AIRCRAFT NOISE MODEL VALIDATION – HOW ACCURATE DO WE NEED TO BE?

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1. INTRODUCTION

The Environmental Research and Consultancy Department (ERCD) of the Civil Aviation Authority provides independent technical advice to the Department for Transport. This includes production of annual noise exposure contours for Heathrow, Gatwick and Stansted airports. ERCD carries out additional research into aircraft noise and its effects on behalf of the UK Aircraft Noise Monitoring Advisory Committee (ANMAC). Recent studies have included research into night time ground noise, noise from arriving aircraft and the effects of aircraft noise at night. ERCD also act as technical advisors on aircraft noise issues to UK representatives at international meetings of ICAO, ECAC and SAE.

An increasing proportion of ERCD's time is devoted to the provision of noise contours for regional airports and local authorities. ERCD has also advised Eurocontrol and the European Commission on the environmental effects of aviation.

The European Commission's noise mapping directive, published in July 2001, has prompted noise consultants and researchers in the field to question the accuracy of noise mapping software. Producers of commercial noise mapping software make claims about accuracy, but some are beginning to ask about the validation exercises that underpin these claims. This paper deals specifically with this issue with respect to aircraft noise modelling, and gives evidence that small changes in noise contour maps can have a dramatic effect on the numbers of people exposed to certain levels of noise.

2. WHY MODEL AIRCRAFT NOISE?

Airports, airlines, local and national authorities and people living local to airports all have an interest in the noise climate around an airport. Historically, this has led to efforts to evaluate and portray the noise climate so that the performance of the airport and its users can be monitored. There are two ways to evaluate the effect of aircraft operations on the noise climate around airports; monitoring and modelling. In a perfect world airports would deploy huge arrays of noise monitors to measure aircraft noise; in reality, this option would be excessively costly and the visual intrusion caused by such an array of microphones would be unacceptable to the general public. Aircraft noise models are mathematical representations of the real world. Such models are able to produce accurate estimates of the noise exposure experienced around airports at a reasonable cost. Aircraft noise models can also be used to predict future noise levels and carry out 'what if' analyses to examine options for noise reduction and mitigation. The use of noise modelling therefore can reduce the need for large arrays of noise monitors.

The use of a noise model does not however mean that noise monitoring is unnecessary. If a noise model is to accurately portray the aircraft noise impact around an airport, that model must be driven by data from noise monitoring, and other sources, such as airport radar and aircraft flight data recorder information. The importance of these data sources in the overall accuracy of noise modelling are considered later in this paper.

3. NOISE MODELLING METHODOLOGY

ERCD uses internationally recommended guidance for the modelling of aircraft noise in the UK, and computes contours using the UK aircraft noise model, ANCON version 2, which it maintains and runs on behalf of the Department for Transport. Aircraft noise exposure contours are normally computed as a 16 hour Leq for an average summer day based on data collected over a 92 day period from mid June to mid September. The average summer day definition dates from the Wilson Committee (1961) and is considered to be appropriate because this tends to be when the air traffic is most intensive, aircraft passengers loads are generally higher, and warm summer temperatures result in diminished aircraft performance. It is also typically when the resident population is more likely to have windows open and wish to use their gardens.

Aircraft noise exposure contours are normally calculated from 57 dBA Leq to 72 dBA Leq at 3dB intervals. The procedure for producing these contours involves calculating the total noise exposure at a large number of grid points across the area under consideration.

Most large airports have noise and track keeping (NTK) systems, which take radar data from air traffic control radars and combine it with flight information such as the aircraft callsign, tail number, type and destination. At the London airports the NTK system captures data from fixed and mobile noise monitors around the airports, to be matched with the operational data. It is this information that keeps noise model databases up to date.

ANCON version 2 calculates Leqs at each point on a grid around the airport by summing the Sound Exposure Levels (SEL) caused by all passing aircraft. To compute the SEL at a particular grid point requires the following data:

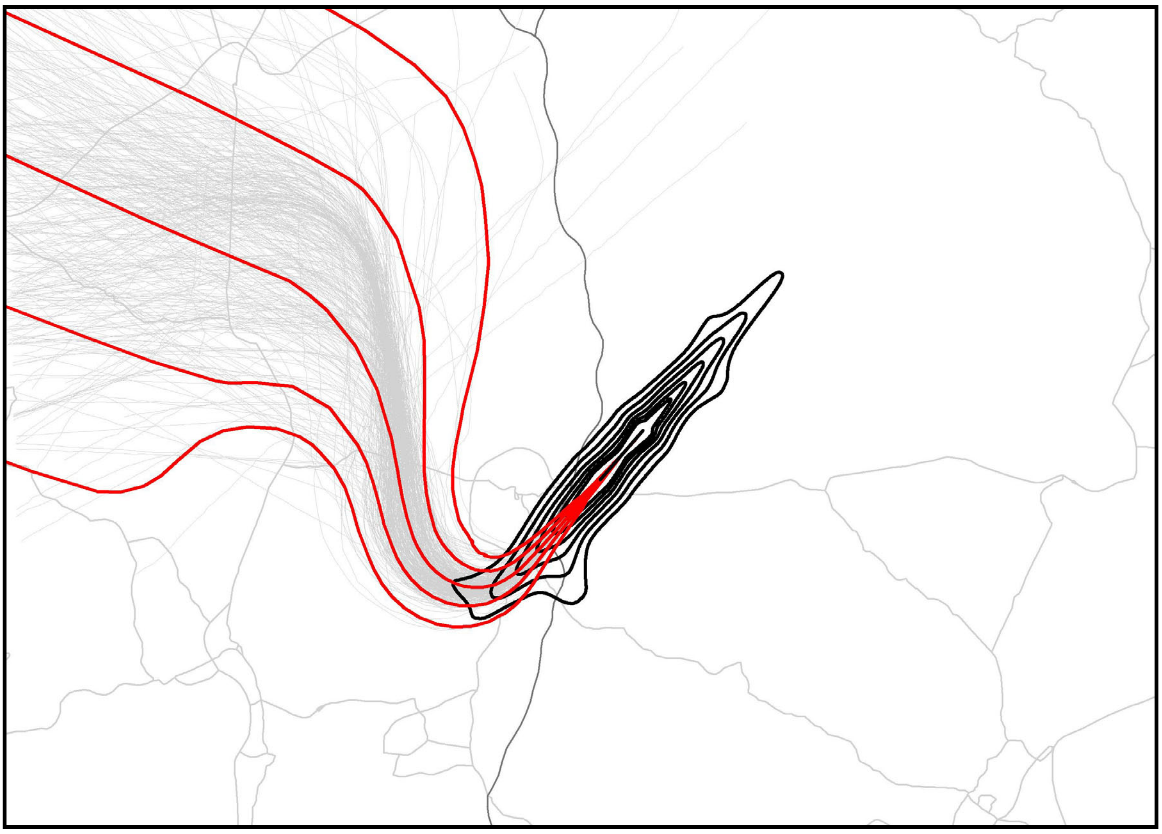
- aircraft position – in 3 dimensions;
- aircraft velocity – relative to the grid point; and
- engine power setting/thrust.

The aircraft position and velocity are available from radar data in the NTK system. Engine power setting/thrust can be derived from the mass of the aircraft (estimated) and aircraft performance data. Applying this data to a noise-power-distance (NPD) curve gives the SEL for an aircraft noise event. A ‘noise fraction’ correction is applied to allow for the fact that the aircraft is modelled as flying along a finite segment. Using this process, the actual performance of an aircraft takeoff or landing is modelled instead of the approach used by some aircraft models which assume a standardised takeoff or landing procedure that may or may not reflect operations at a particular airport.

Even with current technology, PC processing speed does not permit each individual aircraft movement to be considered separately. Movements are allocated to different aircraft ‘types’. Aircraft that are noise significant by virtue of their large numbers or level of noise emissions are represented individually by type and specific engine, e.g. B747-400 with P&W engines. Some are grouped together with other types having similar noise characteristics. For each ‘type’ average profiles of height and speed against track distance are calculated from analysis of radar data. These average profiles are subdivided into appropriate linear segments.

Average ground tracks for each route are calculated based on radar data. Accurate noise exposure estimation requires a realistic simulation of the lateral scatter of flight tracks actually observed in practice. This is done by creating additional tracks a number of standard deviations either side of the central track. The standard deviations and the proportions of traffic allocated to each route are determined by analysis of the radar data. An example of the analysis of track data to give mean tracks and the associated dispersions is shown in Figure 1.

Figure 1: Analysis of radar tracks for a departure route at Stansted airport



At each grid point the logarithmic average of the SEL for the 16-hour period is computed and from this Leq can be obtained. This gives the Leq at a large number of grid points from which contours – the curve describing points of equal Leq – can be drawn.

Contours are calculated according to the actual use of runways in the particular summer period under consideration and are also calculated using a 'standard' modal split using a 20 year moving average. Modal split refers to the percentage of landings and takeoffs on each runway.

In the absence of an NTK system at a particular airport, contours can still be computed. In such cases, radar and noise data can be gathered from alternative sources, or existing performance data from similar airports can be used. However, the accuracy of such noise contours will be diminished relative to the accuracy of contours generated from an airport NTK system. Thus, the preference is always for the use of local data to represent local operations.

4. DIFFERENT NOISE MODELS – DIFFERENT CONTOURS

There are a number of aircraft noise models in use around the world today. Most use common methodologies for noise prediction; on the whole they are driven by data describing the aircraft fleet at an airport, the flight paths and height profiles flown and the noise performance characteristics of the aircraft.

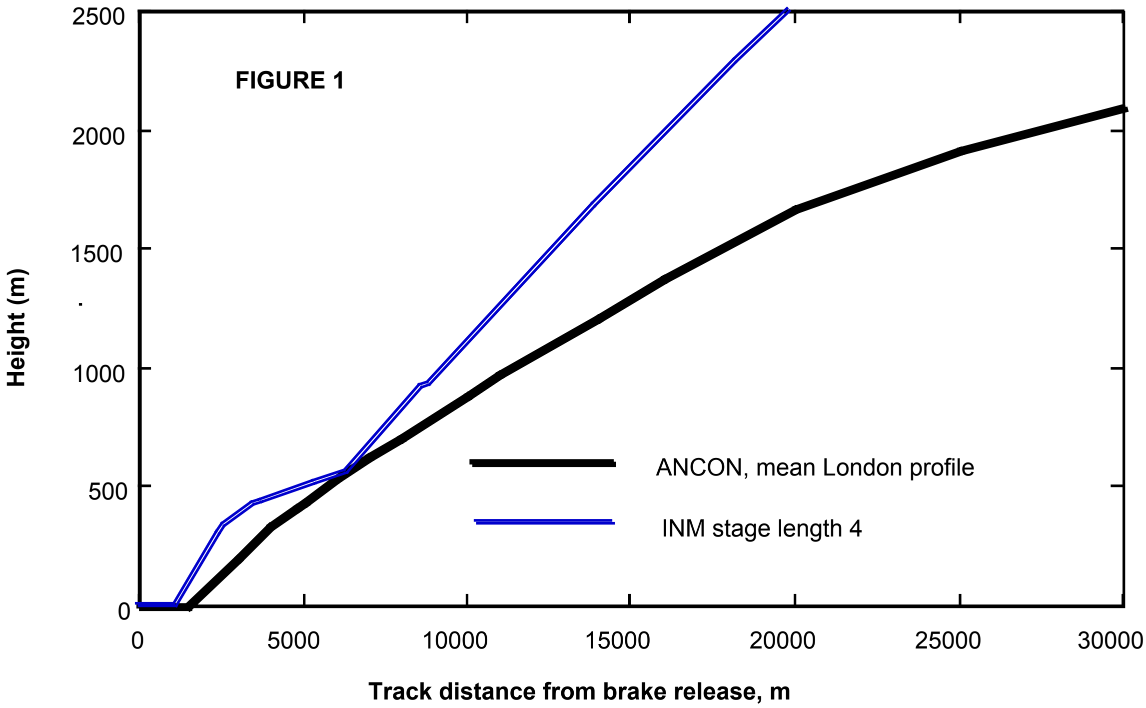
The FAA's Integrated Noise Model (INM) is well known amongst noise modelling specialists. The software is widely available and adopts the practices recommended by the Society of Automotive Engineers (SAE). Countries that use INM include Australia, Belgium, Greece, Hong Kong , Spain and USA. Other countries use variants of INM, for example, Denmark and Finland use DANSIM, their own model, with the INM database. The latest version of INM – version 6.0 – includes 170 aircraft types in its database.

There are significant similarities between INM and ANCON version 2 having both been created from the same guidance material produced by ICAO, ECAC and SAE. However, for a given airport and a given set of operations, it is possible to produce notably different contours, in terms of both size and shape, from the two models. These differences can be accounted for by two primary data source differences:

4.1 Flight Profile Data

Core to the prediction of aircraft noise on the ground are the basic assumptions relating to how aircraft are operated during takeoff and landing. The INM includes default flight profile data built into its databases. All versions of INM assume that departing aircraft take off at full power and follow a prescribed departure procedure in terms of thrust/flap management. In reality, analysis of operations at UK airports has found that virtually all airlines regularly use minimum safe takeoff power to prolong engine life; thrust/flap management procedures also vary from airline to airline. Figure 2 compares the average height profile of B767-300 aircraft operating from London compared to the default INM profile that is appropriate to the average stage length. This clearly shows that the practical experience of flying aircraft at UK airports tends to be somewhat different from INM's standardised flight profiles.

Figure 2: Average height profile of B767-300



For landing operations INM assumes aircraft descend at a constant 3 degrees from 6,000ft whilst decelerating in a smooth manner. In reality aircraft routinely descend more steeply from stack level and then intercept the 3 degree instrument landing system glidepath following a period of level flight. In addition speed controls are often applied at capacity constrained airports, preventing pilots from decelerating in a smooth manner. Hence source noise emission is often greater (due to steeper descent followed by level flight) than assumed by INM, and propagation distances are reduced. Both factors result in higher noise levels on the ground than might be modelled using the default constant 3 degree descent from 6,000ft.

4.2 Noise-Power-Distance (NPD) Data

It is possible for the specialist user to make adjustments to the standard flight profile assumptions based on detailed knowledge of current airline and ATC procedures. However, even when the accomplished user adjusts the standard INM flight profile assumptions to more accurately reflect typical flight operations at UK airports, predicted and measured aircraft noise levels may still not agree due to differences between the industry supplied NPD curves provided with INM and actual monitored noise performance at UK airports. In the INM, NPD data are only available for a limited number of specific aircraft-engine combinations. For many aircraft types operating at UK airports specific data is not available in the INM database. In such cases, the user must identify substitute NPD data for the aircraft type in use, which can result in inaccurate prediction of aircraft noise levels.

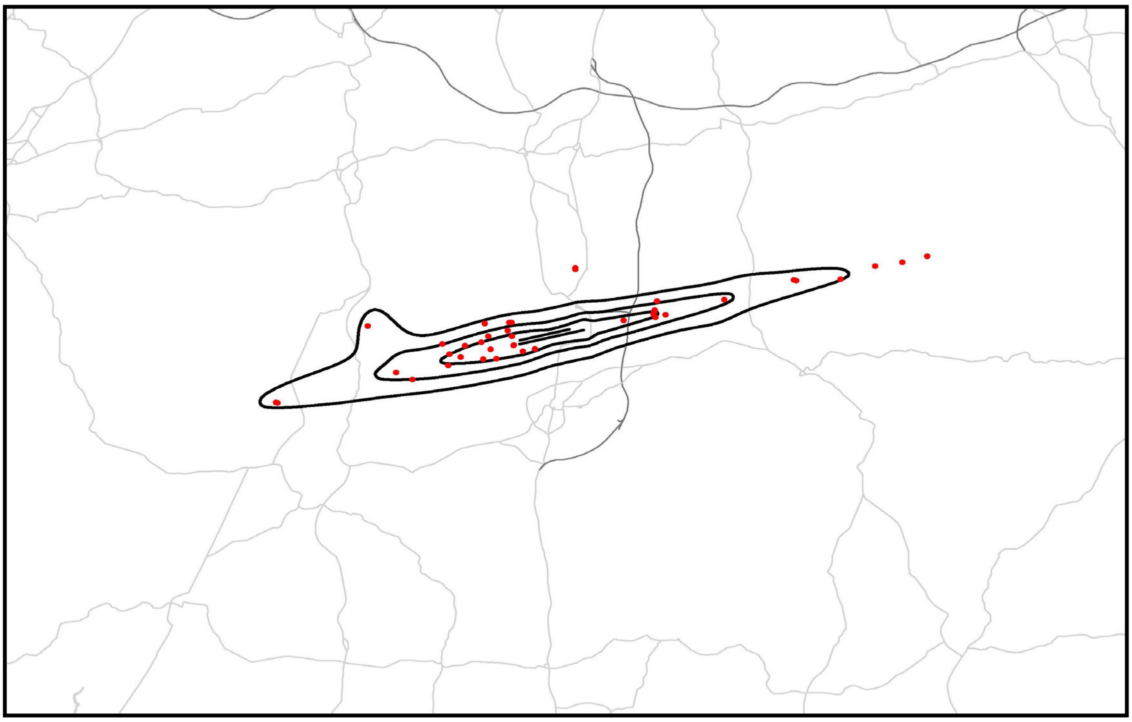
The overall potential difference in contour area taking account of the two factors above can be of the order of 20 to 30%.

5 NOISE MODEL VALIDATION AND ACCURACY

As noise modelling outputs are often used as a tool to aid airport policy formulation, a check on environmental performance between airports or the basis for Section 106 or other planning agreements, it is vital that they accurately represent the local situation. Inaccuracies in the modelling process can lead to policy being set incorrectly and a mismatch between the expectations of local communities and actual experience. In terms of comparability of results between models, the forthcoming EC Noise Mapping Directive specifies that the models used should comply with ECAC Doc 29 noise modelling recommendations. This should ensure that if a number of different models are used, at least they will be using the same methodologies. This however, still leaves the question of the databases used to power the noise models. The producer of the noise maps needs confidence that the outputs are accurately representing the local conditions.

In order to ensure the accuracy of contours produced using ANCON version 2, ERCD routinely collects and analyses hundreds of thousands of noise measurements at carefully selected monitoring locations around UK airports and uses these to validate the output of ANCON. For example in the 2001 summer monitoring period 278,000 noise measurements were acquired at London Heathrow with 330,000 and 219,000 measurements at London Gatwick and Stansted respectively. Figure 3 shows a plot of the recent noise monitor locations used around Gatwick airport.

Figure 3: Recent noise monitor locations around Gatwick airport



This data is processed in conjunction with the matched radar flight profiles so that the effect of in-service source noise emissions and propagation distances are taken into account. Data are carefully screened for adverse weather conditions; the criteria for screening of weather effects is similar to those laid down for aircraft noise certification and that specified in ISO 3891. In general these criteria limit wind speed to a maximum of 10 knots and temperature/humidity variation such that atmospheric attenuation rates do not exceed 12dB/100m at 8kHz. The measured noise data are compared with predicted noise levels based on industry supplied NPD data. Where discrepancies between predicted and measured noise levels are identified, the NPD data are adjusted to reflect measured noise levels. In addition to this, where constant automated noise monitoring equipment is used, there is the ability to conduct a direct validation of the Leq contour values produced by ANCON.

ERCD put this much effort into the validation of ANCON version 2 and the data that it uses because aircraft noise contours are very sensitive to changes in modelling procedures or databases. Large airports tend to be located near to centres of population – it tends to be these areas that provide demand for the services of an airport, and also provide dwellings for airport employees. As a result of this proximity of populations to airports, even a small under or over-estimation of noise exposure level can result in differences of tens of thousands in the estimated numbers of people impacted.

As Table 1 shows, even an overall 1 dBA Leq under-estimation of the 57dBA Leq contours for London Heathrow summer 2000 contours would have caused an underestimation in the population affected of the order of 75,000 people (or about 30 percent of the baseline population).

Table 1: Leq Areas and Populations, London Heathrow, 2000.

Leq Level	∆ Area	% Area	∆ Pop	% Pop
(dBA)	(km²)	(-)	(-)	(-)
56	27.48	+20.3%	75,000	+29.1%
57	-	-		
58	-23.66	-17.5%	-51,000	-19.9%

6. SUMMARY

Aircraft noise modelling has been used successfully for several decades to measure the noise exposure in the vicinity of civil airports. ERCD will continue to develop and validate ANCON version 2 and its databases to reflect best practice and current operating procedures in the UK. The noise mapping activities over the next few years to satisfy the requirements of the EC noise mapping directive will mean that the accuracy of noise maps will be under the microscope. It will be important for producers of noise maps to be able to give evidence of their confidence in the maps they produce, this may require structured evidence of validation procedures.

7. REFERENCES

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