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Aircraft Noise Model Validation

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Abstract

Aircraft noise models are now used widely by a large number of countries. Models vary in detail depending upon the needs of their users. Increasingly, models are becoming more sophisticated as additional needs develop. Traditionally noise models have been used to depict long-term historical noise exposure. However, they are often used to assess noise mitigation options and other 'what if' type scenarios. These applications have meant that a number of noise models have been subject to close scrutiny by interested parties, spurring further validation and model development studies.

Throughout the paper, the various techniques and methods are illustrated using data from a recent UK study of approach noise at London Heathrow airport. The deficiencies with present noise modelling techniques such as lateral attenuation are discussed and possible options for future development are considered.

1. Introduction

Aircraft noise modelling continues to evolve to meet the growing demands associated with aviation and airport expansion. Aircraft noise contours are used in many ways, from forecasting the impact of new developments, quantifying historical trends to the development of noise mitigation options.

These demands have meant that aircraft noise models have become ever more sophisticated. Along with this the validation of such models has also become more complex.

This paper introduces the basic principals used in aircraft noise modelling. The various elements are discussed and validation methods described. Results of a UK validation study are then presented, together with a discussion of the key findings.

2. Background

A number of aircraft models are based entirely on empirical data [1]. Flight profile information is collated from radar data obtained from airports or Air Traffic Control (ATC) and is combined with noise measurements collected on a large scale from fixed or temporary sites in the vicinity of the airport. Noise measurements are normalised using various methods so that a basic description of the source may be generated. From this information, source data is distributed along the flight paths around an airport in order to estimate ground noise levels. Provided that sufficient noise measurements are collected from a large enough number of locations and that the data is normalised appropriately, it is relatively straightforward to produce validated noise estimates.

There are, however, a number of difficulties and limitations with such simplistic models. Data from a large number of measurement sites would be extremely expensive and time consuming to collect and process for a major airport, especially if aircraft noise contours were required on a regular basis. Further, such models do not provide a capability to assess the effects on the contours of changes to aircraft flight profiles, for forecasting or 'what if' analyses.

3. Validation

More elaborate models such as ANCON 2 [2] and INM [3] use a deterministic approach to noise modelling as recommended by international guidance [4, 5, 6]. The key difference is that these relate aircraft performance (flight profile) to engine power settings and hence source noise. Noise propagation (NPD) data is then used to estimate aircraft noise levels on the ground.

For such models, validation becomes a much more complex task as shown in **Figure 1**.

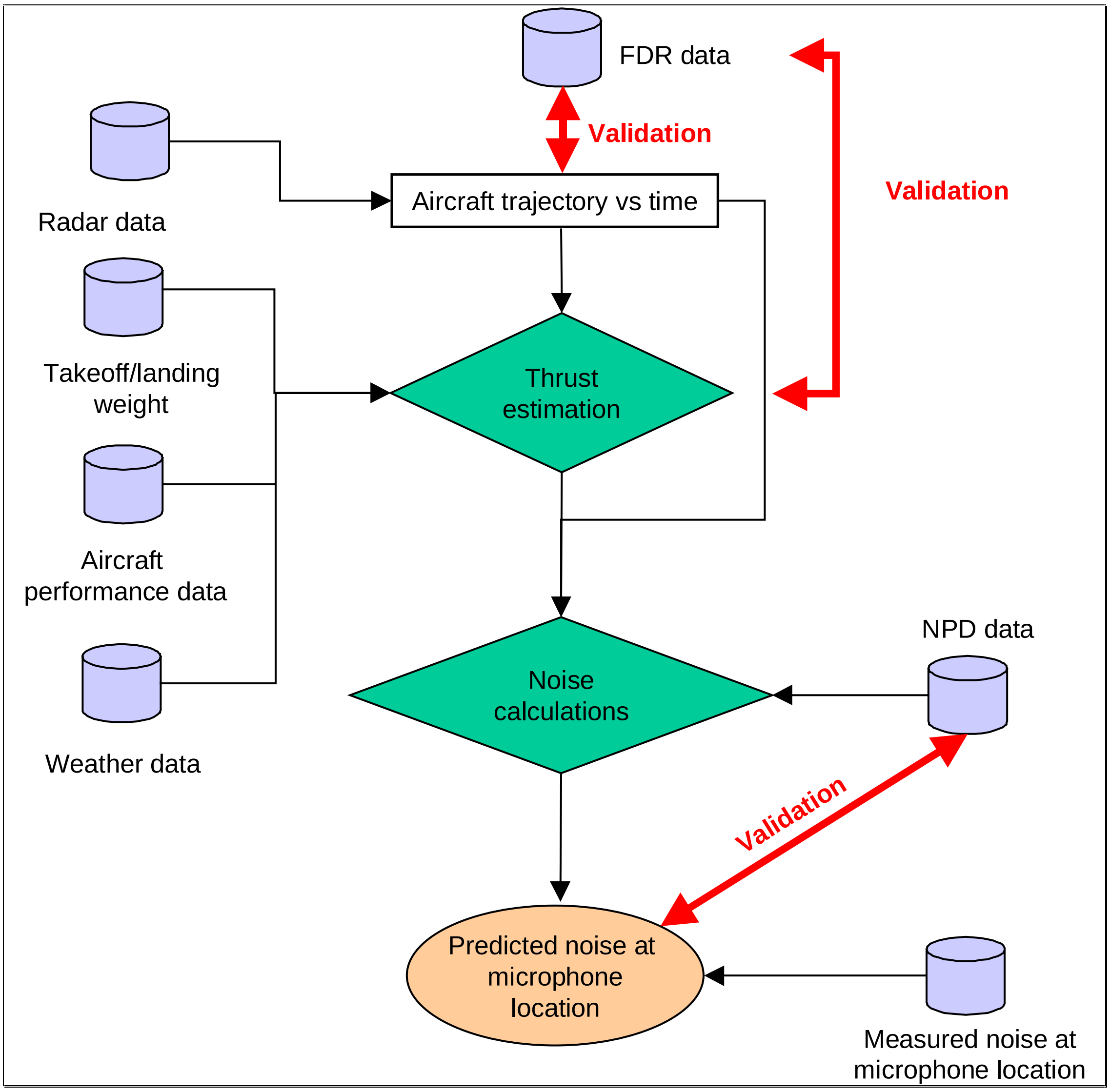


Figure 1: Validation Model

This is because more parameters are estimated during the modelling process and errors in intermediate calculations may be additive, thus creating the potential for larger differences between estimated and measured noise levels. It is essential that all parts of the modelling process are assessed and validated individually. The difficulty lies in the fact that not all of the parameters required are routinely available.

Although most large airports now operate noise and flight path monitoring systems, these do not directly show how aircraft are operated, nor provide details on aircraft configuration and engine power settings. However, it is possible to estimate some of these parameters from radar data and attempts have been made to validate this additional process [7]. Until such methods mature, reliable detailed aircraft performance information is best obtained from on-board aircraft Flight Data Recorders (FDR). Such information is difficult to obtain but may be regarded as 'gold standard' data for validation of subsequent processes.

Acoustic interference is a perpetual obstacle to reliable noise monitoring. One consequence of data loss is a risk of overestimating average noise levels. Thus careful siting of microphones and rejection of measurements made during poor weather is essential. Microphone siting is a particular problem around London Heathrow due to the lack of free space and the presence of other noise sources e.g. roads, railway lines. The criteria for screening of weather effects is similar to those laid down for aircraft noise certification [8]. In general these limit windspeed to a maximum of 10 knots and temperature/humidity variation such that atmospheric attenuation rates do not exceed 12dB/100m at 8kHz.

4. Approach Noise Study

The UK aircraft noise model ANCON 2 was recently used in a study of approach noise at the London Airports [9], the aim being to quantify potential noise reductions in an assessment of potential mitigation options. The description here concentrates on the validation of industry supplied NPD data for London Heathrow. FDR information was collected for approximately 25 arrival flights for each of four aircraft types. Following post processing, the data described the last fifteen minutes of each flight and provided information on aircraft position (inertial reference or GPS where available), pressure altitude, aircraft configuration, engine power setting, speed (ground, true and calibrated airspeeds) and bank angle at one second intervals. Simultaneous noise measurements were collected using five microphone locations under the westerly approach path - see **Figure 2**.

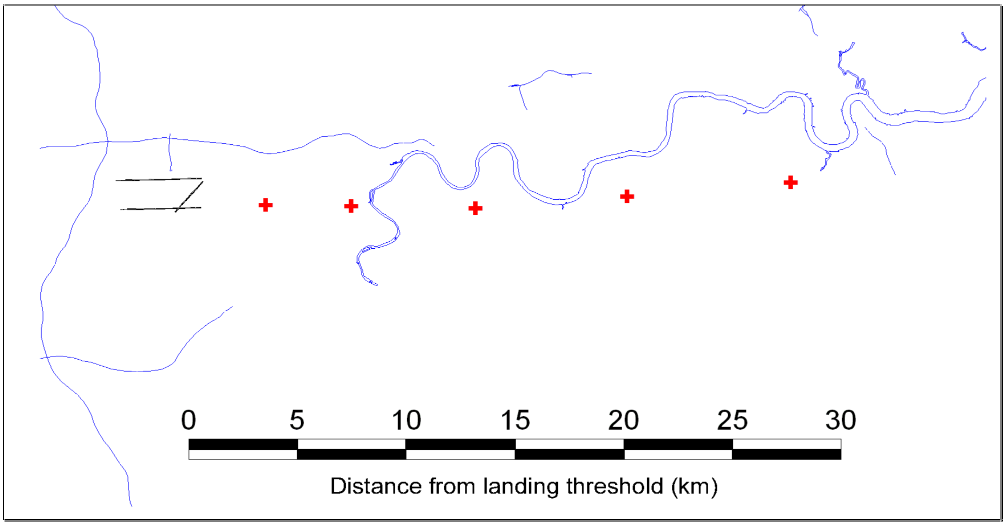
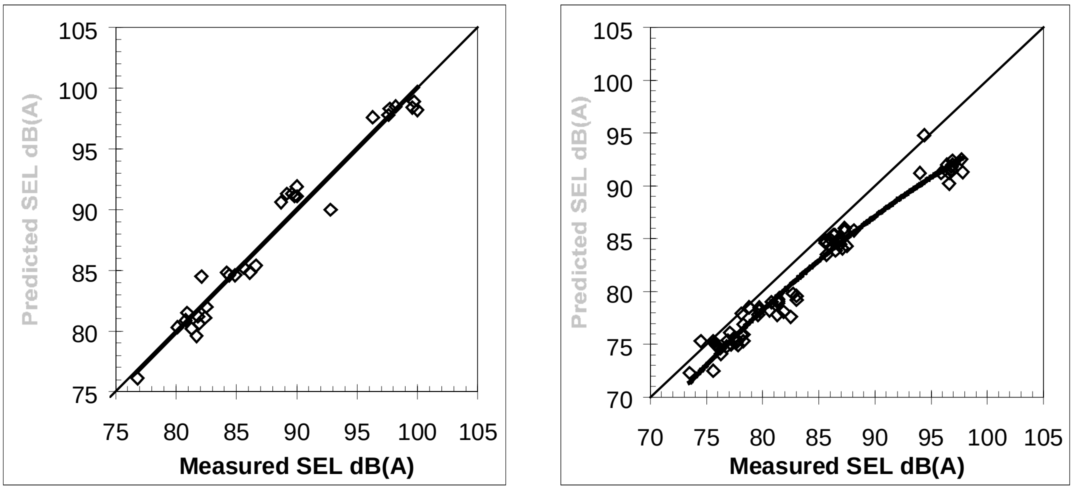


Figure 2: Microphone locations (from [9])

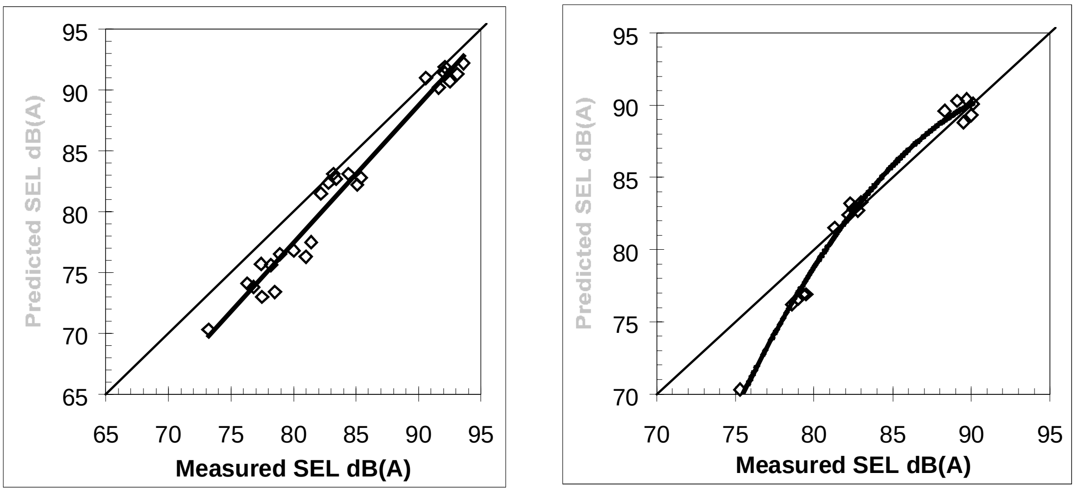
At distances greater than 20km from the airport it was difficult to find monitor locations where there would be sufficient confidence that aircraft noise events would not be missed or contaminated by noise from other sources. To be sure of the data quality at these extended distances, attended measurements were taken during the early hours and morning period, when (to obtain accurate SEL measurements) background levels were at least 10dB below peak L_{Amax}.

5. Results

Industry-supplied NPD data provided with the INM version 5.2 was used initially to estimate noise levels at the five microphone locations. **Figures 3(a) to 3(d)** show predicted vs measured SEL for four aircraft types that operate regularly at London Heathrow.



(a): Boeing 747-400 (b): Boeing 767-300



(c): Boeing 737-400 (d): Airbus A320-111

Figure 3: (From [9])

Figure 3(a) shows predicted vs measured SEL data for the Boeing 747-400 with RR RB211-524H engines. Excellent agreement is seen between predicted and measured levels across all five monitor locations. Measurements cover a range of 25dB and correspond to propagation distances of 500 to 5,000ft. It should be noted that three engine models are available for the Boeing 747-400 and that the industry supplied data relates to the Pratt & Whitney PW4056 powered variant. However, noise certification data suggest all three engine models are very similar. This would appear to be confirmed by the results shown here.

Figure 3(b) shows results for the Boeing 767-300 also with RR RB211-524H engines. An under-prediction of around 2-3dB is seen at low noise levels corresponding to far-out distances. At the closest measurement point the under-prediction is seen to increase to around 5dB. It is important to note here that the industry supplied NPD data is derived from noise certification measurements. For the approach phase these measurements correspond to an aircraft at a height of around 400ft. NPD data for greater distances is normally based on spectral extrapolations of this data. Thus for all the aircraft analysed here, the best correlation is to be expected for measurements at the microphone closest to the landing threshold where noise levels are highest. It would appear in this case that the NPD data does not correlate with measurements. Again, however the supplied NPD data is for a GE CF6-80 powered Boeing 767-200 and does not match with the engine-airframe combination being analysed. It is likely that the lack of specific NPD data for this airframe-engine combination is the main reason for the differences.

Figures 3(c) and 3(d) show results for the Boeing 737-400 and Airbus A320-111. Here both airframe-engine combinations match the provided NPD data. Both aircraft use similar engines from the CFM 56 family, the 737-400 using -3 series engine and the A320 using -5 series engine. Both also exhibit very similar results when comparing predicted SEL levels with measured SEL levels. At the two close-in microphone sites, excellent agreement is seen between predicted and measured levels. However, beyond these two sites at distances greater than 5nm from the landing threshold, predicted levels are increasingly below measured levels. At this point it is difficult to identify any single reason for the differences. Since NPD data combines both a source description (noise vs engine thrust) and propagation characteristics (noise vs distance) it difficult to say which, if any, may be in error, since the very low power settings are also coincident with the longer propagation distances. In addition the measured data has not been corrected back to certification propagation conditions, i.e. 70 percent humidity, 25 degC on which the NPD data is based. Although differences in attenuation rates are likely to be very small, any differences will be amplified significantly over long propagation distances. It should also be noted that although the Airbus A320 NPD data used here was obtained from the INM 5.2 database, Aerospatiale/Airbus did not originally supply this data. New data for a more representative Airbus A320 model has been supplied by Aerospatiale/Airbus and incorporated into the INM 6.0 database. It has not been possible to re-analyse the A320 measurements using this revised data.

6. Conclusions

The parts of the noise model requiring validation have been described and a validation study has been presented that was conducted using the UK Aircraft Noise Model, ANCON version 2. The validation process illustrates how FDR data was used so as to prevent assumptions or errors in one part of the modelling process from affecting the assessment. As is often said, two wrong answers do not make a right answer.

The results show that in general and under as controlled conditions as is possible in the field, predicted noise levels correlate well with measurements when using the industry supplied NPD data. However, in some areas differences arise that may be due to the lack of NPD data for specific airframe-engine combinations. Clearly, the dominant types will vary airport to airport, but it is recommend that industry endeavour to supply more information covering the major aircraft types.

It is also recommended that industry review the accuracy and applicability of current NPD data to operations at low power settings, which are often associated with optimised approach procedures.

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