euro•noise '92

THE USE OF L_{eq} AS AN AIRCRAFT NOISE INDEX

Roy E Cadoux

Deputy Head, Environmental Noise Research & Analysis
Civil Aviation Authority

1. INTRODUCTION

In order to assess the impact of aircraft noise on people living near airports, a number of methods have been developed to quantify the noise in terms which indicate its likely adverse effects upon people. These effects are numerous and complicated and, in practice, it has proved necessary to average both the human response variables and the noise exposure. The most commonly used index of human response to aircraft noise intrusion is 'average annoyance', as measured for example by a Guttman Annoyance Scale (see Glossary).

The sounds of aircraft flying to or from a nearby airport are usually easily identified as such; they often exceed the background (usually road traffic noise) by margins of 20 dB or more. For this reason it has become normal practice to quantify aircraft noise exposure using event-based indices rather than the distribution statistics employed to quantify road traffic noise and other more continuous sounds. The magnitude of the noise is therefore defined in terms of the average sound level and the number of aircraft noise events during a specified period of time.

In the UK, the Department of Transport (DTp), which has responsibility for determining Government policy on aircraft noise, uses contours of aircraft noise exposure both to record the changes which occur from year to year (contours for the London airports are published annually), and to forecast the likely environmental effects of proposed future changes in aircraft and airport operations. They are also used by other national and local government agencies for development control purposes; they are often presented in evidence at Public Inquiries into airport developments. Typical L_{eq} contours for Heathrow Airport are shown in Fig 1.

This paper describes the use of L_{eq} for quantifying aircraft flight-noise exposure in the UK, and the development of the CAA's aircraft noise contour model.

THE USE OF L_{eq} AS AN AIRCRAFT NOISE INDEX

2. HISTORICAL OVERVIEW

The UK's official aircraft noise exposure index can be traced from the Wilson Committee [1], which derived the NNI (Noise and Number Index - see Glossary) [2, 3] in the early 1960's based on social survey studies around Heathrow. Since then the CAA has maintained and developed a computer model to generate contours of aircraft air noise exposure. These are based on annually updated input information describing noise levels, height profiles, flight routeings and traffic data.

While Inquiry Inspectors and government policy makers, on the whole, have accepted NNI as a valuable planning tool, its use has been subject to criticisms from environmental groups. Research continued to determine how well NNI related to people's perception of annoyance from aircraft noise. In particular, the UK Aircraft Noise Index Study (ANIS) was carried out by the CAA [4] in 1984 to investigate whether improvements might be possible.

Important conclusions of the ANIS Report [4] were that a good fit to aircraft noise annoyance responses is given by L_{eq}(24 hr) (see Glossary), and that continued use of NNI might have lead to inaccurate assessments because of its particular combination of noise and number terms, and its 80 PNdB cut-off. L_{eq} also has the great advantage that it is widely used for quantifying other kinds of noise exposure. Following this work the Department of Transport initiated a public consultation in 1986 on the advisability of adopting L_{eq}(24 hr) as the UK aircraft noise index.

A total of 61 submissions were received during the consultation process, of which four expressed opposition to the replacement of NNI by L_{eq}, and five were neutral. Comments and criticisms, many of them very detailed, covered almost every aspect of the ANIS study, and a large amount of work was undertaken to consider carefully all the points raised [5]. Although support for the adoption of L_{eq} was widespread, most consultees expressed reservations about the details of the proposals, the main area of concern being the use of a 24 hour index, ie without special consideration for disturbance in the evening or night.

There had in fact been earlier CAA studies of the effect of noise on sleep [6, 7], on the basis of which it was decided to distinguish between 'day' (0700 to 2300 local time) and 'night' (2300 to 0700: the night-time noise monitoring period at the London airports) in the application of noise indices. Night contours using L_{eq}(8 hr) have been adopted by DTp to evaluate the effectiveness of restrictions on night operations at airports. The daytime L_{eq}(16 hr) metric does in fact correlate about as well with aircraft noise disturbance response as does L_{eq}(24 hr), and therefore L_{eq}(16 hr) has been used as the daytime metric. The practice in the previous NNI scheme was to compute noise exposures for the average summer day, by using input data appropriate to the period mid-June and mid-September (which usually corresponds to the busiest period). This procedure has been continued in the calculation of L_{eq}.

3. THE CHANGE FROM NNI TO Leq

L_{eq}(16 hr) was officially introduced as the UK index of aircraft noise exposure in 1990 [8], and the aircraft noise contour model (ANCON) was developed [9]. Both L_{eq} and NNI contours for the London airports were published for the years 1988 and 1989. From 1990 only L_{eq} contours will be produced for the London airports.

Although there is no unique relationship between L_{eq} and NNI, the L_{eq} contours for the major airports, published at 3 dBA intervals between 57 and 72 dBA, correspond approximately to the NNI contour bands between 35 and 60 NNI as follows:

Leq	NNI
57	35
60	40
63	45
66	50
69	55
72	60

4. INPUT DATA

The philosophy behind the CAA's noise modelling procedures, for nearly thirty years, has been to use up-to-date measured information as input data, appropriate to the airport under consideration. This ensures that the model does properly reflect ongoing changes in aircraft performance, noise emissions, aircraft types and air traffic control practice.

Large numbers of measurements are made at appropriate airports during the summer of each year. In addition to the aircraft noise levels measured at a range of points around each airport, radar information is used to give the aircraft position, height and speed for each flight. Radar information is also used to determine the mean height and speed profiles for each aircraft type, and the mean tracks and lateral dispersion distributions for each route. Analysis of the Air Traffic Control runway logs provide information on runway utilisation (average percentage of movements on each runway) and traffic mix (details of numbers of movements of each aircraft type on each route).

The first stage of data analysis is to determine for each aircraft type a set of L_{Amax} 'Reference Noise Levels' (L_{ref}) at 152.5m (500 ft) from the aircraft), and the corresponding average height and speed profiles. The L_{ref} values and height profiles are such that the maximum noise levels calculated from them match the average measured noise levels for each type at all measurement positions.

Mean flight tracks for each route and the mean height profiles for each type are input as a series of straight-line segments. Lateral dispersion about the mean tracks is modelled by including a number of subsidiary 'dummy' tracks either side of the mean, carrying an appropriate proportion of the total traffic for that route.

5. CALCULATION OF L_{eq}

ANCON determines contours by calculating values of L_{eq} at a large number of individual grid points based on the approximation:

$$L_{eq} = L_{SE} + 10 \log N - 10 \log T$$

where N is the number of aircraft events, T is the time period in seconds and L_{SE} is the logarithmic average sound exposure level of the N events.

To estimate the average sound exposure level at any grid point for all flights, the noise contributions from each straight-line segment of each flight path are summed, ie adding together each different aircraft type on each route to or from the airport (Fig 2).

The calculation of the contribution from a particular segment is a two-stage process. The first stage is to determine a 'base' sound exposure level, which is the sound exposure level that the aircraft would generate if it flew along a locally coincident but infinitely long path at uniform speed V, emitting constant noise, and is given by:

$$\delta L_{SE\infty} = L_{max} (L_{ref}, S_p) + 10 \log S_p/V + \delta L_{\infty}$$

where L_{max} is the peak level calculated as a simple function of L_{ref} and slant range S_p. The second term represents a 'duration correction' to convert L_{max} to L_{SE}, and the final term is an adjustment (to account for the effects of source directivity), determined from analysis of measured data. The model was designed in this way for compatibility with the NNI model, so that use could be made of the existing database.

The second stage is to account for the fact that the actual finite length of the segment restricts the noise energy from that segment to a fraction F of the infinite line value. This is termed the 'noise fraction' of the segment, and is calculated as a function of the angles subtended by the ends of the segment - a technique adapted from the FAA's Integrated Noise Model [10], based on the figure-of-eight directivity pattern of the sound radiated by a lateral dipole source.

Except at high angles of elevation, the value of sound exposure level is further reduced by the effects of lateral attenuation (D), which is calculated by the SAE procedure for jet aircraft noise [11]. The contribution of one segment is thus:

$$\delta L_{SE} = \delta L_{SE\infty} + 10 \log F - D$$

For airports with many different aircraft types and routes (especially those involving turns), noise contour modelling can involve a very large number of calculations. Computing time is minimised by excluding from the calculations those type/segment combinations whose peak noise levels lie below a cutoff threshold (set at 55 dBA).

6. GROUND NOISE

Special procedures are applied in modelling noise when aircraft are on or near to the runway - ie during start of roll, runway acceleration, initial climb, and during the landing ground roll to include the use of reverse thrust (see Glossary). The model excludes sources of static or manoeuvring ground noise, such as taxiing and engine testing, which are invariably treated separately in planning applications etc.

7. FURTHER MODEL DEVELOPMENTS

The model in its current state is by no means the final version. As with its NNI predecessor, ANCON will be subject to repeated testing and refinement through a continuing process of data collection, analysis and comparisons of theory and measurement.

8. REFERENCES

[1] COMMITTEE ON THE PROBLEM OF NOISE, 'Noise: Final Report', HMSO Cmnd 2056, July 1963

[2] DIRECTORATE OF OPERATIONAL RESEARCH AND ANALYSIS, 'The Noise and Number Index', CAA DORA Comm 7907, September 1981

[3] L I C DAVIES, 'A Guide to the Calculation of NNI', CAA DORA Comm 7908, Second Edition, September 1981

[4] P BROOKER, J B CRITCHLEY, D J MONKMAN & C G RICHMOND, 'United Kingdom Aircraft Noise Index Study: Final Report', CAA DR Report 8402, January 1985

[5] J B CRITCHLEY & J B OLLERHEAD, 'The Use of Leq as an Aircraft Noise Index', CAA DORA Report 9023, September 1990

[6] DIRECTORATE OF OPERATIONAL RESEARCH AND ANALYSIS, 'Aircraft Noise and Sleep Disturbance: Final Report', CAA DORA Report 8008, August 1980

[7] DIRECTORATE OF RESEARCH, 'Noise Disturbance at Night near Heathrow and Gatwick Airports: 1984 Check Study', CAA DR Report 8513, February 1986

[8] DEPARTMENT OF TRANSPORT, 'Change Agreed to Daytime Noise Index for Aircraft Noise', DTp Press Notice No 304, September 1990

[9] J B OLLERHEAD, 'ANCON: The CAA Aircraft Noise Leq Contour Model - Version 1', CAA CS Report 9120 (in preparation)

[10] US FEDERAL AVIATION ADMINISTRATION, 'FAA Integrated Noise Model User's Guide', FAA Report FAA-EE-81-17, October 1982

[11] SOCIETY OF AUTOMOTIVE ENGINEERS, 'Prediction Method for the Lateral Attenuation of Airplane Noise During Take-off and Landing', Aerospace Information Report AIR 1751, 1981

9. GLOSSARY

Guttman Annoyance Scale - a psychological scaling technique used for attitude measurement. The one used for aircraft noise annoyance combines measures of annoyance and disturbance.

L_{eq} - Equivalent Continuous Sound Level, measured for present purposes in dBA. The measurement period is denoted in brackets - 0700 to 2300 is L_{eq} (16 hr) and 2300 to 0700 L_{eq} (8 hr). Throughout the paper L_{eq} refers to the total noise energy from the aircraft rather than that from all sources.

NNI - Noise and Number Index given by:

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

where L_{PN} is the average Perceived Noise Level (a special scale used to measure aircraft noise, approximated by $L_{PN} = L_{Amax} + 13$) and N is the number of aircraft events in an average day with noise levels greater than 80 PNdB. The average day duration defined as 0700 to 1900 hrs local.

Reverse Thrust - forward-directed power applied by aircraft on landing, shortly after touchdown on the runway, to assist braking.

Start of roll - The period before an aircraft takes off, from when the throttles are first increased to take-off power to when the aircraft rolls down the runway.

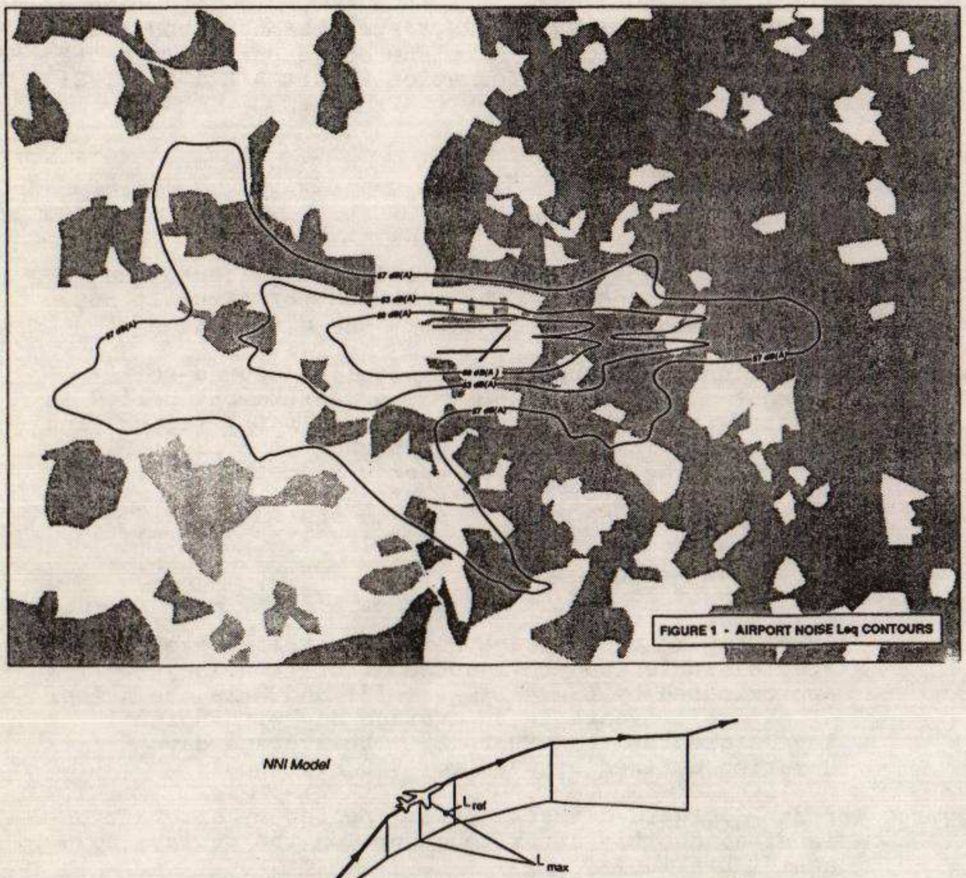

FIGURE 1 - AIRPORT NOISE Leq CONTOURS

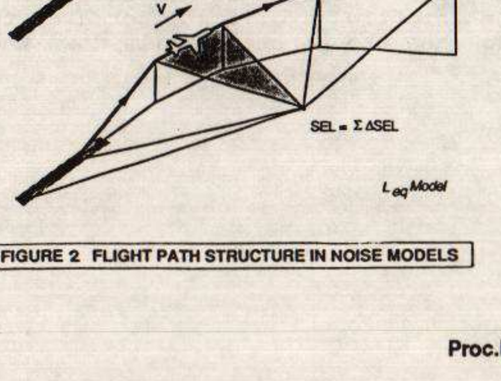

FIGURE 2 FLIGHT PATH STRUCTURE IN NOISE MODELS