance. This would not be so because the NNI expression is calibrated against annoyance using a 12-hourly traffic for 'N'. The nub of the matter is whether this rate is being sampled at the most suitable time to be representative of annoyance. In fact the NNI period (12 hours a day averaged over the 3 summer months) covers the times when traffic is at a peak, aircraft are heavily loaded, temperature is high and windows are kept open, so that annoyance might be expected to be best related to this traffic. The need to consider some change would certainly arise if the diurnal pattern were substantially altered or if the growth of traffic within the NNI period differed markedly from the annual growth, which would be untypical of airport growth. As regards night time traffic, it is not at present the policy to combine day and night under a single index, with annoyance weighted for the time of day as some indices do. This may be reconsidered following the social survey of sleep interference (Ref 9), but it is worth noting that night annoyance has played some part (Figure 2) in the calibrations of the NNI.

Scales of Annoyance

14 The next question is how severely aircraft noise affects the community. What is sought is to assess people's 'annoyance' with aircraft noise in such a way that this can be compared with an index of their exposure to it. Such an assessment is subjective and has to be based upon a structured set of questions. For instance, a person can be asked to indicate upon a proffered numbered scale, such as 7, 6, 5 .... 1, what he judges to be the degree of his annoyance, or, alternatively, he might be asked to choose a descriptive term from a proffered ordered set, such as 'very much', 'moderately', 'little', 'not at all'. This latter 4 point scale has been called the Aircraft Noise Annoyance Scale (ANAS). Another scheme is to ask a set of questions which can be scored by a process developed by Guttman so as to produce a well ordered scale. In 1961 the Government Social Survey closely followed the early work of Borsky in the USA (Ref 19) and tested a number of different question sets by the Guttman process. The 6 point set given in Figure 2 was the simplest which performed well and was chosen by Wilson for the annoyance scale of Figure 1. This is referred to as the Guttman Annoyance Scale (GAS). As would be expected, the GAS and ANAS Scores have been found to be highly correlated (Ref 3).

15 The concept of the GAS (Figure 2) has a certain complexity and presumptuousness which invite criticism, but it has been subjected to a good deal of testing (Refs 6, 7) which shows it to be surprisingly robust. Two criticisms by Hart (Ref 20) are of interest. He observes that 3 points out of the possible maximum score of 6 are allotted to interference with specific activities (e.g. television viewing) so that anyone not engaging in these (e.g. having no television) might be unable to express his full annoyance as a GAS score. Indeed, some

individual scores may be low for this reason, but they will be few because the specified activities are almost universal (e.g. television ownership was 81% in 1961, 90% in 1967). Moreover these low individual scores will not at all affect the use of community average scores shown against the NNI in Figure 1 unless the incidence of low scoring is itself related to noise exposure; e.g. unless television ownership is related to noise exposure or to distance from an airport, which would seem to be most unlikely. Hart also remarked that asking questions in the GAS form: 'When you hear an aircraft does it interfere..... if so how much does it annoy you?' tends to exclude the effect of increases of aircraft number on the annoyance. This is a conjecture which seems reasonable, but which may be of limited truth because people's total response to aircraft noise colours their replies to questions on restricted aspects of it - as indeed happens in other matters. They may be implicitly allowing frequency to influence their estimates of annoyance even though not specifically asked about it.

The ANAS scores are not open to this criticism but respondents' scores in the 1967 survey match up well with the GAS scores over a range of aircraft number at a constant noisiness, which suggests that community averaged GAS scores cannot be very deficient in representing the influence of number although possibly a few individual GAS scores have been affected in the way that Hart conjectures.

16 These scales of annoyance have been created methodically but subjectively and the terms used such as 'annoyance', 'little', 'moderately', etc., are left to individual interpretation. They are not likely to mean quite the same thing to all people. There are, for instance, no grounds for saying that all people who classify themselves 'little annoyed' are less annoyed than everyone who rates himself 'moderately annoyed', although we may reasonably suspect that this will be so for most people. Thus this sort of doubt about classifying every individual's annoyance is overcome by looking at the community at large for which a scale such as the ANAS provides a count of the proportion of people who rate themselves at each level of annoyance and yields numbers which have considerable meaning and reliability in describing community annoyance (Figure 3).

17 The Guttman procedure is designed to give considerable assurance that the GAS scores 0, 1, 2....6 are in increasing order of annoyance, but we may not presume that a score of 6 just doubles the annoyance represented by a score of 3 - not even for the same individual under different conditions. The steps in annoyance represented by the numbers may not be equal, although we may feel from the nature of the GAS questions that they might be nearly so. The pitfall in describing scale points by numbers 0, 1, 2, ... 6, whereas they should really have been described as 0, 1st, 2nd .... 6th, is that they might inadvertently be subjected to mathematical processes for which they are not suited.* Wilson (Figure 1) uses a GAS score averaged over

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* Technical Note

This is a criticism of some of the 'multiple regression' techniques used in the 1967 analysis (Ref 3). With hindsight these methods can be seen as inappropriate and hence the results are indicative rather than definitive. Fortunately, the main results (for example see para. 3) have been verified, using 'non-parametric' statistical methods (ref 4-7).

people who suffer similar noise exposure. This, although an approximation, gives a reasonable measure of community annoyance. Its reasonableness may be appreciated by looking at the overall picture of individual GAS scores plotted against NNI in Figure 4. Notice that these scores reflect the wide spread of individual annoyance within any group at a common noise exposure, and that there is a general upward drift in everybody's annoyance as NNI increases but little change in the way the individual scores are clustered around the mean. Thus the community mean can be seen to be a representative measure and to be proportional to NNI. This GAS data, if translated into the presentational form used for ANAS in Figure 3, shows the proportion of people who scored 1, 2, etc., GAS units, and gives a similar picture presented by these annoyance scores. The consistency between the two pictures obtained from the differently constructed scales (ANAS and GAS) indicates that NNI is a useful and valid representation of public annoyance with aircraft noise.

18 In both Heathrow surveys the NNI has been set in the context of nuisances generally and Figure 5 reproduces one of these presentations for Appendix XI of Ref 1. This evidence shows that very few people find noise to be a major disamenity below about 32 NNI but that above this level it becomes an increasingly more prominent reason for wishing to leave the district and from about 50 NNI upwards it becomes the main reason. Seen in this perspective the NNI is showing a behaviour quite consistent with its representation of public annoyance in Figures 3 and 4.

19 There is now a considerable amount of experience of the usefulness and validity of the NNI for immediate control and short term development, but less certainty about its use for those long term planning purposes where some new circumstances need to be envisaged. If present economic and social trends continue the future may be expected to bring larger numbers of less noisy aircraft overflying people who place more value on a quiet environment than is the case today. There is therefore an argument in favour of testing the Index to ensure that it can continue to be representative of annoyance in these changing conditions.

ASSESSMENTS OF THE NNI AT OTHER AIRPORTS

20 Although the NNI was formulated on the basis of social surveys around Heathrow Airport it has been used at many other airports in the UK and has been tested at several airports in the United States (Ref 16). Figures 6 and 7 show the results of calibrating the NNI against the GAS at Heathrow, Gatwick and two provincial airports. These are taken from the results of research carried out by Ollerhead and others at Loughborough under contract to the Department of Trade (Refs 4-7). Ollerhead concluded that the NNI correlated as well with the GAS at the provincial airports as it did at Heathrow and that although GAS might not be the best possible annoyance measure it had not been shown to be drastically inaccurate or inconsistent nor had any intrinsically better index been suggested. There were, of course, different circumstances at different airports and some differences in the responses of people but these could be related to the natural differences in the local situations and social norms rather than to variable behaviour of the GAS, and Ollerhead concluded 'GAS might certainly be

accepted as a form of cumulative attitudes scale which is likely to be as reliable and stable as any other' (Ref 7).

21 In the Netherlands in 1964 the Kosten Committee (Ref 21) proposed an index based on a survey of 1000 people living in eight different neighbourhoods around Amsterdam (Schiphol) Airport. An annoyance scale similar to the GAS was used and the results indicated an agreement between annoyance and NNI closely resembling that for Heathrow.

22 In 1965-66 the University of Paris (Ref 22) conducted some 2000 interviews amongst people living around Paris (Orly), Paris (Le Bourget), Marseilles and Lyons Airports. Again annoyance was measured on a scale similar to the Guttman Scale and the relationship between annoyance and NNI was similar to that found at Heathrow.

23 During 1967, in surveys sponsored by NASA, 8207 people who lived around airports at Chicago, Dallas, Denver, Los Angeles, Miami, New York and Boston were interviewed. The results, reported by the research organisation Tracor Inc in 1970 (Ref 16), showed that annoyance measured on a Guttman-type attitude scale was predicted very similarly by the American indices, Composite Noise Rating (CNR) and Noise Exposure Forecast (NEF), and by a formulation of NNI which they had modified to include separate day and night time components.

24 A resumé of aircraft noise environmental indices, with their mathematical formulations, is given at Annex 1. For the most part the formulae are similar and accordingly produce similar contours which correspond closely to the NNI. A useful review of these indices will be found in Ref 23 - but note that not all components of indices are justified by reference to social survey results.

CONCLUSION

25 The purpose of an index is to assist in the regulation of noise abatement and land use. It should be representative of the disamenity, impartial and practical to calculate and to apply. The NNI has been seen to meet these requirements and has gained wide acceptance in a range of applications at international and domestic airports of the UK. It is generally similar to many of the indices in use elsewhere and none of them performs substantially better.

26 There can be no ideal index which will adequately represent every aspect of each situation in which it will be used, nor is it effective to have a range of different, albeit more accurate, indices for use within a common area of administrative policy. One of the choices for the future will be whether aircraft noise policy should remain a distinct area or be absorbed within the area of noise control of all kinds, for which purpose the Leq is under continuing consideration. For the time being the NNI remains the official measure of the impact of aircraft noise, and if it is chosen to apply it in any comparatively new area, e.g. helicopters, club, training, military operations, the same process of testing and careful calibration should be applied in order to achieve consistent representation of community annoyance.

A somewhat similar situation arises when NNI is used for long term planning, where the now established trend towards increasing numbers of less noisy aircraft and higher environmental standards (which is expected to continue beyond the turn of the century) requires that a check be kept upon its behaviour in representing community annoyance under these different circumstances.

27 Continuity in the use of an environmental index is of great practical importance: present policy is to maintain the NNI as a valid and acceptable index by a combination of consultation, application and research until a more widely acceptable alternative is found and also to support international efforts to achieve this objective.

REFERENCES

1 Committee on the Problem of Noise

'Noise' Final Report

HMSO Cmnd 2056 July 1963

2 MIL Research Limited

'Second Survey of Aircraft Noise Annoyance around London (Heathrow) Airport'

HMSO 1971

3 McKennell A.C.

'Aircraft Noise Annoyance around London (Heathrow) Airport'

Central Office of Information SS.337, April 1963

4 Ollerhead J B

'Estimating Community Annoyance due to Airport Noise'

Loughborough University of Technology, TT 7203, February 1972

5 Edwards R M and Ollerhead J B

'A Survey of Aircraft Noise Annoyance in an Area of Invariant Noise to Eliminate the Effects on Annoyance of Varying Noise Exposure'

Loughborough University of Technology TT 7405 May 1974

6 Ollerhead J B and Edwards R M

'A Further Survey of Some Effects of Aircraft Noise in Residential Communities near London (Heathrow) Airport'

Loughborough University of Technology TT 7705 June 1977

7 Ollerhead J B

'A Comparison of Annoyance Caused by Aircraft Noise near London, Manchester and Liverpool Airports'

Loughborough University of Technology TT 7706 June 1977

8 Department of Trade

'Night Disturbance from Aircraft Noise at Heathrow and Gatwick'

A Consultation Document, 1977

9 Civil Aviation Authority

'Aircraft Noise and Sleep Disturbance' - Final report.

DORA Report 8008, August 1980

10 Davies L I C

'A Guide to The Calculation of NNI'

DORA Communication 7908, September 1979

11 Noise Advisory Council

'Aircraft Noise: Should the Noise and Number Index be Revised?'

HMSO 1972

12 Department of Trade

'Airport Strategy for Great Britain - Part 1 (1975) The London Area, Part 2 (1976) The Regional Airports'

13 Commission on the Third London Airport

'Report'

HMSO, 1971

14 Department of Trade

'Maplin'

Review of Airport Project HMSO 1974

15 International Civil Aviation Organization

Airport Planning Manual Part 2 - 'Land Use and Environmental Control' 1st Edition

ICAO Doc. 9184 - AN#902 part 2, 1977

16 Tracor

'Community Reaction to Airport Noise: Final Report'

Tracor Document No. T-70-AU-7454-U September 1970

17 Patterson J H et al

'Subjective Ratings of Annoyance produced by Rotary-Wing Aircraft Noise'

US Army Aero Medical Research Laboratory - USAARL Report No. 77-12 May 1977

18 Evers Eileen

'The Effects of Helicopter Noise in the London Area'

Prepared by SCICON for the CAA, DORA Report 7506 1975

19 Borsky P N

'Community Reactions to Air Force Noise' Part II

USA WADD Technical Report 60-689 (II) March 1961

20 Hart P E

'Population Densities and Optimal Aircraft Flight Paths'

Regional Studies, Vol 7 pp 137-151

University of Reading, 1973

21 Kosten C W et al

'Aircraft Noise Abatement'

Report of the Dutch Committee on Aircraft Noise Abatement to the Minister of Traffic and Public Works, Delft, Netherlands - 1967 (English Translation available as NASA TT F-12, 093 - 1969).

22 Coblenz A et al

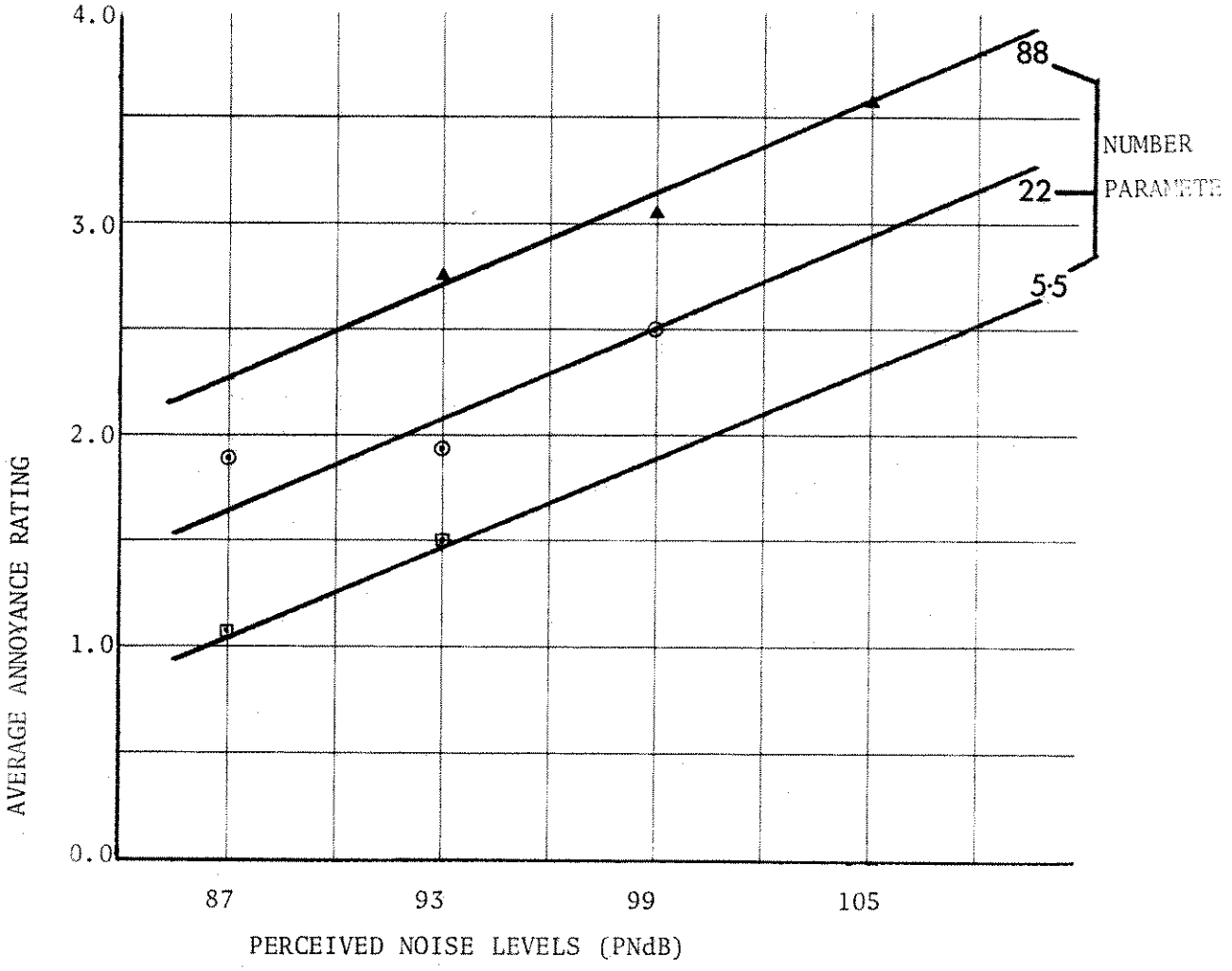
'Enquete sur le Bruit Autour des Aeroports'

Document AAA/16/67, Laboratoire d'Anthropolgie Appliqué, Paris. 1967

23 OECD

'Reducing Noise in OECD Countries'

OECD, Paris, 1978



NUMBER PARAMETER SYMBOL

▲ 88

⊙ 22

⊡ 5.5

Figure 1 Annoyance v noise level from the Wilson Committee's Report

The method of computing Guttman Annoyance Score (Scale N/1) is taken from the report of the 1967 Social Survey at Heathrow (Ref 2).

Eight questions are scored but the last three questions are counted as one item ie a respondent can only score a total of one point for the three questions even if scoring one point on each.

CARD A
The noise bothers or annoys me
VERY MUCH
MODERATELY
A LITTLE
NOT AT ALL

CARD D
VERY ANNOYED
MODERATELY ANNOYED
A LITTLE ANNOYED
NOT AT ALL ANNOYED

Q 12 (a) SHOW CARD A: Please look at this scale and tell me how much the noise of the aircraft bothers or annoys you (ORDINARY FLIGHTS NOT SONIC BOOM)

[Score one point for "very much", "moderately" or "a little"]

Q 15 (ii) Do the aircraft ever wake you up? IF "YES", SHOW CARD D AND ASK - When they wake you up, how annoyed does this make you feel?

[Score one point for "very annoyed" or "moderately annoyed"]

Q 15 (vi) Do the aircraft ever interfere with conversation? IF "YES" SHOW CARD D AND ASK - When they interfere with conversation, how annoyed does this make you feel?

[Score one point for "very annoyed" or "moderately annoyed"]

* Q 15 (iii) Do the aircraft ever interfere with listening to radio or TV? IF "YES" SHOW CARD D AND ASK - When they interfere with listening to radio or TV, how annoyed does this make you feel?

[Score one point for "very annoyed", "moderately annoyed" or "a little annoyed"]

Q 15 (v) Do the aircraft ever make the house vibrate or shake? IF "YES" SHOW CARD D AND ASK - When they make the house vibrate or shake, how annoyed does this make you feel?

[Score one point for "very annoyed", "moderately annoyed" or "a little annoyed"]

Q 15 (vii) Do the aircraft ever interfere with or disturb any other activity? IF "YES" SHOW CARD D AND ASK - When they interfere with or disturb any other activity, how annoyed does this make you feel?

[Score one point for "very annoyed", "moderately annoyed" or "a little annoyed"]

Q 15 (viii) Do the aircraft ever bother, annoy or disturb you in any other way? IF "YES" SHOW CARD D AND ASK - When they bother, annoy or disturb you in any other way, how annoyed does this make you feel?

[Score one point for "very annoyed", "moderately annoyed" or "a little annoyed"]

Q 15 (i) Do the aircraft ever startle you? IF "YES" SHOW CARD D AND ASK - When they startle you, how annoyed does this make you feel?

[Score one point for "very annoyed", "moderately annoyed" or "a little annoyed"]

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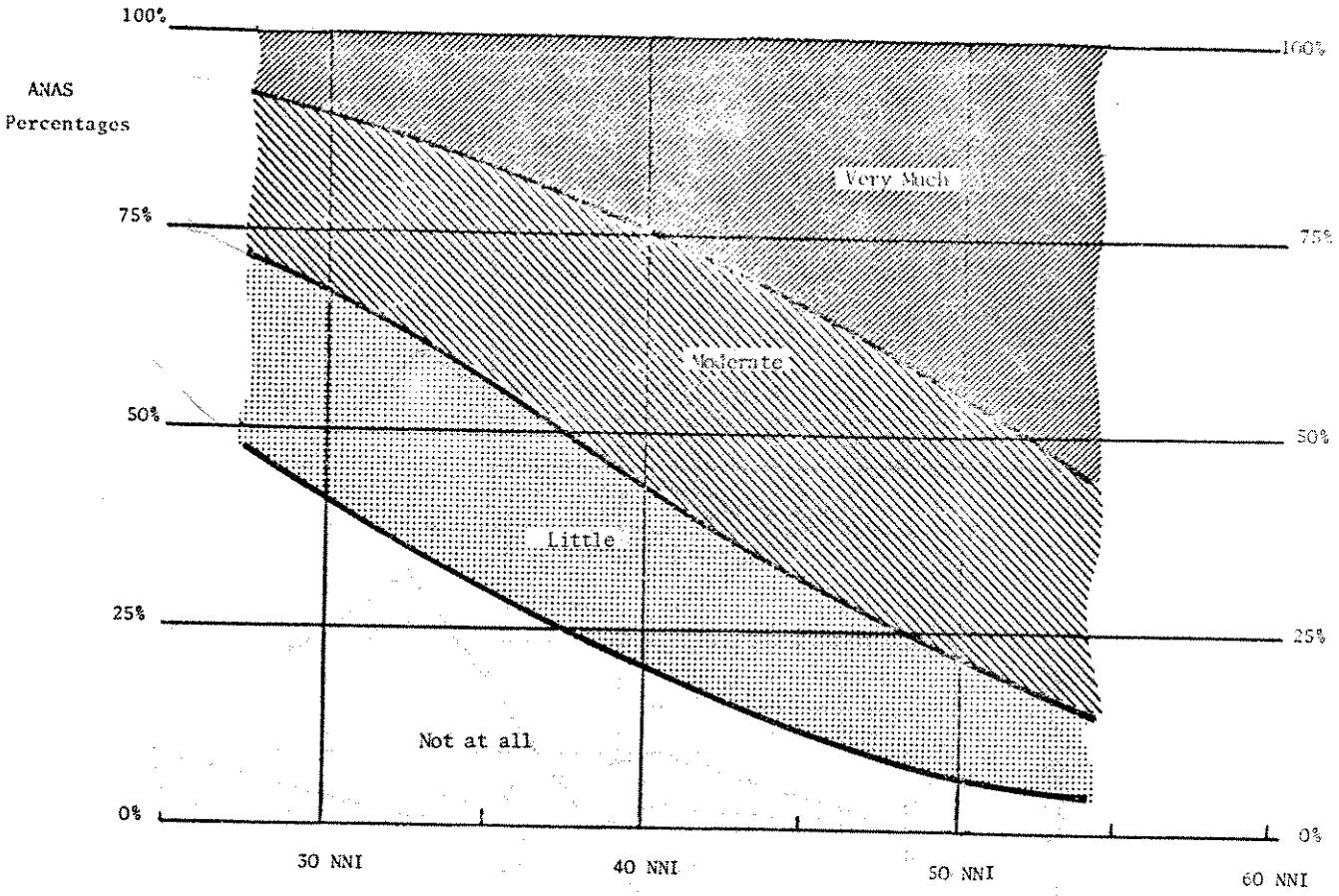
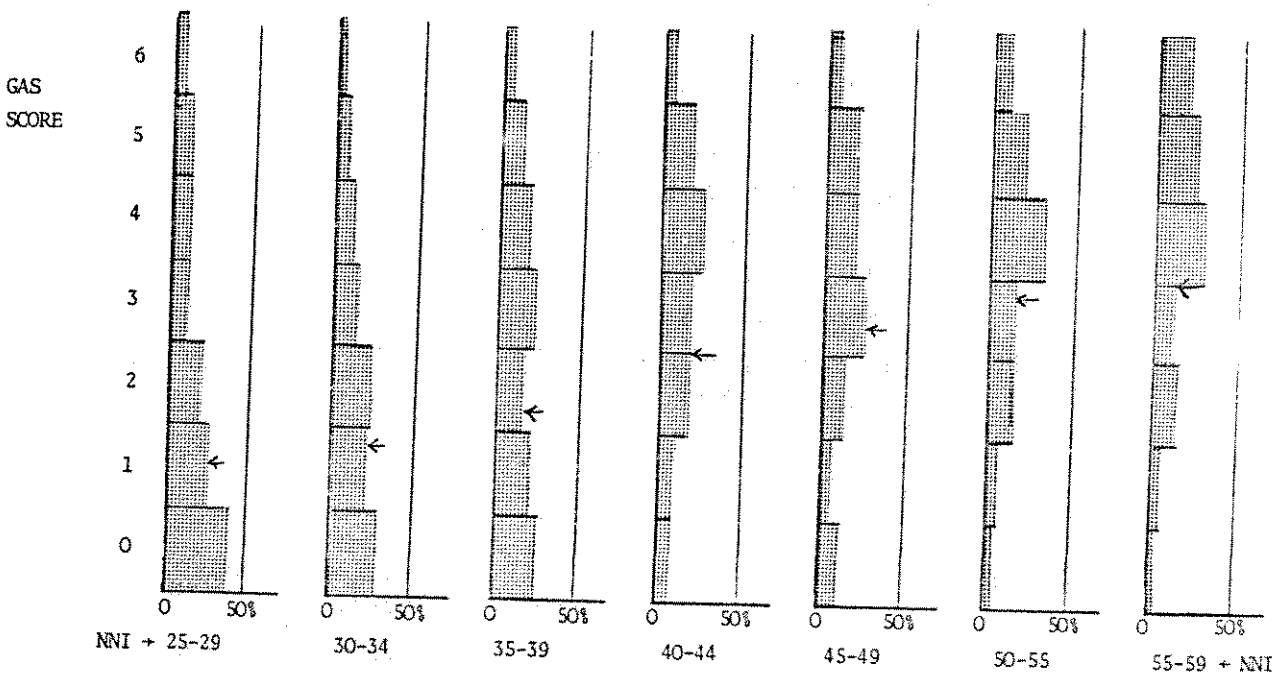
* If the respondent has no TV and has a score of 3 or more on the above system add one extra point.

Figure 2 Computation of the Guttman Annoyance Score



Note: The figure shows the ANAS Scores for people at given NNI values - the thickness of the band indicates the percentage with a particular response. Thus, for example, about 25% of respondents exposed to 40 NNI are 'very much annoyed'. (Data source: 1967 survey, DORA calculations [ref SB/20/03] using probit analysis)

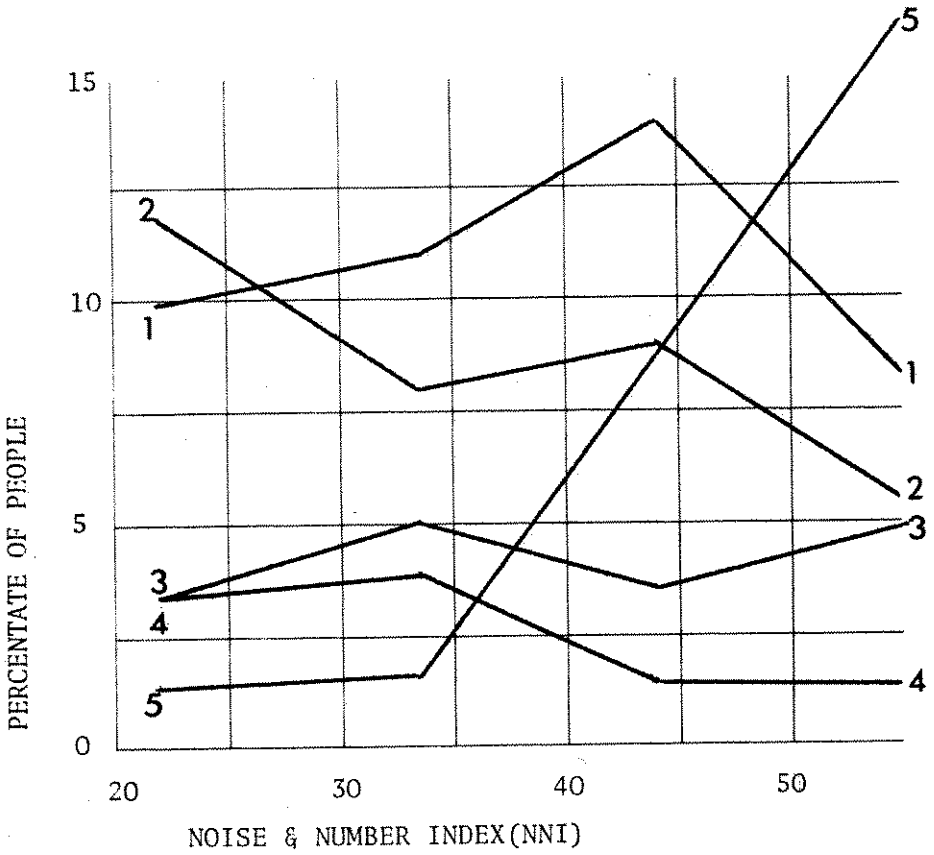
Figure 3 ANAS Scores v NNI



(Data source: Ref 2 - Table P4)

← The average GAS score representing 'COMMUNITY ANNOYANCE'

Figure 4 GAS Scores at various NNI levels



Key

1 TO GO WHERE THE CLIMATE IS BETTER

2 TO GO TO BETTER LIVING ACCOMMODATION

3 TO GET AWAY FROM SMOKE/DIRT/SMELLS

4 TO BE NEARER WORK

5 TO GET AWAY FROM AIRCRAFT NOISE

Figure 5 Percentage of people giving particular reasons for wanting to move.

(from the Wilson Committee Report)

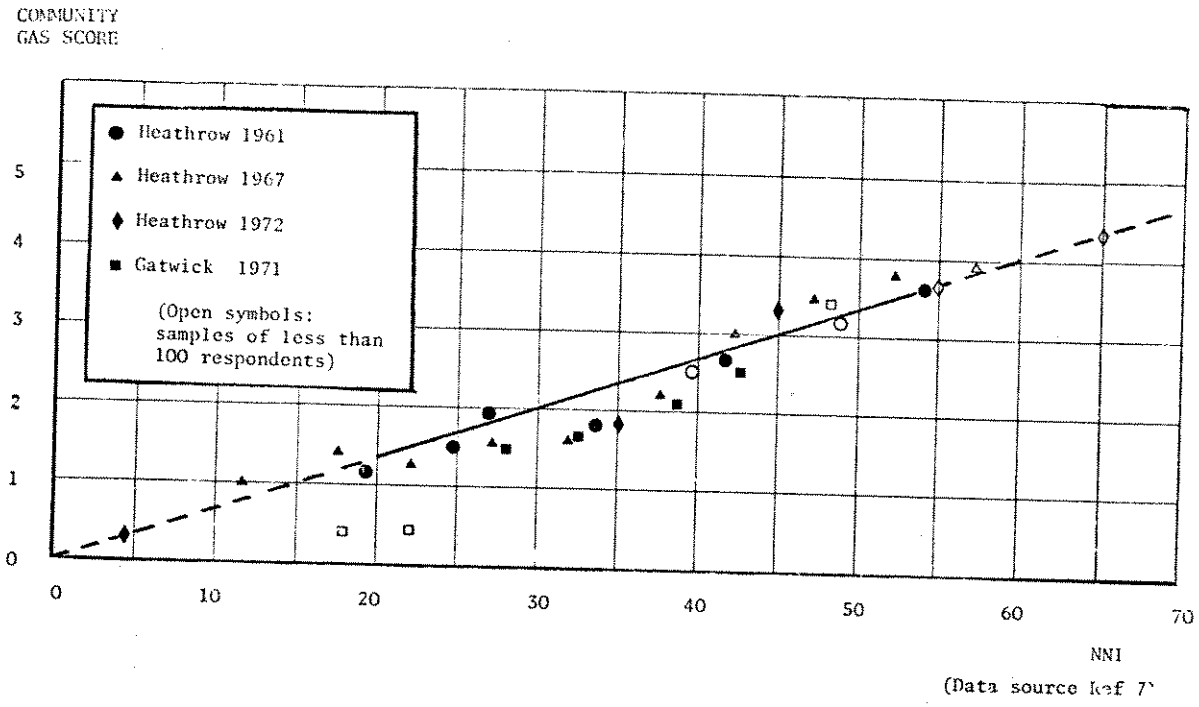


Figure 6 Calibrations of community GAS at London Airports

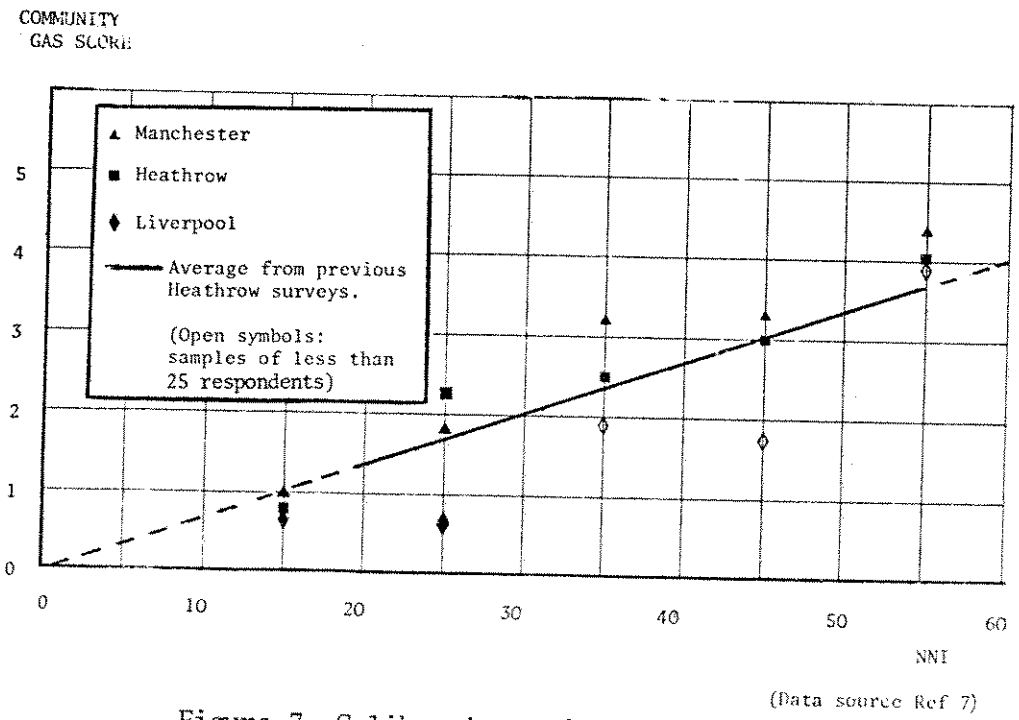


Figure 7 Calibrations of community GAS at Provincial Airports

ANNEX 1

AIRCRAFT NOISE EXPOSURE INDICES USED IN OTHER COUNTRIES

A.1 Since the 1960's, researchers working independently in many countries have defined a large number of noise exposure indices all aimed at quantifying aircraft noise exposure in a form which would correlate well with community annoyance reactions. Some of these indices, eg NNI, are the result of the direct correlation of physical noise variables with community response as elicited by social survey. Other indices are based partly on the results of psycho-acoustic laboratory investigations whilst some are formulated on the basis of 'community reaction experienced'. In some cases correction factors and weightings are employed to take account of the different times at which noise events occur although there appears to be little firm evidence to support some of the weightings used. This annex is a brief review of the more widely used indices with emphasis on their basic structure, general form and the similarities between them, rather than a discussion of their exact definitions and full details of their evolution and application - for this reason source references for indices are not given.

A.2 Noise exposure indices describe the physical exposure by the inclusion of some or all of the following characteristics of aircraft noise: almost invariably i and ii below are included in an index whilst the others are included in some indices.

i The logarithmic average peak noise level ($\overline{L}$), on one of various noise scales, of the maximum noise levels of aircraft overflights.

ii The number (N) of aircraft noise events in a given reference time (T).

iii The 'quality' of the noise eg its spectral composition and the presence of discrete frequency components, although these factors are generally incorporated within the noise scale.

iv The duration (τ) of the noise of each event above background or some other level.

v The background noise level.

vi The time of day or night or season of the year when the noise events occur.

Indices are not always defined either to include these factors or variables explicitly or in a form which is amenable to ready calculation. For this reason equivalent, sometimes approximate, forms of an index are derived.

A.3 The characteristics of the aircraft noise listed above are not of equal effect in contributing to the total correlation between a noise exposure index and community annoyance. The many social

surveys performed have demonstrated that the inclusion in an index of i and ii above - average noisiness and number of events - provides the bulk of the correlation that is attainable between noise exposure and average annoyance. This accounts for the almost universal inclusion of these two characteristics. Although inclusion of other physical characteristics in an index may improve correlation such improvement is marginal and the reason is generally that such additional variables or characteristics are themselves highly correlated with $\overline{L}$ and N. Duration is a good example: by itself duration, ie total duration of noise level above some fixed levels regarded as the threshold of annoyance, is probably as well correlated with annoyance as a function of the form $\overline{L}$ + K Log N. However when duration is included in an index already containing $\overline{L}$ and N the improvement in the correlation of the index with annoyance is marginal.

A.4 There has been criticism of the inclusion of duration and weighting of night flights - criticism at least of the form in which these factors are included in most indices. For example, Odell (Ref A1) and Pianko (Ref A2) have argued that duration of signal, where it refers to time between 10 dB-down points, assume that annoyance is a direct function of energy content of the signal and may not closely reflect the true annoyance. Ollerhead (Ref A3) has questioned the logic of the evening and night-weighting concluding that a weighting of 10 dB for night flights is probably too large and extends over too long a period, although an evening weighting of 5 or 6 dB is a clear requirement.

A.5 Many indices in current use are variants or derivatives of the Equivalent Continuous Sound Level (L_{eq}). Currently, this index is being widely proposed as a standard expression of noise exposure for aircraft noise as well as noise from other sources and it is an appropriate starting point in any examination of noise exposure indices. In the following sections indices are first defined as formally as possible consistent with brevity. These formal definitions are boxed and following these, approximate derived forms which appear in the literature are given.

A.6 L_{eq} is the notional steady sound, which at a given position and over a defined period of time, would have the same A-weighted acoustic energy as the fluctuating noise. The mathematical definition of L_{eq} over an interval from time t_1 to time t_2 is*

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \left(p_A(t)/p_{ref} \right)^2 dt \right] \quad dB \qquad (1)$$

where $p_A(t)$ is the A-weighted sound pressure as a function of time and p_{ref} is the reference pressure, 20 micro-Pascals.

For all practical purposes in the context of aircraft noise this may be written

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} 10^{L_A(t)/10} dt \right] \quad dB \qquad (2)$$

where L_A is the A-weighted sound pressure level.

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* Note all logarithms here are to base 10.

A.7 Where the noise exposure from a succession of aircraft overflights is being considered the Single Event Noise Exposure Level (L_{AX}) provides the means of computing L_{eq} without evaluation of the continuous integral. At a point on the ground the rise and fall of noise level from the passage of an aircraft is roughly triangular with time and this allows L_{AX} to be defined approximately as

$$L_{AX} = L_{A}max + 10 \log \tau/2 \qquad (3)$$

where τ is the duration in seconds between the 10 dB-down points.

A.8 Equation (2) above may now be written

$$L_{eq} = 10 \log \left[\frac{1}{T} \sum_{i=1}^{N} 10^{L_{AXi}/10} \right] \qquad (4)$$

where a succession of N aircraft noise events occurs in the reference period T and L_{AXi} refers to the ith noise event. It should be noted that L_{eq} in the present context refers to aircraft noise alone.

Using equation (3), (4) now becomes

$$L_{eq} = 10 \log \left[\frac{1}{T} \sum_{i=1}^{N} 10^{L_{A}max_i/10} \times \frac{\tau_i}{2} \right] \qquad (5)$$

where L_{Amax} and τ_i are the peak noise level and duration (between 10 dB-points) of the ith aircraft. If the logarithmic average peak noise level is $\bar{L}_A$ and the duration of each event has the same value, τ, then equation (5) is approximated by

$$L_{eq} = \bar{L}_{A} + 10 \log N + 10 \log \frac{\tau/2}{T} \qquad (6)$$

Equation (6) is of a form similar to nearly all current indices of noise exposure. The last term is a correction term for the duration (above 10 dB-down) of the aircraft noise events. This form is an approximation to the general case where the events are not of equal duration. (The International Standards Organisation (ISO) has recently revised its previous recommendations for quantifying the noise exposure from a sequence of aircraft noise events. In ISO 3891 the use of L_{eq} to quantify aircraft noise exposure is recommended).

A.9 Germany and Austria both use the Störindex (Q) as the national measure of noise exposure: this index appears to be a mathematical formulation based on combined results of psycho-acoustic experiments.

It is defined as

$$Q = 13.3 \log \frac{1}{T} \int_{T} 10^{L_A(t)/13.3} \, dt \qquad (7)$$

Comparison with (2) shows that this is a form of L_{eq} with the constant 10 being replaced by 13.3.

In application the formula is rewritten as

$$Q = 13.3 \log \frac{1}{T} \sum_{i=1}^{N} g_i t_i \, 10^{L_{Ai}/13.3} \qquad (8)$$

where i refers to the ith flyover and

T = reference period (six months with the heaviest traffic)

N = number of flyovers in the reference period

g_i = 1 (for day flights 0600-2200 hours)

5 (for night flights 2200-0600 hours)

[In Austria g_i = 10 for night flights]

t_i = duration of the noise event above the 10-dB down-points.

The approximation for T = 24 hours and t_i = 20 seconds for all values of i is

$$Q = \bar{L}_A + 13.3 \log N_c - 48.3 \qquad (9)$$

where $N_c = (N_d + 5N_n)$

N_d = number of flights 0600-2200 hours

N_n = number of flights 2200-0600 hours

A.10 The Yearly Day-Night Average Sound Level (L_{dn}) recommended by the Environmental Protection Agency in the United States is essentially an L_{eq} over the 24 hour period obtained by combining the L_{eq} for the daytime period (0700-2200 hours) and the L_{eq} for the night-time period (2200-0700 hours) where all aircraft events during this latter period incur a 10-decibel penalty. The values are computed for each day and averaged over the whole year. In January 1981 the Federal Aviation Administration (FAA) published an interim regulation prescribing requirements for airport operators who choose to develop an airport noise compatibility planning programme under the Federal programme. In this requirement noise exposure is measured by the index L_{dn}. The specific methodology for evaluating L_{dn} is too detailed for inclusion here but can be found in Ref A4. L_{dn} can be defined by

$$L_{dn} = 10 \log \frac{1}{365} \sum_{i=1}^{365} 10^{L_{dni}/10} \qquad (10)$$

where L_{dni} is the day-night average sound level for the ith day out of one year and to accord with previous notation in this annex may be written approximately as

$$L_{dn_i} = 10 \log \frac{1}{24} \left[15 \left(10^{L_{di}/10}\right) + 9 \left(10^{(L_{ni}+10)/10}\right) \right] \qquad (11)$$

where L_{di} = L_{eq} for day time period of ith day

L_{ni} = L_{eq} for night time period of ith day

It should be noted from Ref A4 that the FAA does not intend L_{dn} to apply to airports used exclusively by helicopters: moreover it is stated "The FAA has spent several years examining the appropriateness of night time penalties in general and the 10-decibel value in particular. In that examination we have relied heavily on the research and recommendations of the National Aeronautics and Space Administration, the EPA and other governmental agencies. What has been shown during that examination is that while the specific weight or value of the penalty is subject to debate in terms of both amplitude and time period of application, there is general agreement that some penalty is appropriate".

A.11 The State of California used Community Noise Equivalent Level (CNEL) up to the time of the FAA interim regulation described above: whether it can or will continue to use CNEL is not clear. CNEL is essentially the same as L_{dn} except that an evening period (1900-2200 hours) is introduced splitting the 24 hour period into three periods: a weighting of 5 dB is applied to all flights in the evening period.

CNEL can be written as

$$\text{CNEL} = 10 \log \tfrac{1}{24}\left[12\left(10^{L_d/10}\right)+3\left(10^{(L_e+5)/10}\right)+9\left(10^{(L_n+10)/10}\right)\right] \qquad (12)$$

where L_d = L_{eq} for day time period

L_e = L_{eq} for evening period

L_n = L_{eq} for night time period

Both L_{dn} and CNEL are approximated by

$$\bar{L} + 10 \log N_c - 39 \qquad (13)$$

where N_c = $(N_d + 10N_n)$ for L_{dn}

and $(N_d + 3N_e + 10\ N_n)$ for CNEL

N_d, N_e, N_n being the number of flights in the day, evening and night respectively.

A.12 The noise exposure index proposed by ICAO is the Weighted Equivalent Continuous Perceived Noise Level (WECPNL): it is used in Italy, Finland and Japan, although sometimes with some modification. As in the case of L_{dn} and CNEL it is a mathematical formulation which is a distillation of other indices but is not

directly related to any social survey. WECPNL is virtually identical to CNEL, except that noise levels are expressed on the EPNdB scale (which implicitly includes the duration of the noise event within the scale) rather than the dBA scale and an arbitrary adjustment of - 5dB, 0, or 5dB is made to the computed value of the index depending on the average monthly climatic conditions.

A.13 Two other indices are in use in the United States, although the Composite Noise Rating (CNR) originated by the US Air Force has now been largely superseded by the FAA index - the Noise Exposure Forecast (NEF). Both these indices are loosely based on 'case histories of community reactions to aircraft noise'. NEF is defined as

$$NEF = 10 \log \sum_i \sum_k 10^{NEF_{ik}/10} \qquad (14)$$

where $NEF_{ik} = EPNL_{ik} + 10 \log [nd_{ik} + 16.67\ nn_{ik} - 88]$

where k = aircraft type or class

i = flight path segment

EPNL = Effective Perceived Noise Level

nd = number of day operations (0700-2200 hours)

nn = number of night operations (2200-0700 hours)

NEF is approximated by

$$NEF = \bar{L}_{EPN} + 10 \log N_c - 88 \qquad (15)$$

and CNR is approximated by

$$CNR = \bar{L}_{PN} + 10 \log N_c - 12 \qquad (16)$$

where $N_c = (N_d + 16.7N_n)$ in both cases.

A.14 Two indices with a striking similarity to those described above are the Australian Annoyance Index (AI) and the South African Noisiness Index ($\overline{NI}$). AI is defined as

$$AI = 10 \log \Sigma\ 10^{L_{PN}max/10} \qquad (17)$$

which approximates to

$$AI = \bar{L}_{PN} + 10 \log N \qquad (18)$$

The basic daytime expression for computing $\overline{NI}$ is

$$\overline{NI} = 10 \log \sum_{i=1}^{N} \frac{t_i}{t_o} 10^{L_{Ai}/10} \qquad (19)$$

where t_i = effective duration of ith event

$t_o = 8.64 \times 10^4$ seconds (= one day).

Appropriate additional constants may be introduced to adjust for day, evening and night hours or for various seasons of the year.

$\overline{NI}$ may be approximated by

$$\overline{NI} = \bar{L}_A + 10 \log N - 39.4 \qquad (20)$$

AI originated from an analysis of complaints around Sydney Airport whilst $\overline{NI}$ was based on a preliminary social survey of community response to aircraft noise exposure.

A.15 In both France and the Netherlands the indices in use are based on social survey results. In the Netherlands the Kosten Committee described an index called Total Noise Rating B where

$$B = 20 \log \sum_{i=1}^{N} a_i 10^{L_{Ai}/15} - 157 \qquad (21)$$

where N = number of flyovers in one year

a_i = 10 (2300-0600 hours)

= 8 (0600-0700 hours)

= 4 (0700-0800 hours)

= 1 (0800-1800 hours)

= 2 (1800-1900 hours)

= 3 (1900-2000 hours)

= 4 (2000-2100 hours)

= 6 (2100-2200 hours)

= 8 (2200-2300 hours)

Where $a_1 = 1$ for daytime hours and where N is the average number of flights per 24 hour day this reduces to

$$\frac{B}{1.33} = \bar{L}_A + 15 \log N - 80 \qquad (22)$$

A.16 The Psophic Index used in France is defined for daytime (0600-2200 hours) by

$$\mathcal{N}_{day} = \bar{L}_{PN} + 10 \log N - 30 \qquad (23)$$

there are different forms of the index for night-time

$$\mathcal{N}_{night} = \bar{L}_{PN} + \lambda \log (3N_1 + N_2) + K \qquad (24)$$

where $\lambda = 10$ for $(3N_1 + N_2) \leq 64$

$\lambda = 6 \log (3N_1 + N_2) - 1$ for $(3N_1 + N_2) > 64$

$K = -51$ for take-off

$K = 56$ for landing.

A.17 The similarity of the various indices described above is apparent from the comparison of approximate forms given below, all based on the assumption of daytime operation and an effective duration of 10 seconds for noise events. $\bar{L}$ in each case is the logarithmic average of peak noise levels.

$$Q = \bar{L}_A + 13.3 \log N - 48$$

$$L_{dn} = \bar{L}_A + 10 \log N - 39$$

$$CNEL = \bar{L}_A + 10 \log N - 39$$

$$WECPNL = \bar{L}_{EPN} + 10 \log N - 39$$

$$NEF = \bar{L}_{EPN} + 10 \log N - 88$$

$$CNR = \bar{L}_{PN} + 10 \log N - 12$$

$$AI = \bar{L}_{PN} + 10 \log N$$

$$\overline{NI} = \bar{L}_A + 10 \log N - 39$$

$$\frac{B}{1.33} = \bar{L}_A + 15 \log N - 80$$

$$\mathcal{N} = \bar{L}_{PN} + 10 \log N - 30$$

N.B. Some of the equations appear in the literature with the constants taking different values. This arises as a result of some authors using different definitions of duration.

A.18 The indices described above are all of the general form

$$\bar{L} + k \log N$$

In all cases k = 10 except in the Störindex Q (k = 13.3), Total Noise Rating B (k = 15) and NNI (k = 15). The prevalence of indices with k = 10 is due to the equal energy principle embodied in L_{eq}. Otherwise the main differences between indices is the scale on which L is measured and the weighting times of the day. In respect of noise scales it matters little whether L_{PN} or L_A is used since L_{PN} is closely approximated by $L_A + 13$ but the use of L_{EPN} implies a correction for duration within the noise scale. In regard to the weighting systems and the periods of the day or night to which they apply there seems to be little empirical evidence to support the values used.

REFERENCES

A1 Odell A.H.

' Problems in predicting aircraft Noise Exposure'

Noise Control Engineering - July- August 1977

A2 Pianko M.

'Study of Aircraft Noise during Take-off'

L'Aeronautique et L'Astronautique 18 (1970-72)

A3 Ollerhead J.B.

'Variations of Community Response to Aircraft Noise with Time of Day'

Noise Control Engineering - Sept-Oct 1978

A4 Federal Aviation Administration

'Establishment of New Part 150 to Govern the Development and Submission of Airport Operator's Noise Compatibility Planning Programs and the FAA's Administrative Process for Evaluating and Determining the Effects of those Programs'

Federal Register/Vol 46, No.16/ Monday, January 26, 1981/ Rules and Regulations